OCWD Comments on: Draft Temescal Basin Groundwater Sustainability Plan, September 2021.

The Orange County Water District (OCWD) is responsible for managing the Orange County Groundwater Basin, which is part of the Coastal Plain of Orange County Groundwater Basin (DWR Basin 8-1). In 2017, OCWD, along with partner agencies, submitted an Alternative to a Groundwater Sustainability Plan (Alternative) to the Department of Water Resources (DWR) to show that Basin 8-1 had been sustainably managed over the last 10 years. DWR approved the Alternative on July 17, 2019.

OCWD thanks the Temescal Basin Groundwater Sustainability Agency (GSA) for reaching out and including OCWD in the public participation process of developing the Temescal Basin Groundwater Sustainability Plan (GSP or Plan). Not only is the Temescal Basin adjacent to Basin 8-1, Coastal Plain of Orange County Groundwater Basin, OCWD owns and manages wetlands and a large area of riparian habitat behind Prado Dam that is within the Temescal Basin. The health of this riparian habitat is dependent on surface flows of the Santa Ana River (SAR) and its tributaries as well as rising groundwater. There are data gaps within this area that need to be filled, particularly with respect to interconnected surface water. A number of studies are ongoing by multiple agencies to better understand the impacts of increased recycling of SAR water and groundwater pumping on SAR flows and rising groundwater and their potential impacts to interconnected surface water and riparian vegetation.

Our detailed comments are presented below, but in general, our comments can be summarized as follows:

1. Additional data needs to be obtained in the north end of the Temescal Basin and Prado Basin to adequately characterize the interconnection of surface water and groundwater and establish the appropriate sustainability criteria and minimum thresholds.
2. The Temescal Basin GSA needs to closely coordinate with adjacent upstream groundwater basins, such as the Chino Basin, to ensure that their groundwater management activities do not create undesirable results in the Temescal Basin, particularly in the area of interconnected surface water and groundwater.

OCWD provided prior comments on the Temescal Basin GSP, Draft Plan Area, Sept. 2020. These comments are presented in Attachment A for completeness.

OCWD is providing initial comments on the Draft GSP in this letter and may follow up with additional comments during the public review period after the GSP is submitted to DWR.

The Regional Water Quality Control Board's Basin Plan defines the 'Prado Basin Management Zone'. It is defined as follows in the Regional Board's Basin Plan:

> The Prado Basin Management Zone is generally defined by the 566-foot elevation above mean sea level. It extends from Prado Dam up Chino Creek, Reach 1A and 1B to the concrete lined portion near the road crossing at Old Central Avenue, up the channel of Mill Creek (Prado Area) to where Mill Creek becomes named as Cucamonga Creek and the concrete-lined portion near the crossing at Hellman Road, up what was formerly identified as Temescal Creek, Reach 1A (from the confluence with the Santa Ana River upstream of Lincoln Avenue) (this area is indistinguishable because of shifting topography and is now considered a part of the Prado Basin Management Zone), and up the Santa Ana River, Reach 3 to the 566-foot elevation (just west of Hamner Avenue). The Prado Basin Management Zone encompasses the Prado Flood Control

> Basin, which is a created wetlands as defined in this Plan (see the discussion of wetlands elsewhere in this Chapter). Orange County Water District's wetlands ponds are also located within the Prado Basin Management Zone.

OCWD, the Army Corps of Engineers and the United States Fish and Wildlife Service commonly refer to the reservoir area behind Prado Dam, up to elevation 566 feet, as 'Prado Basin'. In these comments, we will refer to the area using the terminology in the Regional Board's Basin Plan – as the 'Prado Basin Management Zone' or PBMZ.

Page ES-8, Sustainable Management Criteria. In this section, "The Minimum Threshold for depletion of interconnected surface water is the amount of depletion that occurs when the depth to the water along the southern edge of the Prado Wetlands is greater than 15 feet for a period exceeding one year." Later in the GSP, it is stated that this is an initial value subject to change as more data is collected. Based on the limited data available, this should be considered a starting point to be refined as the large existing data gaps in the northern part of the Temescal Basin and the PBMZ are filled. Additionally, the minimum threshold should be linked to impacts on interconnected surface water and groundwater, such as adverse impacts on riparian vegetation.

Page 2-25, Section 2.8.5, Neighboring Basin Coordination. We are glad to see that Chino Basin is included in coordination and data sharing. The Chino Basin is adjacent to the Temescal Basin, and thus it is important that the Temescal Basin GSA monitor conditions in the Chino Basin to ensure they do not cause undesirable results in the Temescal Basin, particularly with respect to the interconnection of surface water and groundwater. OCWD provided comments on this issue and others during the public participation process, which are documented on pages 627-628.

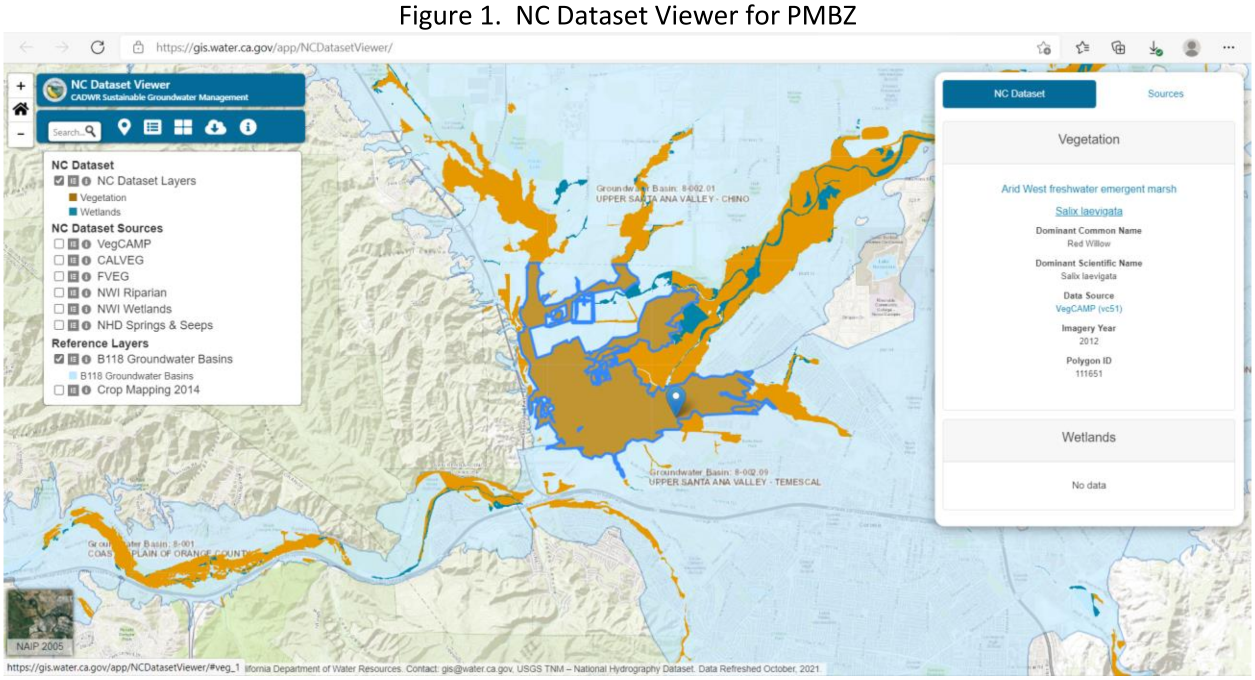
Page 4-12. Section 4.6.4 Monitoring Networks. We suggest that OCWD and other agency wells are included in the PBMZ to the Monitoring Network. OCWD is in the process of installing more than a dozen shallow monitoring wells in the PBMZ to provide more information on shallow groundwater conditions. These wells will be critical in understanding how groundwater management of the Chino and Temescal Basins impacts interconnected surface water and groundwater dependent ecosystems in the PBMZ.

Page 4-15. Section 4.10.1, Stream Flow Measurements. In the discussion of stream flow measurements on Temescal Creek as measured by the USGS gage at Main Street in Corona, CA (Gage No. 11072100), only recent data from 2012 to present is shown (Figure 4-18). In contrast, historical data for the outflow from Prado Dam from 1949 to present is shown. All available historical data from 1980 to present for the Temescal Gage at Main Street is shown in Figure 21 in Attachment B. It is important to note that a noticeable decline in minimum flows is noted in the mid-2000s and has been very low over the past decade. These reductions in flow are due to reduced discharges of treated wastewater and perhaps other factors and has adversely impacted the quantity and quality of riparian habitat in Temescal Creek. OCWD staff biologists reviewed historical aerial photographs and have prepared a summary of the changes noted since 1939, which is presented in Attachment B. This historical summary indicates that the quantity and quality of habitat in the lower reaches of Temescal Creek rapidly declined starting in approximately the mid-2000s. This area remains a good candidate to restore habitat and ecological health provided there was sufficient water supplies.

Page 4-15. Section 4.10.2, Depth to Groundwater. In this section, it is acknowledged that "available data are of limited use for this purpose due to insufficient vertical and geographic coverage." As mentioned above, OCWD has installed multiple new shallow monitoring wells and is the process of constructing additional monitoring wells in the PBMZ that will be critical to understanding interconnected surface water and groundwater in the north end of the Temescal Basin. We look forward to further development by the Temescal Basin GSA of the understanding of the interconnection of surface water and groundwater using data from OCWD wells, wells installed by the Temescal Basin GSA, and well installed by other agencies.

Page 4-17. Section 4.10.3, Riparian Vegetation. This section contains little information about the lower reach of Temescal Creek. This lower reach was very productive until the mid-2000s, when surface flows were reduced. See comments on Section 4.10.1, Stream Flow Measurements and Attachment B for more information on the history of vegetation in the lower reach of Temescal Creek. Section 4.10.3 also needs additional discussion of riparian vegetation in the PBMZ, in the area in and around the Corona Airport. Section 4.10.3 should identify the number of acres of riparian vegetation within the PBMZ (generally speaking the area below ground elevation 566 feet above mean sea level). A key source of data that should be included and shown below (Figure 1) is data from a joint effort of CA DWR and the Nature Conservancy to map areas referred to by DWR as 'natural communities commonly associated with groundwater ([NC Dataset Viewer (ca.gov)](https://gis.water.ca.gov/app/NCDatasetViewer/)).

Figure 1. NC Dataset Viewer for PMBZ



Page 4-18 to-21. Section 4.10.4, Wetlands and Interconnected Surface Water. Surface water can now be temporarily impounded behind Prado Dam up to elevation 505 ft msl during the flood and non-flood seasons. This change was approved by the US Army Corps of Engineers in April 2021. Please make the appropriate changes to the text of this section.

This section addresses the wetlands/riparian habitat and interconnected surface water in the PBMZ and the north end of the Temescal Basin. Within this section, multiple indirect lines of evidence are presented in an attempt to show that the wetlands are sustained by surface flows and not groundwater. Clearly there are critical data gaps that need to be filled to adequately understand the interconnection of surface water and groundwater in the north end of the Temescal Basin and the PBMZ. The additional monitoring wells OCWD has and is installing will provide key data and should be utilized by the Temescal Basin GSA as it becomes available. In addition, the Integrated Santa Ana River Model (ISARM), that was used as part of the Habitat Conservation Plan (HCP), cannot be relied on in its current configuration within the PBMZ. Although the ISARM is a useful tool to evaluate watershed wide conditions, there are data gaps within the PBMZ that need to be filled in order to adequately calibrate the model to make it useful in understanding interconnected surface water and groundwater in the area. This may require the development of a PBMZ Sub-model that would include portions of the Temescal Basin

The draft GSP states:

> "The correlation of precipitation and river flow with Prado groundwater levels and the lack of correlation with groundwater pumping north and south of the wetlands indicates that the wetlands are primarily sustained by surface inflows."

Additionally, the draft GSP states:

> "The low importance of groundwater as a factor in managing Prado Wetlands is also implicit in the Upper Santa Ana River Habitat Conservation Plan (HCP) (ICF 2020)."

OCWD disagrees with these statements. The statement about the perceived lack of correlation with Prado groundwater levels and groundwater pumping north and south of the wetlands should be revised to account for the following factors:

- Historical pumping north of the PBMZ in the Chino Basin may not be of sufficient magnitude to induce observable historic changes in groundwater elevation in the PBMZ. This is particularly the case since there have been some changes in overall pumping in the southern portion of the Chino Basin as agricultural-related groundwater production has declined (see for example the report '2013 Chino Basin Groundwater Model Update and Recalculation of Safe Yield Pursuant to the Peace Agreement', prepared by Wildermuth Environmental Inc for Chino Basin Watermaster, October 2015).
- The ability to observe changes in groundwater elevations in the PBMZ and relate changes to a particular factor like pumping can be obscured or made more complicated to detect due to recharge of groundwater from surface water.
- There is an overall lack of sufficient historical groundwater elevation data on the eastern side of the PBMZ, such as near the Corona Airport; this lack of sufficient data restricts or limits the ability to reach definitive conclusions regarding the impacts of pumping on groundwater levels.
- Surface water and groundwater are connected in the PBMZ and also along the Santa Ana River upstream of the PBMZ. Surface water flow in the SAR and its tributaries upstream of the PBMZ and surface flow into the PBMZ help support groundwater levels as surface water flows recharge the shallow groundwater system.
- The flow rate in the Santa Ana River and its tributaries such as Temescal Creek and Chino Creek are projected to decline in the future due to water recycling, stormwater capture, and other factors. As described in the Draft EIR for the Upper Santa Ana Habitat Conservation Plan (HCP), flows in the SAR reaching the PBMZ are estimated to decline in the low flow period (summer to early Fall) to approximately 35 to 40 cubic feet per second. With decreased flow in the Santa

> Ana River and its tributaries, groundwater levels in the PBMZ are anticipated to decline in the future. Under these future conditions, groundwater pumping may have a greater impact on groundwater levels in the PBMZ.

Regarding the state perceived low importance of groundwater as a factor in managing Prado Wetlands and information in the Upper Santa Ana River HCP, OCWD submitted extensive comments on the draft EIR for the HCP. These comments have not yet been addressed in writing and the EIR for the Upper Santa Ana HCP has not been certified. OCWD's comments on the draft EIR included several issues related to groundwater levels and riparian vegetation in the PBMZ. Additionally, the Upper SAR HCP public review draft document (May 2021) states:

> "The Upper Santa Ana River Sustainable Resources Alliance (Alliance) would create an account within SARCCUP, or other conjunctive use program, to purchase water that would be used to supply environmental flow. Alternatively, additional discharge from the aforementioned WWTPs could be purchased by the Alliance to provide supplemental flow."

Provision for supplemental flows to sustain environmental resources is included in the proposed HCP to account for uncertainty in model projections and potential impacts that may occur. The supplemental flows, if needed, would help recharge groundwater and support groundwater levels. It is not appropriate to state or imply that the HCP contains evidence that groundwater is of low importance in managing environmental resources such as riparian vegetation in the PBMZ.

A portion of the PBMZ is within the Temescal Basin. The GSP should identify the number of acres of the PBMZ that are within the Temescal Basin.

Page 5-19. Section 5.7.2.4, Riparian Evapotranspiration. The draft report says, "These calculations are applied at model cells within the Prado Wetlands where aerial photographs indicate the presence of potential riparian vegetation." The word 'potential' should be removed from this sentence. The number of acres of riparian habitat should be identified. There is clear evidence of riparian habitat in the portion of Temescal Basin within the PBMZ and there is also evidence that the riparian vegetation is dependent on interconnected surface water and groundwater. Attachment B discusses how riparian vegetation was negatively impacted when surface flows declined in the lower portion of Temescal Creek, within the PBMZ.

Page 6-4. Section 6.1, Summary of Sustainable Management Criteria. In this section, "The minimum threshold for depletion of interconnected surface water is defined as the historical minimum water levels (maximum depth to water) in shallow monitoring wells in the southern Prado area, where these shallow water level declines are correlated with Temescal Basin pumping and/or water levels."

First of all, this minimum threshold does not meet the definition established in Section 354.28(c)(6) of the Regulations, which states that "The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results" (CCR, 2016). Minimum thresholds only apply to the interconnected stream reaches.

The PBMZ has Beneficial Uses identified in the Regional Water Quality Control Board's Basin Plan. The Beneficial Uses identified for the PBMZ include 'WILD' and 'RARE'. 'WILD' is defined in the Regional Board's Basin Plan as:

> Wildlife Habitat (**WILD**) waters support wildlife habitats that may include, but are not limited to, the preservation and enhancement of vegetation and prey species used by waterfowl and other wildlife.

'RARE' is defined as:

> Rare, Threatened or Endangered Species (**RARE**) waters support the habitats necessary for the survival and successful maintenance of plant or animal species designated under state or federal law as rare, threatened or endangered.

The PBMZ contains wildlife habitat for the least Bell's vireo, which is an endangered species identified by the US Fish and Wildlife Service. The US Fish and Wildlife Service has also identified critical habitat for the least Bell's vireo, and the PBMZ includes area with this designated critical habitat. Additionally, the RARE beneficial use occurs in the PBMZ by virtue of nest locations of the least Bell's vireo occurring in the PBMZ. As a result, the minimum threshold needs to consider not only the potential changes in surface water depletions caused by groundwater pumping and or management actions, but also impacts to the beneficial uses in the PBMZ.

Secondly, no data are presented to document what the "historical minimum levels" are. As noted in prior comments, there are data gaps in the northern Temescal Basin and PBMZ that need to be filled. As such, it is not possible to establish a minimum threshold until these data gaps are filled.

Finally, because the Temescal Basin is hydrologically connected to the Chino Basin and other basins, it is not possible to isolate the impacts of pumping in adjacent basins from those in the Temescal Basin. This is why it is critical that the Temescal Basin GSA monitor and coordinate with adjacent basins to ensure that their actions do not cause or contribute to undesirable results in the Temescal Basin.

Page 6-31. Section 6.6.6.1, Description of Measurable Objectives. Measurable objectives are presented for TDS and Nitrate. While we appreciate that the TDS of basin outflows is included, other constituents of concern should also be included. There are some constituents of concern that may have Maximum Contaminant Levels (MCLs) established in the future that may require additional actions to reduce concentrations in outflow to the Orange County Groundwater Basin, including stormwater.

Page 6-32 to 6-33. Section 6.6.2.1, Surface Water Users. Similar to Section 4.10.4, multiple lines of indirect evidence are used to imply that groundwater discharge to the PBMZ is not significant and not expected to decrease significantly in the future. As stated above, additional data needs to be collected and the ISARM needs to be further developed to better understand interconnected surface and groundwater interactions in the north end of the Temescal Basin and the PBMZ.

Page 6-33, Section 6.7.2.3, Riparian Vegetation. The conclusion that the wetlands are primarily sustained by surface water and not groundwater is based on Section 6.6.2.1. See comments on this section above.

Page 6-33. Section 6.7.3, Definition of Undesirable Results. This definition should include potential impacts to groundwater dependent ecosystems or natural communities commonly associated with groundwater. OCWD has been managing riparian vegetation in the PBMZ for many years to support the endangered least Bell's Vireo. Through these actions, the PBMZ has become one of the most heavily populated areas of least Bell's Vireo in California. Any reduction in the quality of riparian habitat caused by impacts to surface/groundwater interactions could also affect least Bell's Vireo habitat.

Page 6-34. Section 6.7.6, Minimum Threshold. We are glad to see that it is acknowledged that there are data gaps and uncertainties regarding establishing the minimum threshold of depth to water exceeding 15 feet for more than one year. This threshold should be refined based on Section 354.28(c)(6) of the Regulations and OCWD comments on Section 6.1 above.

Page 6-35. Section 6.7.6.2, Effect of Minimum Threshold on Sustainability of Adjacent Areas. A key source of water supplies to the Coastal Plain of Orange County Groundwater Basin (Basin 8-1) is the baseflow of the Santa Ana River (SAR). SAR baseflow is a combination of surface flow and rising groundwater within the PBMZ. Any reduction in rising groundwater will result in reduced baseflow to Basin 8-1. It is unclear what evidence would be used to quantify the "historical minimum" of groundwater discharge to the SAR in the PBMZ. As mentioned in prior comments, there are significant data gaps with respect to the interconnection surface water and groundwater that need to be filled.

Page 6-36. Section 6.7.6.5, How the Minimum Threshold will be Monitored. OCWD supports the installation of additional wells and filling data gaps. We look forward to coordinating with the Temescal Basin GSA in this effort and further refining the Minimum Threshold for the interconnection of surface water and groundwater (see prior comments).

Attachment A

OCWD Comments on: Temescal Subbasin Groundwater Sustainability Plan, Draft Plan Area, September 2020.

OCWD Comments on: Temescal Subbasin Groundwater Sustainability Plan, Draft Plan Area, September 2020.

The Orange County Water District (OCWD) is responsible for managing the Orange County Groundwater Basin, which is part of the Coastal Plain of Orange County Groundwater Basin (DWR Basin 8-1). In 2017, OCWD, along with partner agencies, submitted an Alternative to a Groundwater Sustainability Plan (Alternative) to the Department of Water Resources (DWR) to show that Basin 8-1 had been sustainably managed over the last 10 years. DWR approved the Alternative on July 17, 2019.

OCWD thanks the City of Corona for reaching out and including OCWD in the process of developing the Temescal Subbasin Groundwater Sustainability Plan (GSP or Plan). Not only is the Temescal Subbasin adjacent to Basin 8-1, Coastal Plain of Orange County Groundwater Basin, OCWD owns and manages wetlands and a large area of riparian habitat behind Prado Dam. The health of this riparian habitat is dependent on surface flows of the Santa Ana River (SAR) and its tributaries as well as rising groundwater. A number of studies are ongoing by multiple agencies to better understand the impacts of increased recycling of SAR water and groundwater pumping on SAR flows and rising groundwater with respect to potential impacts upon riparian vegetation. We have listed some of these studies in our comments.

Specific Comments on the Temescal Subbasin GSP, Draft Plan Area, Sept. 2020 are as follows:

Page 2-3, Section 2.2.6. Please add a description of the Chino Basin Watermaster and other agencies that manage groundwater in adjacent groundwater basins. Even though they do not have jurisdiction within the Temescal Subbasin, the Chino Basin (Upper Santa Ana Valley Basin 8-002.01) is adjacent and upgradient of the Temescal Subbasin. Groundwater management actions taken by the Chino Basin Watermaster and other agencies upgradient of the Temescal Subbasin can affect groundwater conditions within the subbasin. Although a formal coordination agreement is not required, it is important that these agencies know that they must carefully consider any actions that could affect groundwater conditions in the Temescal Subbasin.

Page 2-6, Table 2-1. It is good to see that native vegetation is shown as a significant user of groundwater (18%). Please include a description of this water use and location as a separate subsection in Section 2.4. Also provide information on how the 18% figure was calculated, including assumptions, acreages, etc.

Page 2-8, Section 2.4, Water Resources Monitoring Programs.

Given the significant water use by native vegetation and significant natural resources present in the Prado Basin, we suggest that you add Natural Resources to the list of water resources monitoring categories.

We suggest that you add the following monitoring programs in the appropriate category. We have put a suggested category (or categories) in parentheses.

1. Groundwater Monitoring in Prado Basin by Western Riverside County Regional Wastewater Authority. (Groundwater Levels)
2. Natural resources and groundwater monitoring in Prado Basin by OCWD. (Groundwater Levels, Groundwater Quality, Surface Water Quality, Natural Resources (new category))

3. Chino Basin Watermaster/Inland Empire Utilities Agency Monitoring as part of Prado Basin Habitat Sustainability Committee. (Groundwater Levels, Groundwater Quality, Natural Resources (new category))
4. Upper Santa Ana River Habitat Conservation Plan (HCP) and associated monitoring plans being managed by the San Bernardino Valley Municipal Water District (Valley District) with participation from multiple other agencies including OCWD. (Groundwater Levels, Surface Water Flow, Surface Water Quality, Natural Resources (new category)). Please note that to support the HCP, an Integrated Santa Ana River Model (ISARM) has been developed.

Page 2-24, Table 2-5. Under L), There is a significant amount of information to indicate there are groundwater dependent ecosystems present in Prado Basin and the Santa Ana River and tributaries to the SAR upstream of Prado Basin. Prado Basin is generally defined as the area behind Prado Dam up to elevation 566 feet mean sea level. The groundwater dependent ecosystems present within Prado Basin and Santa Ana River and its tributaries need to be carefully considered in the Plan.

Attachment B

Temescal Creek Riparian Habitat Timeline

Prepared by David McMichael, Biologist

Orange County Water District

December 2021

Temescal Creek Riparian Habitat Timeline

Prepared by David McMichael, Biologist

Orange County Water District

December 2021

Temescal Creek has long shown a tendency to grow a riparian belt especially as it nears its confluence with the Santa Ana River. Temescal Creek was protected from the scouring effect of the river hidden behind the Norco bluffs, which means riparian habitat would have been allowed to mature creating a perennial haven for wildlife. Aerials taken in 1939 and 1953 clearly show riparian trees growing thick along Temescal Creeks (Figures 1-2).

Figure 1. Temescal Creek and the Prado Basin in 1939

Figure 2. Temescal Creek and the Prado Basin 1953

This timelapse habitat study focuses on a portion of Temescal Creek that is not channelized. This natural setting is confined to a roughly 2 mile stretch from Lincoln Ave. downstream past to where it meets the Santa Ana River. Upstream of Lincoln Ave the creek is channelized. This concrete channel originates at Temescal Canyon Lake in the city of Corona. Two segments will be studied using aerial imaging, and observations from the ground. The first segment begins at Lincoln Ave. and continues down to Auburndale Street. The next segment will be area of the creek immediately upstream and downstream of Rincon St.

The segment immediately downstream of Auburndale St. will not be looked at due to the proximity of an earthen dike project which involved the removal of habitat. Multiple fires in this area also made habitat comparisons difficult. It should be noted that the habitat along this stretch has not regrown following the completion of this project and no recruitment has been noted here.

The area of Temescal Creek which joins with the Santa Ana River flood plain will also not be discussed due to the proximity of water from the river as well as several fire events. The Willow Forest in this area seems to be in optimum health and any alteration of species composition seems to be from the shifting nature of the river. When the river moves away (west) from the creek it's possible to find more Mulefat recruitment, but when the river flows south its common for there to be wetland species' such as Cattails. Water will often form ponds near the end of the Corona Airport runway.

1994

Habitat along Temescal Creek was generally good where water was available. Figure 3 indicates that creek bottom between Lincoln Ave. and Auburndale St. was lined with riparian trees with clumps of Mulefat immediately upslope of the creek. Ground observations from this period indicate that the Mulefat was established right up to the farmed fields on the south side of the creek. The darker clumps were Black Willows, Cottonwoods, and Arroyo Willows. There were and still are a few clumps of Eucalyptus on the site and Arundo donax is also present during this time mixed in the riparian.

The aerial at figure 4 indicates that the thick Willow Forest seen behind the Prado Dam has creeped up to Rincon Street an extended into the Corydon St. corner. Mulefat was common in the upland areas adjacent to and well away from the creek bed. Besides seasonal invasives such as Black Mustard other perennial non-natives such as Tamarisk and Arundo were seen only sporadically. They were not abundant along this segment of the creek.

Figure 3. 1994 Temescal Creek – Lincoln Ave. to Auburndale St.

Figure 4. 1994 Temescal Creek at Rincon St.

2003

Habitat conditions remain relatively unchanged in these 2003 aerials but key invasives such as Tamarisk are beginning to spread in Temescal as well as the entire Prado Basin (Figures 5-6). Tamarisk is a more xeric riparian species with deep root systems able to tap into deeper ground water sources. Mulefat is also becoming more common along the banks of the creek. Mulefat is a transitional riparian species which can exist at different elevational zones often growing alongside sage scrub patches upslope of riparian settings. Mulefat is more tolerant of dry conditions as it can monopolize lower ground water levels than Black Willows.

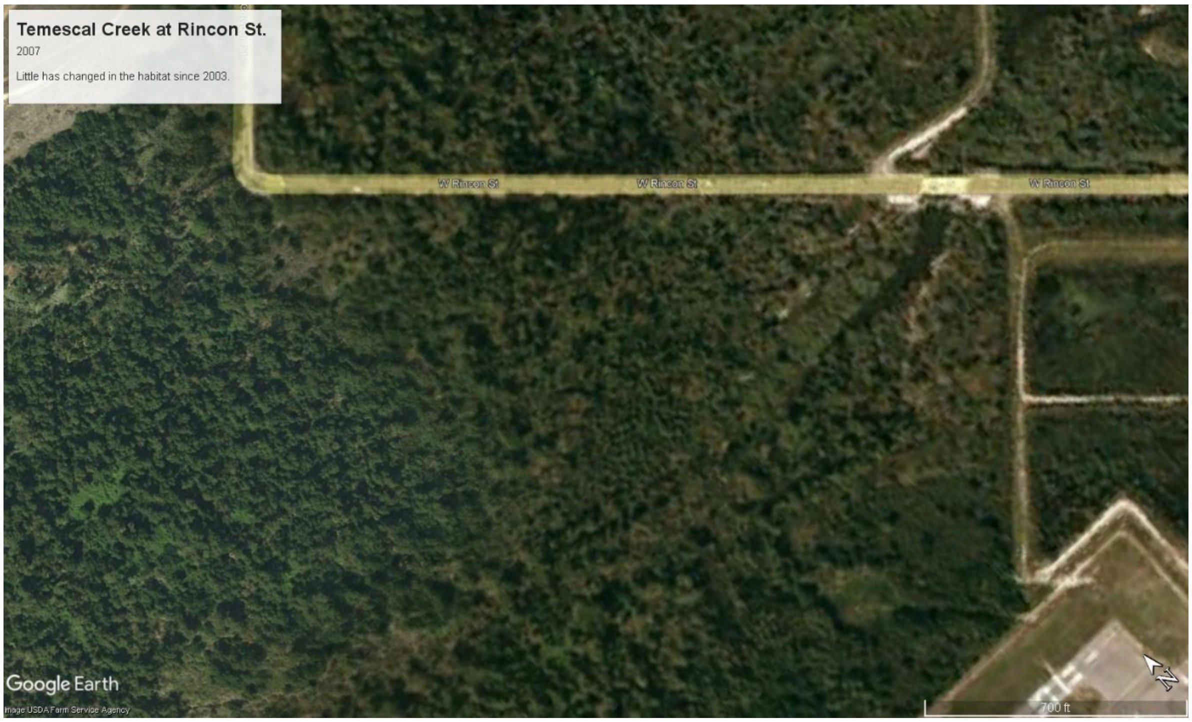
Figure 5. 2003 Temescal Creek – Lincoln Ave to Auburndale St.

Figure 6. 2003 Temescal Creek at Rincon St.

2007

Figure 7 shows that little changed along Temescal from 2003 to the end of 2007. There were some significant weather events in the basin such as the historic flood in 2004-2005 where 33.94" of rain fell over a relatively short period of time. This event caused destructive flooding in Prado Basin and resulted in a long pool retention time behind the dam. The rain year of 2005-2006 was a relatively average rain year with 11.53” of rain but the bulk of this came late in the season resulting in another long inundation period behind the dam. These subsequent inundation events should have had little impact on the habitat along Temescal Creek except in the lowest portion of the creek near the Santa Ana River. The final important weather impact happened in 2006-2007 when the area saw historic low rainfall at 3.37”. Drought conditions can be very damaging to riparian habitat but any sort of impactful damage to the habitat was not seen until 2009.

Figure 7. 2007 Temescal Creek at Rincon St.



<u>2009</u>

The aerials taken in 2009 showed a drastic shift in the disposition of the riparian habitat along Temescal Creek. The segment of Temescal Creek from Lincoln Ave. down to Auburndale St. showed significant loss of both Willow and Mulefat habitat (Figure 8). Much of the creek bottom banks still shows some Black Willows stands but many of the historic patches are now gone. Upslope of the creek where the Mulefat used to reside was also vacant save for some weedy annual species.

Figure 9 indicates that the Rincon St. segment of Temescal Creek is dramatically altered from previous aerials. The Black Willow Forest has retreated downstream and in its place non-native such as Perennial Pepperweed, and Tamarisk has begun to form monocultural stands. Mulefat is still present but competing with pepperweed in the upland sites. Channel scouring is evident as well which could have removed some of the riparian habitat during the previous year’s big rain events.

Figure 8. 2009 Temescal Creek- Lincoln Ave. to Auburndale St.

Figure 9. 2009 Temescal Creek at Rincon St.

<u>2009-2021 Temescal Creek (Lincoln Ave.-Auburndale St.)</u>

These aerials indicated that the habitat downstream of Lincoln Ave. further degraded during the 2009-2021 period. Further Black Willows disappeared and Mulefat continued to be uncommon over the entire site. No recruitment of native riparian species was noted during this period. Some Eucalyptus continue to reside at this site but most of the non-native species' seen further downstream are also absent from this stretch.

Figure 10. 2012 Temescal Creek – Lincoln Ave. to Auburndale St.

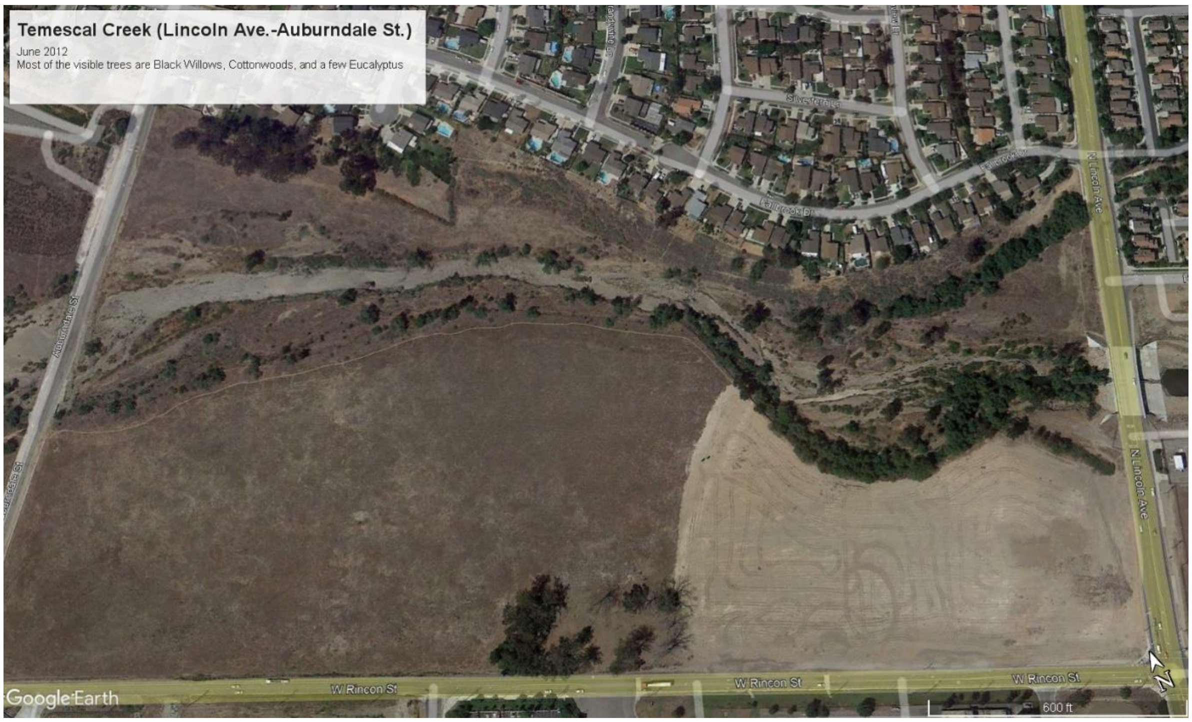
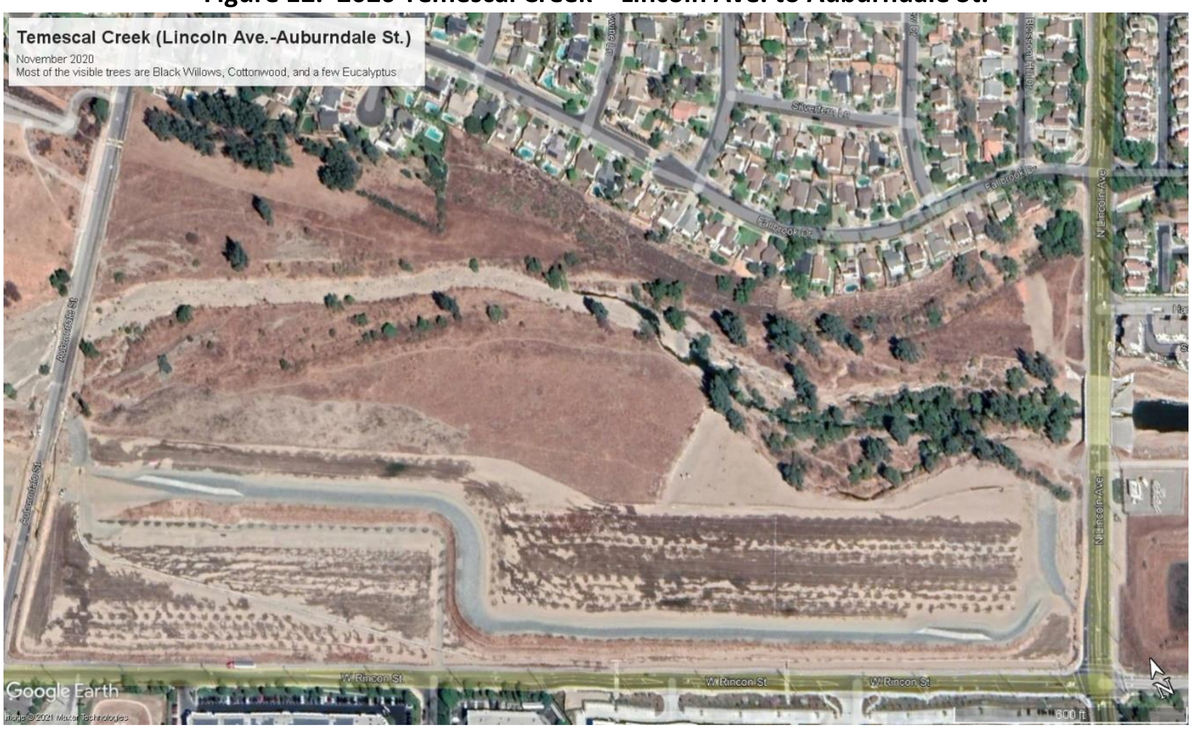


Figure 11. 2018 Temescal Creek – Lincoln to Auburndale St.

Figure 12. 2020 Temescal Creek – Lincoln Ave. to Auburndale St.



<u>**2014 Temescal Creek at Rincon St.**</u>

Figure 13 shows the continual retreat of Black Willows away from the Rincon St. area. Some patches continue to remain around the Corydon -Rincon curve but it's clear the Willows are disappearing from the area. Perennial Pepperweed and Tamarisk continue to plague the site and some of the upland patches of Mulefat appear to be in decline.

Figure 13. 2014 Temescal Creek at Rincon St.

2016-2017 Temescal Creek at Rincon St.

The invasive species were removed from the Rincon St. area in 2015-2016 and treatment continued until 2019. This included the physical removal of Arundo and Tamarisk but also the spraying of Perennial Pepperweed. The removal of the exotics facilitated the recruitment of Mulefat into this area Recruitment was primarily in those areas where Perennial Pepperweed was treated (Figures 14-15). There was little evidence of lasting recruitment by young Willows even during average rainfall years. Mulefat recruitment and habit transition to more xeric riparian species has been seen in other parts of the basin where drought stress and low ground water levels create conditions unfavorable to Black Willow growth. Mulefat have deeper root structure than Black Willows and other water dependent species. Mulefat continued to thin out in those areas that do not get flood irrigated during the winter.

Figure 14. 2016 Temescal Creek at Rincon St.

Figure 15. 2017 Temescal Creek at Rincon St.

2020-2021 Temescal Creek at Rincon St.

During 2020 and 2021 the encouraging growth and recruitment of Mulefat in the Rincon St. area has been halted and instead the evidence suggests that many Mulefat plants have begun disappearing and those that remain appear stunted and sporadic. The remaining mature Black Willow trees are persisting but there is still no recruitment of young willows and very little recruitment of Mulefat plants (Figures 16-17). There appears to be an influence from the Santa Ana River on the remaining Willow Forest where the constantly shifting course of the river often favors the Temescal creek area. The larger willows must be able to tap into ground water replenished by the river.

Figure 16. 2020 Temescal Creek at Rincon St.

Figure 17. 2021 Temescal Creek at Rincon St.

Least Bell's Vireo Distribution

Figure 18 suggests that least Bell's Vireo were previously widely distributed below Lincoln Ave, but Figure 19 suggests that in recent years Vireo have not stayed in those areas where the habitat is unsuitable for nesting success. Figure 20 shows the distribution of least Bell's Vireo in 2021. least Bell's Vireo is currently completely absent along Temescal Creek from Lincoln Ave. to Auburndale St.

Figure 18. Least Bell's Vireo Distribution 2007-2021

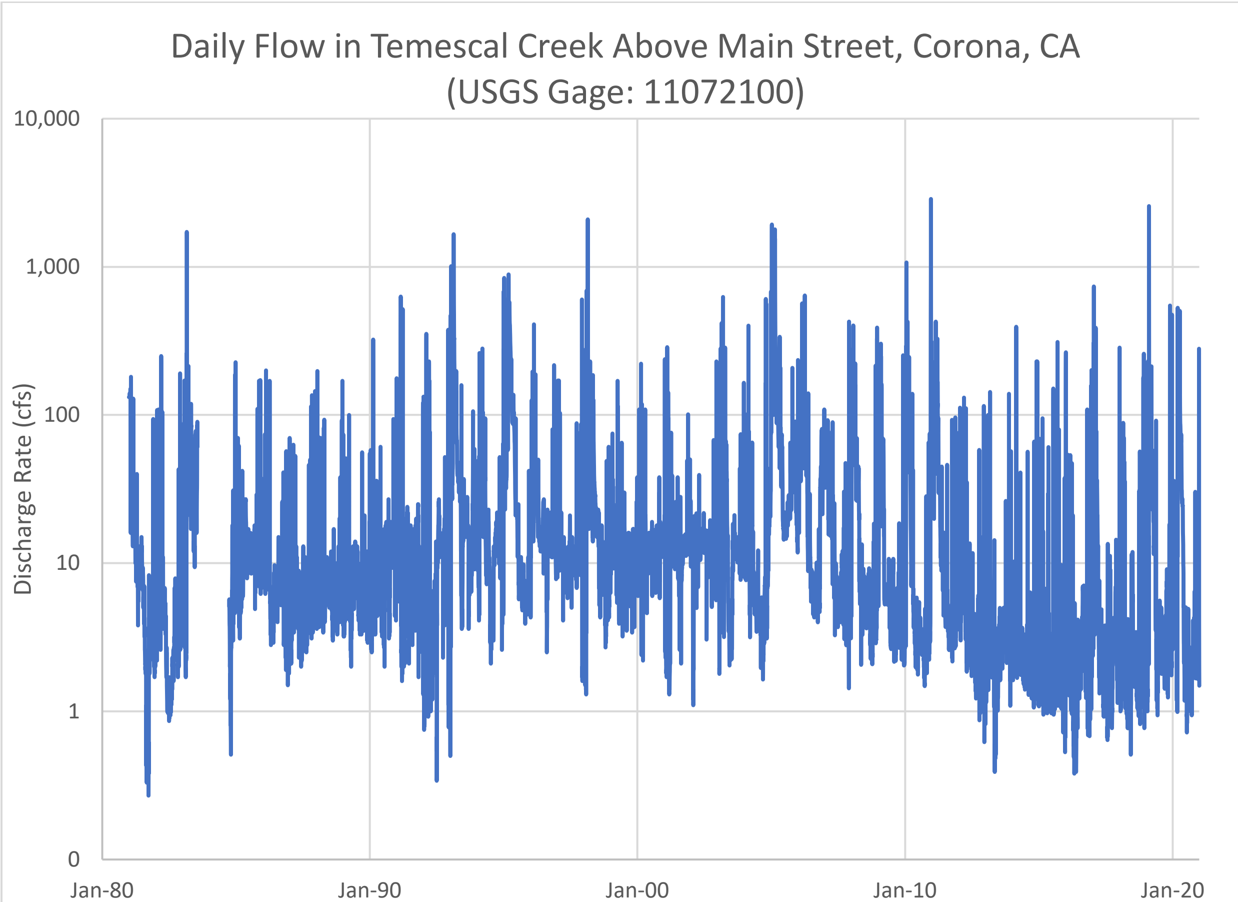
Figure 19. Least Bell's Vireo Territories 2019-2021

Figure 20. Least Bell's Vireo Territories 2021

Stream Flow Measurements

Figure 21 shows all the available daily measurements of streamflow in Temescal Creek at Main Street in Corona, CA, which is USGS Gage 11072100. What is important to note is the decline in the daily minimum flows that started in the mid-2000s and have been persistently at 1 cfs or less since 2012. These changes in flows correlate with the changes in vegetation described above.

Figure 21 Daily Flow in Temescal Creek at Main Street, Corona, CA



<u>Conclusion</u>

Aerial imagery of the downstream portion of Temescal Creek below Lincoln Ave. indicated that this portion of the Santa Ana River Watershed saw many decades of optimum growth and health of its riparian species', mainly Black Willow and Mulefat. These important riparian species provided refuge to many species of birds and wildlife including least Bell's Vireo and Southwestern Willow Flycatcher.

There is evidence that this portion of the watershed saw considerable dieback around 2009 but it's possible that this began earlier with subtle habitat transitional changes noted as early as 2003. The 2009 event is substantial but the inability of the habitat to recover and establish new trees and shrubs in later years shows a shift in the water regime. This condition can no longer sustain water dependent riparian species and may even exclude more xeric species. The further decline of Temescal Creek habitat will eventually exclude riparian nesting bird species entirely if the structure of the habitat cannot repair itself.

City of Corona
Utilities Department
"Protecting Public Health"

Office: 951.736.2234
Fax: 951.735.3786

755 Public Safety Way
Corona, CA 92878 – www.CoronaCA.gov

January 13, 2021

To: Adam Hutchinson, Orange County Water District

RE: OWCD Comments on Draft Temescal Basin GSP 12.14.2021

The Temescal Basin Groundwater Sustainability Agency (GSA) appreciates your thorough review of our Groundwater Sustainability Plan (GSP). Throughout the process, the Temescal Basin GSA has encouraged and welcomed public input, including the comment letter you submitted December 14, 2021. We have reviewed your comments. Detailed responses to your comments, including identification of edits to the GSP, are provided below.

Responses are organized to be consistent with your comments on specific pages and sections of the Draft GSP.

Comment on Page ES-8, Sustainable Management Criteria

Response:

The minimum threshold for interconnected surface water is a starting point and may be revised in future periodic evaluations as additional data and understanding of interconnected surface water and groundwater become available. This minimum threshold is discussed in greater detail in Chapter 6.

Comment on Page 2-25, Section 2.8.5, Neighboring Basin Coordination.

Response:

Corona is aware of future potential items of concerns and Corona representatives actively attend and engage in local inter-agency working groups / committees This comment also referenced comments OCWD submitted previously that included suggestions for additional information to be included in Chapter 2 of the GSP. Thank you for reminding us of these comments; text related to your comments has been added to Chapter 2.

Comment on Page 4-12. Section 4.6.4 Monitoring Networks.

Response:

The GSP used data for OCWD monitoring wells in the PBMZ, including PDHQ, PD3A, PD3B, PD4, PD6A, PD6B, PD9, PD10 through PD19, PD14R, PD22 through PD25. In fact, water levels from those wells were the basis for defining the depth to water minimum threshold for riparian vegetation. However, all of those wells are in the northern part of PBMZ. Thus, the data gap in the southern part identified in the Temescal Basin GSP still stands. We are aware that there are newly installed shallow monitoring wells in the southern portion of the PBMZ. However, those wells were installed during preparation of this GSP and any water level data collected from them does not correlate to the time period assessed in the Temescal GSP, which includes data through 2018. Data and information from these newer wells will be used in future updates to the Temescal GSP.

Comment on Page 4-15. Section 4.10.1, Stream Flow Measurements.

Response:

The historical vegetation analysis along the lower reach of Temescal Wash by OCWD staff biologist David McMichael (attachment B of the comment letter) is excellent and is similar to analysis Todd Groundwater completed for reaches of Temescal Wash in the Bedford-Coldwater and Elsinore Basins. We concur with the finding that riparian vegetation canopy extent and density along Temescal Wash from North Livermore Avenue to below West Rincon Street decreased greatly beginning around 2009. OCWD's analysis concluded that decreased base flow in Temescal Wash was a likely cause of the die-back. Flows at the gage near Main Street do show a decrease in base flow beginning around 2009. The analysis attributed the decrease in flows to decreased discharges from Corona water reclamation facilities. However, we note that discharges at that time were from WRF-1 to Butterfield Drain, which enters Prado Wetlands downstream of the gage and impacted reach. Also, those discharges were not decreased until a State Water Resources Control Board decision was made in 2011.

Declining groundwater elevations might have contributed to the vegetation die-back, but historical data are insufficient to verify that hypothesis. The nearest well with water level data was the Butterfield Park well, which had a period of record only for 2011-2016. Water levels declined steadily during that period, which coincided with drought conditions and small water-level declines in other Temescal Basin wells. However, water levels had been higher in 2009, and had also been lower than the 2011-2016 range in the late 1990s and early 2000s, when there was no vegetation die-back. So available water level data do not entirely correlate with the timing of changes in vegetation.

The GSP affirms the possibility that declines in water table elevation in the southern part of the PBMZ could impact riparian vegetation, and the sustainable management criteria for interconnected surface water are designed to prevent such impacts in the future.

Finally, it should be emphasized that SGMA does not require that GSPs restore groundwater conditions (including GDEs) to any state they were in prior to 2015.

Comment on Page 4-15. Section 4.10.2, Depth to Groundwater.

Response:

See response to above comment regarding Page 4-12. Section 4.6.4 Monitoring Networks.

Comment on Page 4-17. Section 4.10.3, Riparian Vegetation.

Response:

With respect to vegetation die-back along the lowermost reach of Temescal Wash, see response to above comment Page 4-15. Section 4.10.1, Stream Flow Measurements.

With respect to NCCAG vegetation mapping, the NCCAG riparian vegetation and wetland maps were both evaluated during the analysis of interconnected surface water and GDEs. The vegetation polygons are included in Figure 4-21 and

Section 4.10.3 "Riparian Vegetation" includes a page of discussion of the mapping and the related NDVI and NDMI information.

Comment on Page 4-18 to-21. Section 4.10.4, Wetlands and Interconnected Surface Water.

Response:

The text has been changed to state that the target impoundment elevation behind Prado Dam is 505 feet in all seasons.

The temporal correlation of factors potentially associated with vegetation in Prado Wetlands is not flawed due to "critical data gaps that need to be filled to adequately understand the interconnection of surface water and groundwater". Additional data are always useful. Nevertheless, the analysis stands on its own as making good use of available data. Specifically, it includes information from OCWD wells in the Prado Wetlands. The GSP furthermore concurs that there is a data gap regarding water table elevations in the southern part of the wetlands. That data gap does not undermine the conclusions drawn from the rest of the data. The data gap will be filled primarily to confirm relationships of pumping and water levels farther south in the Temescal Basin with water table depths along the southern edge of the wetlands.

If regional groundwater models used for the Prado Basin Adaptive Management Plan, the 2019 Annual Report of the Prado Basin Habitat Sustainability Committee, and the Upper Santa Ana River Habitat Conservation Plan are found to be flawed based on OCWD's review, revised modeling results can be considered during the 5-year update of the GSP.

We agree that the Santa Ana River and the pool of water impounded behind Prado Dam are almost certainly hydraulically connected with a shallow water table at least most of the time. However, the shallow water table is not strongly connected to deeper aquifers and pumping stresses due to the relative abundance of fine-grained sediments in the Prado Wetlands part of the Chino-Temescal Basins region.[1] The draft GSP does not assert that Prado Wetlands are entirely disconnected from groundwater, but that as a practical matter the water supply for the wetlands is almost entirely derived from surface inflows.

If surface inflows to Prado are expected to decline in the future as the comment suggests, OCWD is free to intervene with the wastewater dischargers who currently supply those flows. It is worth noting that the City of Corona continues to comply with an agreement adopted in 1968 and modified in 2011 to provide reclaimed water inflow to the Prado Wetlands. Furthermore, as long as the pool behind Prado Dam is held at a constant elevation, groundwater discharge into that area will remain essentially constant.

[1] "The distinction between aquifer systems is most pronounced within the west-southwest portions of the Chino Basin. This is likely because of the relative abundance of fine-grained sediments in the southwest (multiple layers of clays and silts). Groundwater flowing from high-elevation forebay areas in the north and east become confined beneath these fine-grained sediments in the west-southwest, and these sediments effectively isolate the shallow aquifer system from the deep aquifer system(s)." (from page 2.9, last paragraph, of Wildermuth Environmental, Inc. October 2015. 2013 Chino Basin groundwater model update and recalculation of safe yield pursuant to the peace agreement. Prepared for Chino Basin Watermaster).

The comment states that supplemental surface inflows to the Prado Wetlands "would help recharge groundwater and support groundwater levels". Percolation from the river would likely maintain the shallow water table described above. But with respect to the overall Temescal Basin, the Prado Wetlands cannot simultaneously be a recharge boundary and a discharge boundary.

Comment on Page 5-19. Section 5.7.2.4, Riparian Evapotranspiration.

Response:

We have removed the mention of "potential riparian vegetation" in Prado Wetlands from the text.

Comment on Page 6-4. Section 6.1, Summary of Sustainable Management Criteria.

Response:

The comment asserts that sustainable management criteria for interconnected surface water must be expressed as a rate of stream flow depletion. The GSP regulations do include a clause to that effect. However, the very next clause (§354.28(d)) states "An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence." This is explicitly discussed in section 6.7.5 of the GSP. If the primary beneficial use of interconnected surface water is riparian vegetation—as it is in the Prado Wetlands—then water table depth is an appropriate metric for defining sustainable management criteria. Plants do not care about the rate of flow across a stream bed, but they do care about the depth of the water table.

The Basin Plan's inclusion of WILD and RARE as beneficial uses of surface water in Prado Wetlands simply corroborates the GDE discussion in the GSP, which covers arroyo chub, least Bell's vireo and southwestern willow flycatcher (section 4.10.5), among other species.

The comment objects that minimum historical groundwater levels are used in the sustainable management criteria definitions for interconnected surface water. This statement was in the introductory summary of sustainable management criteria at the beginning of chapter 6. It was an editorial oversight. The statement has been changed to "The Minimum Threshold for **depletion of interconnected surface water** is defined as a depth to water of 15 feet in shallow monitoring wells in the southern Prado area, where declines to lower water levels are correlated with Temescal Basin pumping and/or water levels." The revision is consistent with the actual minimum threshold definition presented in section 6.7.

The last paragraph of the comment implies that the GSP is responsible for ensuring that groundwater management in the Chino Basin does not impact Prado Wetlands or downstream water users. The GSP must show that actions taken to achieve sustainability in the Temescal Basin do not impair the ability of adjacent basins to achieve sustainability. Potential effects of sustainable management criteria on adjacent basins are discussed in sections 6.2.6.3, 6.3.6.2, 6.5.4.2, 6.6.5.4, and 6.7.6.2. In contrast, the Chino Basin appeared to adopt its goal of "hydraulic control" (that is, zero groundwater outflow to Prado

Wetlands) without consideration of impact on Temescal Basin sustainability. The Temescal Basin GSA has no authority relating to subsurface outflows from the Chino subbasin.

Comment on Page 6-31. Section 6.6.6.1, Description of Measurable Objectives.

Response:

The GSP includes description and analysis of several constituents of concern. Nitrate and TDS were selected because objectives are set in the Basin Plan, there are sufficient baseline data, and they serve as indicators for both natural and anthropogenic impacts. Additional water quality minimum threshold components may be considered in future periodic evaluations of the plan. In addition, the monitoring network will continue to track and record water quality for the minimum threshold and for all constituents of concerns.

Comment on Page 6-32 to 6-33. Section 6.6.2.1, Surface Water Users.

Response:

This comment basically reiterates the previous comment on Page 4-18 to-21. Section 4.10.4, and the response to that comment applies here. Furthermore, the comment presents no information to refute the analysis in the GSP nor indicates which additional data specifically need to be collected to refute or improve the analysis.

Comment on Page 6-33, Section 6.7.2.3, Riparian Vegetation.

Response:

This comment also reiterates concerns presented in the comment on Page 4-18 to-21. Section 4.10.4, and the response to that comment applies here.

Comment on Page 6-33. Section 6.7.3, Definition of Undesirable Results.

Response:

The comment notes that OCWD has been working to expand and improve wetland habitat in Prado Wetlands for many years, primarily to provide habitat for the endangered least Bell's vireo, a bird that resides in the wetlands. The GSP does not interfere with that objective and program. The interconnected surface water sustainable management criteria are designed to avoid future impacts to Prado Wetlands vegetation (and by extension to the vireo) due to groundwater management.

Comment on Page 6-34. Section 6.7.6, Minimum Threshold.

Response:

There are no "data gaps and uncertainties regarding establishing the minimum threshold" for interconnected surface water. The data gaps relate to implementing the minimum threshold. We expect the minimum threshold to continue to be adequate. Shallow monitoring wells will be installed in the southern Prado Wetlands area during the first five-year GSP implementation period. During the five-year GSP update, the appropriateness of the 15-foot depth to water criterion used in the minimum threshold will be reviewed in light of data from the new wells. This could potentially lead to a revised minimum threshold definition.

Comment on Page 6-35. Section 6.7.6.2, Effect of Minimum Threshold on Sustainability of Adjacent Areas.

Response:

It is a simple matter of groundwater hydraulics that if groundwater levels within the Temescal Basin do not drop below historical minimum water levels, the discharge at the Basin boundary (to Prado Wetlands, the Santa Ana River and/or Chino Basin) will not drop below its historical minimum.

The comment expresses a concern about "any reduction in rising groundwater" that contributes to Prado Dam outflow. However, nothing in the GSP contemplates a reduction in groundwater outflow from the Temescal Basin.

Comment on Page 6-36. Section 6.7.6.5, How the Minimum Threshold will be Monitored.

Response:

The Temescal Basin GSA likewise appreciates OCWD's efforts to monitor groundwater levels in the Prado Wetlands area. The information for OCWD's shallow wells in the northern Prado area was extremely useful for preparing the GSP. The Temescal Basin GSA intends to continue its cooperation with OCWD and share monitoring data from the new shallow wells to be installed in the southern part of the Prado Wetlands.

APPENDIX J

Temescal Groundwater Sustainability Plan Numerical Groundwater Model Documentation Report

Home Gardens
County Water District

TEMESCAL BASIN GROUNDWATER MODEL DOCUMENTATION REPORT

PREPARED FOR THE TEMESCAL GROUNDWATER SUSTAINABILITY PLAN

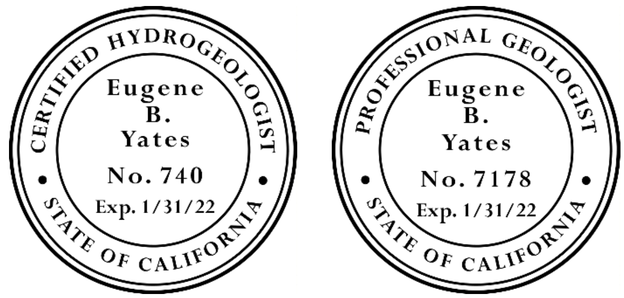
December 2021

TODD GROUNDWATER

2490 Mariner Square Loop, Suite 215
Alameda, CA 94501
510.747.6920
www.toddgroundwater.com

SIGNATURE PAGE

Gus Yates, PG, CHg
Senior Hydrologist
Todd Groundwater, Alameda, CA



Michael P. Maley, PG, CHg, CEG, PE
Principal Hydrogeologist
Todd Groundwater, Alameda, CA

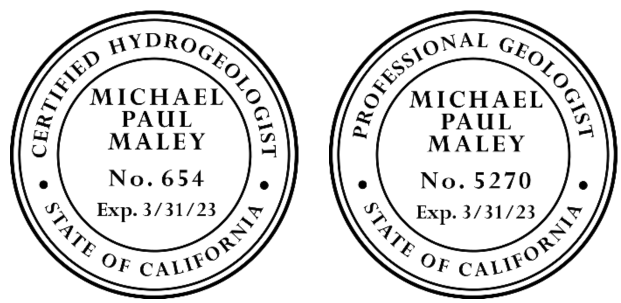


Table of Contents

List of Tables (all tables follow text)

List of Figures (all figures follow text)

1. INTRODUCTION

The groundwater model was developed to support the Groundwater Sustainability Plan (GSP) for the Temescal Subbasin (Basin) of the Upper Santa Ana Valley Basin (Department of Water Resource [DWR] Groundwater Basin 8-002.09) and is prepared in accordance with Sustainable Groundwater Management Act (SGMA). For convenience, DWR Basin 8-002.09 (DWR 2016b) will be referred to as the Temescal Basin (Basin) in this memo.

1.1. SCOPE AND OBJECTIVE

SGMA effectively requires that groundwater modeling be used to demonstrate that a GSP will achieve sustainable basin operation. A previous model of the Temescal Basin model was updated and refined to simulate surface water and groundwater conditions for the entire Basin, update key parameters, match the DWR Basin boundary, and improve discretization, geologic layering and aquifer parameter distribution to reflect new information. The resulting model focuses on applicability to SGMA GSP regulations, including consistency with DWR Best Management Practices for surface water and groundwater modeling (DWR 2016a). This comprehensive groundwater model serves as a quantitative tool for computing Basin-wide water budgets and the effects of sustainability criteria and management actions.

1.2. SUMMARY OF PREVIOUS MODELS

A groundwater model of the Temescal Basin was previously developed to support development of the 2008 City of Corona Groundwater Management Plan (Todd and AKM, 2008). That model did not cover the entire extent of the Basin as defined by DWR and simulated the period from 1990 through 2004. However, information regarding bedrock elevations, aquifer characteristics, layering, inflows and outflows served as a starting point for constructing the new model.

The development of the Temescal Basin Model utilized information from groundwater model from adjacent basins. The Model developed for this GSP also includes a portion of the Chino Basin to better simulate the interactions with the adjoining basin and assess conditions in the Prado wetlands area. Information for the northern part of the model flow domain in the Chino Basin was based on documentation of the Chino Basin groundwater model o developed in 2015 and has been updated several times since then (WEI, 2015 2020). In the vicinity of the Arlington Gap, a groundwater model of the Riverside-Arlington Basin, which simulates conditions on the eastern side of the Arlington Gap, was used to help understand groundwater flow through Arlington Gap into the Temescal Basin (Geoscience, 2009, WRIME, 2010, 2011).

2. BASIN GEOLOGY AND STRUCTURE

The following summarizes the hydrogeologic conceptual model (HCM) and groundwater conditions from the main body of the Temescal Basin GSP report. The HCM and groundwater conditions create a foundation for the technical aspects of the Basin's hydrogeology necessary for model development. This section references figures and text from **GSP Sections 3 and 4**.

2.1. TEMESCAL BASIN

The Temescal Basin covers approximately 23,500 acres or 37 square miles of the southwest part of upper Santa Ana Valley in western Riverside County as shown on **Figure 1**. The following summarizes the physical description of the Temescal Basin and surrounding areas as described in the GSP.

2.1.1. Groundwater Basin

The Basin covers approximately 23,500 acres or 37 square miles of the southwest part of upper Santa Ana Valley in western Riverside County (**Figure 1**). The Basin is located between the Santa Ana Mountains to the west and a lower, parallel range of hills to the east.

The Basin has connection four other groundwater basins or subbasins defined by DWR Bulletin 118 (DWR 2016b). The Basin is separated from the Bedford-Coldwater Subbasin of the Elsinore Groundwater Basin (DWR Basin No. 8-004.02) to the south by a groundwater divide Eagle Canyon and Bedford Canyon. The Basin is connected to the east by a narrow body of alluvium through Arlington Gap to the Riverside-Arlington Subbasin of the Santa Ana Valley Groundwater Basin (DWR Basin No. 8-002.03). To the north, the Basin adjoins the Chino Subbasin of the Santa Ana Valley Groundwater Basin (DWR Basin No. 8-002.01) along a line that approximately follows the Santa Ana River. This boundary is permeable, and groundwater can flow in either direction between the two basins depending on their respective groundwater levels. To the west, the Basin has a narrow connection along the Santa Ana River with the Coastal Plain of Orange County Groundwater Basin (DWR Basin No. 8 001).

SGMA allows a groundwater basin to be subdivided into management areas if it facilitates sustainable management in areas within the Basin where groundwater conditions or water use and supplies are distinctly different. The Temescal Basin has not been divided into management areas; the GSP treats it as a single unit.

2.1.2. Physiography

Ground surface elevations at the surface of the Basin slope northward toward the Santa Ana River at a slope of 200-300 feet per mile. Elevations range from approximately 470 feet above mean sea level (msl) at the base of Prado Dam to approximately 1,500 feet above msl to the south (see **GSP Figure 3-1**). The tributary watersheds reach up to approximately 4,000 feet msl at the highest peak in the Santa Ana Mountain watersheds west of the Basin. Watersheds east of the Basin are significantly lower in elevation and rise only to about 1,600 feet.

2.1.3. Hydrology

The Basin covers a portion of the Santa Ana River watershed. **Figure 2** shows the locations of the Santa Ana River, Temescal Wash, Prado wetlands area, minor streams and tributary watersheds to the

Temescal Basin. The Santa Ana River roughly follows the northern edge of the Basin, flowing from east to west. Prado Dam impounds the river near the western edge of the Basin, where the river enters a canyon that passes through the Santa Ana Mountains to the coastal plain in Orange County. The largest surface waterway in the interior of the Basin is Temescal Wash, which originates near Lake Elsinore and flows through the Bedford-Coldwater Subbasin before entering the southern edge of the Temescal Basin. It continues north through the City of Corona and discharges into the Prado wetlands. A number of small streams enter the Basin from watersheds in the Santa Ana Mountains. Flow in all of them is ephemeral, and with the exception of Wardlow Wash at the northwest corner of the Basin, all of the small creek channels are lined beginning 1,500 to 6,100 feet downstream of the point where they enter the Basin. The Temescal Wash channel is also cement lined along about half of its length between the Basin boundary and the Santa Ana River.

2.2. REGIONAL GEOLOGY

The Basin is located within one of the structural blocks of the Peninsular Ranges of Southern California. The Basin occurs in a linear low-lying block, referred to as the Elsinore-Temecula trough, between the Santa Ana Mountains on the west and the Perris Plain on the east (Todd and AKM 2008). The trough extends from Corona southeast approximately 30 miles and was formed along an extensive northwest-southeast trending fault zone including the Elsinore, Chino, and related faults.

2.2.1. Geologic Units

The oldest rocks in the Basin crop out at the foot of the Santa Ana Mountains. These units are composed principally of volcanic (including the Santiago Peak Volcanics) and metamorphic rocks (including the Bedford Canyon Formation) of Jurassic and Cretaceous age. A thin rim of younger sedimentary units of Tertiary age also crops out along the mountain front generally lying between the Elsinore and Chino faults. This zone of sedimentary units broadens to the north and contains numerous mapped formations of Cretaceous and Tertiary age. The northeastern side of the valley is flanked primarily by granitic rocks of Cretaceous age. Erosion of these units has filled in the trough over time resulting in quaternary-age alluvial fan, channel, and other deposits making up the permeable portions of the Basin (USGS 2004, 2006).

The geologic map (see **GSP Figure 3-5**) shows the distribution of these units in the Basin (USGS 2004, 2006). The main surficial deposits on the floor of the Basin include younger and older alluvial fans deposited from the erosion of volcanic rocks and Bedford Canyon Formation to the west. These units prograde across the Basin to the northeast and are truncated by channel deposits along Temescal Wash.

2.2.2. Faults

The Basin was formed along an extensive northwest-southeast trending fault zone including the Elsinore, Chino, and related faults. The Elsinore and Chino fault zones bound the Basin on the west and trend along the mountain fronts. The Elsinore Fault Zone extends approximately 200 km from Baja California north to the Corona area. It passes through the western margin of the Basin. Some fault traces are inside the Basin and may function as partial barriers to groundwater flow (see **GSP Figure 3-5**).

2.2.3. Definable Basin Bottom

The Basin bottom is defined by bedrock, which is shallow around the perimeter and deep in the center. Depth to bedrock ranges in depth from 10 feet to approximately over 1,000 feet (see **GSP Figure 3-11)**.

The greatest Basin thickness is in the central-west part of the Basin (see **GSP Figure 3-7**). The formation of a trough along the Elsinore-Chino Fault zone is indicated by the asymmetric basin geometry.

Bedrock is much shallower in the eastern portion of the Basin, however there is a slight deepening near the Arlington Gap (see **GSP Figure 3-8**). Here, unconsolidated sediments are approximately 250 feet thick. This area is interpreted to have been eroded by a branch of the ancestral Santa Ana River. The Basin is only about 100 feet thick in the Norco area but over 1,000 feet thick beneath the Santa Ana River, where the Basin adjoins the Chino Basin.

2.3. GROUNDWATER CONDITIONS

Understanding the groundwater conditions is important in development of the surface water and groundwater models. A summary of the discussion of the groundwater conditions and water balance based on the model results is provided in **GSP Sections 4 and 5** is provided below.

2.3.1. Basin Aquifer

Three aquifers provide water supply to wells within the Basin. These include the Channel Aquifer, the Alluvial Fan aquifers and the Sandstone Aquifer (Todd and AKM 2008). Of these three aquifers, the Channel Aquifer is the only principal aquifer as it the most productive aquifer and provides most of the groundwater supply in the Basin. The Alluvial Fan and Sandstone Aquifers have historically been used to a lesser extent than the principal aquifer. The combined Alluvial Fan and Sandstone Aquifers are referred to as the Secondary Aquifers within the Basin.

The Channel Aquifer is the principal aquifer in the Basin. This aquifer is a package of relatively homogeneous and highly permeable sands up to 200 feet thick that have been encountered in many of the Corona wells in the northern half of Basin. This sand package is interpreted as channel deposits of an ancestral arm of the Santa Ana River and, as such, has been referred to as the Channel Aquifer (Todd and AKM 2008). The alignment of the aquifer suggests that an ancestral river channel had entered the Basin at Arlington Gap, eroding the sedimentary units and possibly older alluvial fan deposits in the area. Permeable channel sands were deposited in the eroded channel over time. From the Arlington Gap, the Channel Aquifer trends northwest toward Prado Dam.

The Alluvial Fan Aquifer is composed of both older and recent alluvial fans that have been deposited through time along the mountain front on the western edge of the Basin. These fans have prograded across the Basin from west to east (see **GSP Figure 3-5**). Although these deposits are relatively thick, the entire unit is heterogeneous and cannot be considered one single aquifer. Rather, sand lenses within the deposits collectively form the Alluvial Fan Aquifers. Lithologic data from wells are insufficient to map out the extent of the aquifers or characterize the deposits. Limited data indicate relatively fine-grained textures throughout much of the area, especially with depth (Todd and AKM 2008).

The Sandstone Aquifer is composed of the older sedimentary units underlying the alluvial Basin that provide sufficient well yields to categorize them as aquifers. Although generally grouped with other bedrock units, the subsurface sedimentary rocks of Tertiary age in the northeast Basin area contain sandstone layers that are screened in several Corona wells. Due to the limited production, small areal extent, increasing depths, and relatively low permeability in most areas, the Sandstone Aquifer is not considered a primary source of water supply.

2.3.2. Basin Boundaries

The Temescal Basin as defined by DWR is bounded on the west by the Santa Ana Mountains and the east by low-lying El Sobrante de San Jacinto and La Sierra hills. The northeastern arm of the Temescal Basin, referred to as the Norco area, consists of relatively low permeability alluvium and bedrock residuum flanked on the east and west by bedrock outcrops. The Basin is connected to four adjacent groundwater basins (**Figure 1**) defined by DWR Bulletin 118 (DWR 2016b). These include:

- The boundary with the Chino Basin (DWR Basin No. 8-002.01) to the north is generally marked by the Santa Ana River and a series of low-lying hills in the Norco area.
- Groundwater from the Riverside-Arlington Basin (DWR Basin No. 8-002.03) flows into the Basin through the Arlington Gap. The Arlington Gap is a narrow restriction along the eastern side of the Basin north of the Temescal Wash.
- The boundary with the Coastal Plain of Orange County Basin (DWR Basin No. 8-001) is a narrow canyon where the Santa Ana River exits the Temescal Basin to the Coastal Plain of Orange County Basin.
- The southern boundary of the Basin is the Bedford-Coldwater Subbasin of the Elsinore Groundwater Basin (DWR Basin No. 8-004.02). The boundary is located at the Bedford Canyon. Generally, there is little to no groundwater flow along this boundary at the eastern portion where it borders the alluvium along the Temescal Wash.

The remaining lateral boundaries of the Basin are formed by contacts with bedrock units. The entire western Basin boundary and much of the eastern boundary of the Basin are contacts between Basin sedimentary units and upland bedrock outcrops (Todd and AKM 2008).

2.3.3. Recharge and Discharge Areas

Recharge to the Basin occurs primarily from stream percolation, wastewater discharge and deep percolation of rainfall and irrigation water, and to a lesser extent from pipe leaks and subsurface inflow from bedrock areas and other basins, as shown in **GSP Table 5-4**. Recharge from streams occurs along the unlined reach of Temescal Wash above Temescal Lake and the unlined reaches of tributary streams along the western edge of the Basin. Recharge associated with wastewater occurs when treated wastewater is discharged to ponds. Deep percolation from irrigation includes historical agricultural irrigation as well as current urban irrigation.

Large amounts of runoff from the mountains flows into channels and the shallow subsurface at the edges of the Basin and then into and through the Basin. Stream flows are flashy, and during brief high-flow events, the amount of stream recharge is limited by the percolation capacities of the unlined channel reaches upstream of the stormwater detention basins. The creek channels are lined with cement downstream of the detention basins.

Return flows are those portions of applied water (e.g., landscape irrigation) that are not consumed by evapotranspiration and hence return to the groundwater system through deep percolation or infiltration. Return flows associated with urban, industrial, and agricultural water uses all have the potential to contribute to recharge to the Basin (Todd and AKM 2008).

Discharge from the Basin is primarily from groundwater pumping. Smaller outflows are to the Santa Ana River near the Prado wetlands, evapotranspiration in the wetlands, and subsurface outflow to the Chino Basin (see **GSP Table 5-4**).

2.3.4. Primary Groundwater Uses

The primary groundwater uses in the Basin are municipal pumping, with limited private pumping for small water system, commercial, industrial and residential users. Groundwater use estimates are included in **GSP Section 5 (Water Budget)**. The Channel Aquifer is primarily used for municipal water supply. Most of the pumping in this area is from wells owned and operated by the City of Corona, with some additional pumping by small community water system, small commercial users and aggregate mines. Until the 1990s, there was significant agricultural pumping to irrigate citrus orchards.

3. RAINFALL-RUNOFF-RECHARGE MODEL

A rainfall-runoff-recharge model developed by Todd Groundwater was used to prepare estimates of groundwater recharge from rainfall, irrigation, bedrock inflow, and pipe leaks. It also generated the estimates of groundwater use for agricultural irrigation and flows in ungauged streams tributary to or within the basin. Several commercially available software programs were used to prepare model input and evaluate model output, such as Microsoft Excel and ArcGIS. Finally, the rainfall-runoff-recharge model and several pre-processing utility programs were developed in the Fortran 90 programming language by Todd Groundwater.

3.1. APPROACH

The rainfall-runoff-recharge model is built around a soil moisture balance of the root zone, which is simulated continuously using daily time steps for the 29-year calibration period. Numerous variables are involved in the physical processes of rainfall, interception, runoff, infiltration, root zone soil moisture storage, evapotranspiration, irrigation, shallow groundwater storage, recharge of deeper regional aquifers from shallow groundwater, and lateral flow of shallow groundwater into streams. Accordingly, the groundwater basin and tributary watersheds were divided into small recharge zones over which the most influential variables were relatively homogeneous. The daily water balance was then simulated for each zone, and the results aggregated geographically to cells in the groundwater model grid and temporally to the model stress periods.

The rainfall-runoff-recharge model provides several benefits to the groundwater modeling effort:

- It represents the hydrological processes with governing equations that reflect the actual physical processes, at least in a simplified way. This allows sensitivity or suspected errors to be traced to specific assumptions and processes.
- It enforces the principle of conservation of mass on the recharge and stream flow values. Beginning with rainfall, all water mass is accounted for as it moves through the hydrological system.
- It allows additional data sets to be included in model calibration. In tributary watersheds with gauged stream flow data, measured flows can be compared with simulated flows, which consist of the sum of direct runoff and shallow-groundwater seepage to streams. Simulated irrigation frequency can be compared with actual grower practices, and applied irrigation amounts can be compared with water delivery data recorded by the District. Simulated urban irrigation amounts can be compared with seasonal variations in measured urban water use, which are primarily related to urban irrigation.
- It provides estimates of stream flow in ungauged tributary streams, as well as runoff from valley floor areas within the active model domain.
- It provides estimates of inflow from bedrock and/or upland areas adjacent to the active model domain and constrains the amounts of inflow according to the water balance for each tributary watershed.
- It simulates the effects of runoff from impervious surfaces in urban areas, either to storm drainage systems or to adjacent pervious soils.
- It simulates changes in land use over the 29-year calibration period and the resulting changes in recharge and irrigation demand.

- It combines and parses all of these flows—plus estimated recharge from leaky water and sewer pipes—into recharge values by model cell and stress period in the format required by MODFLOW.

The following sections describe the input data sets and the assumptions and governing equations used to simulate each hydrologic process included in the rainfall-runoff-recharge model.

3.2. LAND USE AND RECHARGE ZONES

Recharge zones were developed by intersecting and editing numerous maps in GIS. The starting point was a map of the Temescal Basin and the boundaries of all surrounding watersheds that flow into it. The Basin and tributary watersheds were then divided into numerous polygons reflecting land use as of 1990 and changes in land use since then. Land use was delineated into 13 categories based on DWR land use maps for Riverside County from 1993 and 2000, a statewide crop map developed by LandIQ for DWR in 2014 and Google Earth historical aerial imagery available for 1990-2018. The primary change in land use has been urbanization of undeveloped (natural vegetation) areas. Polygons were delineated to represent the locations of changes in land use so that a single, fixed set of polygons could accurately represent the evolution of land use by changing the use type of a polygon beginning in the year that land use changed. Additional divisions of polygons were made on the basis of soil texture, annual rainfall and watershed. This resulted in a total of 224 polygons ranging in size from 2 to 4,529 acres. A map of the zones and their land uses in 1990 and 2018 is shown in **Figure 3.**

Land use in each zone was assigned to one of sixteen categories (see **GSP Table 5-2**). Each land use category is further divided into irrigated, non-irrigated and impervious subareas. These are not explicitly mapped but are expressed as percentages of total zone area. Citrus orchards irrigated with groundwater were common in the Basin in the early 1990s, but except for one small grove those have all been replaced by urban development. Natural land cover categories are grassland, shrubs/trees, dense riparian, sparse riparian and open water. Developed land uses are residential, low-density residential, turf, commercial, industrial and vacant. The natural and developed land uses were mapped by inspection of Google Earth aerial photography. The categories are listed in **GSP Table 5-2** along with their total acreages in 1990, 2018 and 2068 (estimated) in the groundwater basin management areas and tributary watersheds.

3.3. RAINFALL

The distribution of average annual rainfall over the basin and tributary watersheds was obtained from PRISM climate modeling (http://www.prism.oregonstate.edu/). Annual precipitation varies from 11 inches in the Norco area to about 14 inches at the south end of the Basin. It increases to about 21 inches at the top of the highest tributary watershed in the Santa Ana Mountains to the west. **Figure 4** shows the average annual rainfall distribution across the Temescal Basin and its surrounding watersheds. Each recharge zone was assigned an average annual rainfall value based on its location.

The surface hydrology model requires daily rainfall as one of two transient inputs. Daily rainfall for the Elsinore station was used for this purpose, with missing values supplied by correlation with rainfall at the Riverside Fire Station and Claremont-Pomona Stations, both of which also have long periods of record. Daily rainfall for each recharge zone was calculated as Elsinore daily rainfall multiplied by the ratio of zonal average-annual rainfall to Elsinore average-annual rainfall.

3.4. INTERCEPTION

Plant leaves intercept some of the rain that falls from the sky, and the amount is roughly proportional to the total leaf area of the vegetation canopy. The estimated interception on each day of rain ranged from zero for industrial, idle and vacant land uses, to 0.03 inch for turf and 0.06 inch for trees in full leaf. These estimates were inferred from published results of interception studies (Viessman and others, 1977). For each day of the simulation, rainfall reaching the land surface (throughfall) is calculated as rainfall minus interception. Interception storage is assumed to completely evaporate each day and is not carried over from one day to the next.

3.5. RUNOFF AND INFILTRATION

Most throughfall infiltrates into the soil, but direct runoff occurs when net rainfall exceeds a certain threshold. The threshold at which runoff commences and the percent of additional rainfall that runs off are significantly influenced by a number of variables, including soil texture, soil compaction, leaf litter, ground slope, and antecedent moisture. These factors can be highly variable within a recharge zone, and data are not normally available for them. Also, the intercept and slope of the rainfall-runoff relationship depend on the time increment of analysis. Most analytical equations for infiltration and runoff apply to spatial scales of a few square meters over periods of minutes to hours (Viessman and others, 1977). They are suitable for detailed analysis of individual storm events. The curve number approach to estimating runoff also applies to single, large storm events. It is not suitable for continuous simulation of runoff over the complete range of rainfall intensities (Van Mullen and others, 2002). The approach used in the rainfall-runoff-recharge model is similar but less complex than the approach used in popular watershed models such as HSPF (Bicknell and others, 1997).

In the rainfall-runoff-recharge model, daily infiltration is simulated as a three-segment linear function of throughfall, and throughfall in excess of infiltration is assumed to become runoff. The general shape of the relationship of daily infiltration to daily net rainfall is shown in **Figure 5** (upper graph). Below a specified runoff threshold, all daily throughfall is assumed to infiltrate. Above that amount, a fixed percentage of throughfall is assumed to infiltrate, which is the slope of the second segment of the infiltration function. Finally, an upper limit is imposed that represents the maximum infiltration capacity of the soil. The runoff threshold, the percentage of excess net rainfall that infiltrates, and the maximum daily infiltration capacity were assumed to vary by land use and were among the variables adjusted for model calibration. The runoff threshold ranged from 0.2 inches per day (in/d) for unpaved areas in industrial and commercial zones to 1.0 in/d for turf and natural vegetation areas. The infiltration percentage for excess rainfall ranged from 60 percent in commercial and industrial areas to 94 percent in areas of natural vegetation. The maximum daily infiltration was set to 2.5 in/d in upland tributary areas and 4 in/d for zones overlying the Basin. These values were selected on the basis of calibration, although results were not very sensitive to this parameter.

The above parameter values are for soils that are relatively dry. Infiltration rates decrease as soils become more saturated. This phenomenon led to the development of the Antecedent Runoff Condition adjustment factor for rainfall-runoff equations (Rawls and others, 1993). However, application of the concept has been focused on individual storm events. For the purpose of the rainfall-runoff-recharge model, the adjustment provides a means of simulating empirical observations that a given amount of rainfall produces less runoff at the beginning of the rainy season when soils are relatively dry than at the end of the rainy season when soils are relatively wet. This effect is included in the recharge model as a multiplier that decreases the estimated infiltration as soil saturation increases. This multiplier is applied to the runoff threshold, the infiltration slope and the maximum infiltration rate. The multiplier decreases from 1.0 when the soil is dry to a user-selected value between 1.0 and 0.60 when the soil is fully saturated (lower graph in **Figure 5**). A low value has the effect of decreasing infiltration (and potential groundwater recharge) toward the end of the rainy season or in very wet years, and also to increase simulated peak runoff during large storm events. The multiplier under saturated conditions was assumed to be 0.75 for the Temescal rainfall-runoff-recharge model.

Runoff from impervious surfaces was assumed to equal 100 percent of rainfall. Runoff that flows into a storm drain system (known as "connected impervious runoff") contributes to stream flow but not groundwater recharge. However, runoff from some impervious surfaces flows onto adjacent areas of pervious soils ("disconnected impervious runoff"). The surface hydrology model treats this type of runoff as if it were a large increment of additional rainfall where it flows over or ponds on the pervious soils. The excess water can quickly saturate the soil and initiate deep percolation. The model incorporates this process by means of a variable representing the fraction of impervious runoff that becomes deep percolation. Data and literature values are not available for this variable. It was estimated to be 20 percent in residential, commercial and industrial areas and 80 percent in low-density residential areas.

3.6. ROOT ZONE DEPTH AND MOISTURE CONTENT

The storage capacity of the root zone equals the product of the vegetation root depth and the available water capacity of the soil. The available water capacity for each recharge zone was a depth-weighted average for the dominant soil type, as reported in the soil survey (NRCS, 2015). Root depth is a complex variable. Except for cropland, vegetation cover typically consists of a mix of species with different root depths. At a very local scale, roots are deepest directly beneath a plant and shallower between plants. Root density and water extraction also typically decrease with depth within the root zone. To complicate matters, root depth is somewhat facultative for some plants, which means that roots will tend to grow deeper in soils with low available water capacity, such as sands. Finally, root depth in upland watershed areas can be restricted by shallow bedrock.

The root depth selected for each recharge zone essentially represents an average of all these factors. Simulated recharge and stream base flow are both quite sensitive to vegetation root depth, and values were adjusted during the joint calibration of the rainfall-runoff-recharge model and the groundwater flow model. Separate root depths were specified for irrigated and non-irrigated vegetation in each recharge zone. Root depths for turf and crops were required to be the same in all zones. In upland watersheds root depth can be affected by the depth to bedrock, which is often shallow. Outflow from individual tributaries flowing into the basin is not gaged, and uniform rooting depths for grass and shrubs/trees were used throughout all of the watersheds.

3.7. EVAPOTRANSPIRATION

Evapotranspiration is affected by meteorologic conditions, plant type, plant maturity, and soil moisture availability. All of these factors are included in the rainfall-runoff-recharge model. The evaporative demand created by meteorological conditions is represented by reference evapotranspiration (ETo). Numerous equations have been developed over the years relating ETo to solar radiation, air temperature, relative humidity and wind speed. For the purposes of this study, daily values of ETo were obtained from a microclimate station in Temecula (about 20 miles south of the Basin) that is part of the California Irrigation Management Information System (CIMIS) network.

Vegetation factors are lumped into multipliers called crop coefficients. Reference ET is the amount of water evapotranspired from a broad expanse of turf mowed to a height of 4-6 inches with ample irrigation. ETo is multiplied by a crop coefficient to obtain the actual ET of a different crop or vegetation type at a particular stage in its growth and development. Although primarily used for agricultural crops, crop coefficients can also be applied to urban landscape plants and natural vegetation. The only agricultural crop in the Basin is citrus trees, which have a crop coefficient that ranges from 0.5 in winter to 0.91 in mid-summer (U.N. Food and Agriculture Organization, 2006). Irrigated landscaping was assumed to consist primarily of turf, for which a crop coefficient of 0.8 was used in all months (Snyder and others, 2007). Non-irrigated natural grassland consists of annual grasses that go dormant in summer once soil moisture has been depleted. A crop coefficient of 1.0 was assigned in all months, but actual ET decreases to zero as the grasses lower soil moisture to the wilting point in summer. Natural shrubs/trees were assigned a crop coefficient of 0.8 year-round. Those perennial species have deeper roots and do not tend to fully deplete root zone soil moisture during a single dry season (Blaney and others, 1963). Many riparian phreatophytes are deciduous, and a crop coefficient of 0.75 was assigned for winter months to reflect a reduced leaf area index. Their tall stature and linear distribution within an arid landscape raises the crop coefficient in summer months, and a coefficient of 1.10 was assigned to reflect those factors.

3.8. IRRIGATION

Evapotranspiration gradually depletes soil moisture, and for irrigated areas the rainfall-runoff-recharge model triggers an irrigation event whenever soil moisture falls below a specified threshold. The amount of applied irrigation water is equal to the volume required to refill soil moisture storage to field capacity, divided by the assumed irrigation efficiency. An irrigation threshold equal to 70 percent of maximum soil moisture storage was used for citrus, and a threshold of 0.8 was used for urban landscaping. This variable primarily affects the frequency of irrigation; a higher threshold results in more frequent irrigation but approximately the same total amount of water applied annually. Ten percent of water applied to citrus was assumed to percolate past the root zone, and 15 percent was assumed for urban irrigation. This reflects nonuniformity of applied water, such as uneven overlap of sprinkler spray areas. There are additional sources of irrigation inefficiency, such as evaporation of sprinkler spray mist and sprinkler overspray or runoff onto impervious surfaces in urban areas. Thus, total irrigation efficiency is less than 90 percent for citrus and 85 percent for urban landscaping. Total efficiency was used to estimate applied water, but only the deep percolation component was used to estimate deep percolation. Urban irrigation in the Basin is supplied by municipal water purveyors, and irrigation use is included in their metered deliveries.

The rainfall-runoff-recharge model was only used to estimate groundwater pumping for citrus irrigation. Because irrigation is assumed to completely refill soil moisture storage and is less than 100 percent efficient, simulated soil moisture exceeds capacity immediately following an irrigation event. The excess is assumed to become deep percolation beneath the root zone.

3.9. DEEP PERCOLATION FROM ROOT ZONE TO SHALLOW GROUNDWATER

The surface hydrology model updates soil moisture storage each day to reflect inflows and outflows. Rainfall infiltration and applied irrigation water are added to the ending storage of the previous day, and ET is subtracted. If the resulting soil moisture storage exceeds the root zone storage capacity, all of the excess is assumed to percolate down from the root zone to shallow groundwater on that day. In modeling parlance, this is known as a "bathtub model"; vertical unsaturated flow and preferential flow through cracks and root tubes in the soil are not considered.

3.10. MOVEMENT OF SHALLOW GROUNDWATER TO DEEP RECHARGE AND STREAM BASE FLOW

A shallow groundwater storage component may not be part of all groundwater systems, but its presence is sometimes indicated by groundwater hydrographs and stream base flow. In upland watersheds, for example, the shallow groundwater reservoir is what supplies base flow to streams. Without it, simulated stream flow consists of large flows occurring only on rainy days. Physically, it represents the overall permeability and storage capacity of deep soil horizons and bedrock fractures beneath hillsides bordering a gaining stream. It allows the integration of shallow and deep, fast and slow flow paths between the point of rainfall infiltration and the stream. In valley floor areas with flat terrain and deep deposits of unconsolidated basin fill, the presence of a shallow groundwater system is sometimes evident in a lack of response of deep well hydrographs to rainfall recharge events or even wet versus dry years. The shallow zone in that case attenuates the pulses of recharge percolating beneath the root zone into a relatively steady recharge flux, and there may be little outflow to streams.

In the surface hydrology model, the only inflow to shallow groundwater storage is deep percolation from the root zone. There are two outflows: laterally to a nearby creek and downward to the regional groundwater flow system. Outflow to streams is specified as a certain percentage of current groundwater storage, which results in a first-order logarithmic recession of stream base flow, consistent with gaged stream flows. Outflow to the regional groundwater system is simulated as a constant downward flux. This is consistent with flow across confining layers in which the vertical head gradient is near unity. Both outflows are calculated and subtracted from shallow groundwater storage each day. They continue until the storage has been exhausted, resuming whenever a new influx of deep percolation from the root zone arrives. There is no assumed maximum capacity of shallow groundwater storage.

The two parameters defining shallow groundwater flow are the recession constant for flow to streams and the constant downward flow rate for deep recharge. Both of these are obtained by calibration. The recession constant can generally be calibrated by matching simulated to measured stream base flow in gaged watersheds. The deep recharge rate can be used to adjust the long-term partitioning of shallow groundwater mass into base flow versus recharge.

The shallow groundwater component of the surface hydrology model is simple but adequate to capture the fundamental behaviors of logarithmic stream base flow recession and attenuated deep recharge. Other watershed models invoke more complex systems of storage and flow to simulate these processes. For example, the Precipitation and Runoff Modeling System (PRMS) developed by the U.S. Geological Survey includes a total of seven storage components between the point where a raindrop reaches the ground and the stream into which it ultimately flows (Markstrom and others, 2015). This larger number of components and parameters enables relatively detailed matching of observed stream flow hydrographs but is unnecessarily complex for the purposes of groundwater modeling.

3.11. EVAPOTRANSPIRATION BY RIPARIAN VEGETATION

In locations where the water table is shallow, some plants (phreatophytes) can extract water directly from the water table to meet evaporative demand. The rainfall-runoff-recharge model was used to estimate the amount that would be drawn from the water table if a shallow water table were present.

The potential use of groundwater by phreatophytes was assumed to equal the ET demand of the vegetation minus the amount that could be supplied by soil moisture. In practice, this was accomplished by temporarily simulating the vegetation as if it were irrigated using the rainfall-runoff-recharge model, then using the simulated irrigation rates as the maximum rate of withdrawal by roots from the water table. This rate of groundwater use is thought to decrease with increasing depth to the water table because fewer shrub and tree roots are able to reach the water table and the energetics of withdrawing the water become less favorable. The use of groundwater decreases from the maximum rate when the water table is at the land surface to zero when the water table is 20 feet or more below the ground surface. These calculations are applied at model cells where aerial photographs indicate the presence of dense, lush riparian vegetation, which is a sign of phreatophytic water use. These calculations were also made using the MODFLOW evapotranspiration (EVT) module.

3.12. GROUNDWATER INFLOW

Groundwater inflow into the basin from adjacent uplands—also called mountain front recharge—is difficult to estimate. If the basin is bounded by igneous or metamorphic rocks with very limited groundwater flow through fractures, it can be reasonable to assume that inflow from bedrock is negligibly small. If the bedrock is fractured, the total amount of inflow across the long “no-flow” boundaries on the east and west sides of the Basin can be cumulatively significant. Subsurface inflow across those boundaries was estimated using the rainfall-runoff-model results for the tributary watersheds. By this method, the estimates must be consistent with conservation of mass in the watersheds; that is, with the estimates of rainfall, ET, and surface outflow. The resulting estimates are still highly uncertain, however, because groundwater outflow from the watersheds—and surface outflow, too, for that matter—are both small compared to the two largest flows in the watershed water balances: rainfall and evapotranspiration. Thus, a small error in the estimate of either of those flows can result in a large error in groundwater outflow.

Ultimately, groundwater flows produced by the rainfall-runoff-recharge model were calibrated based on their effects on simulated groundwater levels at nearby wells within the basin and on the simulated amount of stream base flow exiting the watersheds. The initial groundwater inflow estimates were generally too high. The estimates were lowered primarily by increasing the estimated root depth of natural vegetation in the watersheds, which is highly uncertain due to the effects of shallow bedrock on rooting depth.

Groundwater inflow from tributary watersheds was smoothed over time to reflect attenuation of recharge pulses that occur during wet months and wet years as they gradually flow through long, relatively slow flow pathways. Smoothing was accomplished by a moving average of simulated groundwater recharge in the tributary areas over the preceding 2 to 10 years. This range represents local variability that was indicated by rates of recession in stream base flow and groundwater levels near the basin boundary during prolonged droughts. The final estimate of average annual groundwater inflow during the calibration period was 5,400 to 7,200 AFY under normal climatic conditions.

3.13. CALIBRATION OF RAINFALL-RUNOFF-RECHARGE MODEL

Parameters in the rainfall-runoff-recharge model were jointly calibrated with the groundwater model. The total amount of dispersed recharge and annual variations in recharge influence simulated groundwater levels, and parameters in the rainfall-runoff-recharge model were adjusted to improve the fit between measured and simulated groundwater hydrographs. The rainfall-runoff-recharge model was also calibrated based on a comparison of measured and simulated daily stream flow at two stream gages on Temescal Wash, one below Lee Lake at the upstream end of the Bedford-Coldwater Subbasin (Temescal Wash at Corona Lake; USGS 11071900) and one at Main Street downstream of the wastewater treatment plant in Corona (Temescal Creek above Main Street at Corona; USGS 11072100). Characteristics and model parameters for that watershed were assumed to also apply to similar watersheds along the western edge of the Basin. Unfortunately, the gage began operation in 2019, which is after the 1990-2018 model simulation period. Nevertheless, the general pattern of flow peaks and base flow recession simulated in prior years was similar to the gaged pattern in 2019-2020, as shown in **Figure 6**.

4. NUMERICAL GROUNDWATER MODEL DEVELOPMENT

The numerical model incorporated the hydrogeological data from the basin and hydrologic model and is capable of simulating historical and future conditions. The following section describes the development of each of the components in the MODFLOW model.

4.1. GENERAL APPROACH

The Temescal Basin Model is a numerical groundwater model, which is a mathematical description of the hydrogeological conceptual model (Bear and Verruijt, 1987). The advantage of a numerical model is that, once in a mathematical format, the model quantitatively combines data on basin geometry, aquifer properties, recharge, and discharge to simulate changes in groundwater elevations and calculate the water balance over time.

The Temescal Basin Model is setup to represent the physical features that influence groundwater flow including the geology, hydrology and climate. Each of these features is mapped onto a model grid that represents the vertical and horizontal distribution of parameters over the Basin based on the hydrogeological conceptual model. The parameters can also be varied through time over a defined base period to represent seasonal variations in precipitation, streamflow and groundwater pumping. A more detailed discussion of how each of these parameters was developed and entered into the Temescal Basin Model is summarized below.

- Model Setup - representation of the physical groundwater basin
- Boundary Conditions – representation of the inflows and outflows from outside of the model
- Aquifer Properties – representation of the flow characteristics of the aquifer
- Initial Conditions – representation of groundwater conditions prior to the model period

The model development was focused on the HCM, as described in **GSP Sections 3 and 4**, with emphasis on defining boundary conditions and flow paths. Aquifer parameters were assigned on a subregional basis within each model layer to represent reasonable aquifer properties for the aquifer being simulated.

4.2. MODEL SETUP

The model also incorporates spatial distribution of the physical features of the Basin and the temporal distribution of time-varying parameters such as precipitation and recharge. The following describes the basic components required to construct a numerical model.

4.2.1. Model Code Selection

The model setup utilizes the MODFLOW modeling code developed by the United States Geological Survey (USGS). The Temescal Basin Model uses MODFLOW-NWT (Niswonger et. al., 2011), which is a standalone version of MODFLOW-2005 (Harbaugh, 2005) that includes an advanced mathematical solver that provides a more robust solution to complex conditions such as rewetting of dry model cells, unconfined conditions and groundwater-surface water interactions. These features improve the ability of the Model to evaluate complex groundwater-surface water interactions and projects to increase future groundwater levels in the Basin.

4.2.2. Base Period

The Temescal Basin Model is setup using water years that run from October through to the following September to capture the cause and effect relationship on groundwater levels of wintertime rain and subsequent summertime groundwater pumping. The model simulates the 29-year base period from October 1989 through September 2018 to represent Water Years (WY) 1990 through 2018. This retains the starting date of prior models, which coincides with the beginning of some key data sets and also the beginning of the period of rapid land use conversion from agricultural to urban. The ending year is the most recent year for which all necessary model input data were available. The 29-year simulation period is desirable for model calibration purposes because it includes a wide range of hydrologic and water use conditions, including wet periods, droughts, changes in groundwater pumping and implementation of lake management measures.

To simulate this base period, the model is subdivided into time intervals termed stress periods. For each water year, monthly stress periods were defined to provide the ability of the model to evaluate temporal at a monthly scale. For the base period, a total of 348 stress periods were defined. Time-dependent parameters, such as groundwater pumping or precipitation recharge, are assigned to for each stress period.

Conditions during the stress period are constant, but parameters can be varied from stress period to stress period. A stress period can be subdivided into shorter time periods, or timesteps, to allow for more temporal resolution within each stress period to help with model convergence. For the Temescal Basin Model, each stress period was simulated using three (3) timesteps. MODFLOW calculates the groundwater elevations and water balance for each time step. The model results provide the groundwater elevations for the final timestep of each stress period, and the summation of the water balance changes for all timesteps for each stress period.

4.2.3. Model Domain and Grid

MODFLOW requires the application of a rectangular grid that encompasses the entire area, or domain, that will be modeled. The model grid forms the mathematical framework for the model. Each grid cell has to be populated with aquifer properties. Physical features such as streams and wells are mapped onto the model grid. Using this information, the MODFLOW model calculates a groundwater elevation at each model grid cell for each timestep. The density of model grid cells is what defines the resolution of the model in resolving drawdown and other hydrologic effects.

The model domain covers all of the Temescal Basin and a portion of the Chino Area in the Prado area (**Figure 7**). The Temescal Basin occupies about 75 percent, approximately 37 square miles, of the southern model domain. The extent of the model domain for the Temescal Basin Model is shown on **Figure 7**. A portion of the Chino Basin was included in the Temescal Basin Model domain to allow for a more natural boundary along the Santa Ana River and Prado wetlands area. The boundary with the Chino Subbasin (DWR Basin No. 8-2.01) to the north is generally marked by the Santa Ana River and a series of low-lying hills in the Norco area. The northern boundary was set at a distance sufficient far so that the assigned boundary condition would not affect groundwater conditions in the Temescal Basin.

The Temescal Basin Model consists of 568 rows, 480 columns and 3 layers. The rows and columns have a uniform spacing of 100 feet. Each 100-foot square represents a model cell. MODFLOW calculates one groundwater level for the center point of each grid cell for each timestep. The total number of grid cells in the Temescal Basin Model is 817,920 cells, of which 425,304 are active cells where MODFLOW calculates a groundwater levels. The active areas, which represent the area within the groundwater basin where groundwater elevations are simulated, covers approximately 35,526 acres. Areas outside of the Basin are represented as no-flow cells where MODFLOW does not perform calculations.

4.2.4. Model Layers

The model layers represent the geologic units that compose the Principal and Secondary Aquifers of the Basin based on the geology and HCM presented in **GSP Section 3** and summarized in **Section 2**. Model layers provide vertical resolution for the model to simulate variations in groundwater elevation, aquifer stresses, and water quality with depth. The model layers are based on an evaluation of the following data sets:

- Surficial geology,
- Faulting,
- Lithologic borehole logs.
- Well construction logs, and
- Previously completed local hydrogeologic conceptualizations and cross sections.

This information was collected and translated into a unified GIS compatible database structure for cross section construction and geographic evaluation. This approach allows any hydrostratigraphic structures relevant to groundwater flow in the Basin to be easily translated from GIS for use in other formats.

For the Temescal Basin Model, three model layers were defined to simulate hydrogeologic characteristics of the principal and secondary aquifers within the Temescal Basin. The model layers are numbered from 1 through 3 from top to bottom. In the Temescal Basin, three model layers were defined that represent the following geologic units:

- Model Layer 1 – Channel Aquifer (Principal Aquifer)
- Model Layer 2 – Alluvial Fan Aquifer (Secondary Aquifer), and
- Model Layer 3 - Sandstone Aquifer (Secondary Aquifer)

Figure 8 shows the general outline of the Channel Aquifer within the Temescal Basin. The top of Model Layer 1 represents the topography that is based on topographic elevation points every 10 meters were extracted from the National Elevation Dataset (http://ned.usgs.gov) throughout the model domain **Figure 9**.

The model layers represent the aquifers within the Temescal Basin. **Figures 10 through 12** show the areal extent and bottom elevation of each of the model layers over the entire model domain. **Figure 13** shows two cross section help to illustrate the shapes and relative thicknesses of three model layers in the Temescal Basin. These cross sections follow along the model grid with the upper cross section on **Figure 13** located along model-grid row 262 and the lower cross section on **Figure 13** located along model-grid column 322 (**Figure 8)**. These The following discussion provides a summary of the geologic units represented by each model layer in accordance with the HCM.

Model Layer 1 represents the Channel Aquifer in the Temescal Basin, which is the primary water supply unit in the Basin (Todd and AKM 2008) where the larger wells are completed. The alluvial deposits are a mix of interlayered gravels, sands, silts, and clays resulting from alluvial fan and fluvial processes. Model Layer 1 ranges up to 200 feet thick. Alluvial aquifer materials are present in other parts of this hydrologic area, but their extent and production capacity are uncertain. In these areas, Model Layer 1 represents a relatively thin layer that is rarely saturated. The extension of Model Layer 1 is a requirement of MODFLOW to provide for continuity across the model domain. In these areas, Model Layer 1 has a minimum thickness of ten feet, and is conceptualized as the soil and shallow unconsolidated sediments that overlie the older alluvial fan and consolidated sedimentary geologic units.

Model Layer 2 represent the Alluvial Fan Aquifer (Secondary Aquifer) that is composed of heterogeneous sand and fine-grained sediments. Although these deposits are relatively thick, the entire unit is heterogeneous and cannot be considered one single aquifer. Rather, sand lenses within the deposits collectively form the Alluvial Fan Aquifers. Lithologic data from wells are insufficient to map out the extent of the aquifers or characterize the deposits. Limited data indicate relatively fine-grained textures throughout much of the area, especially with depth (Todd and AKM 2008).

Model Layer 3 represents the Sandstone Aquifer (Secondary Aquifer) that consists of sedimentary rocks of Tertiary age containing sandstone layers that are penetrated by several Corona wells (Todd and AKM 2008). Due to the limited production, depth, and relatively low permeability in most areas, the Sandstone Aquifer is not considered a primary source of water supply. The bottom of Model Layer 3, which the lowest model layer in the Model, is a no-flow boundary condition, representing the older bedrock formations that are assumed to be relatively impermeable.

In the Chino Basin, Model Layers 1, 2 and 3 represents the aquifer layer defined in the Chino Basin Model (WEI, 2015, 2020). The definition of the model layers in the Chino Basin were set up to conform as well as possible to the model layers used in the Chino Basin Model (WEI, 2015, 2020). These Chino Basin layers were correlated to the three model layers defined in the Temescal Basin.

4.2.5. Faults

The Elsinore and Chino fault zones bound the Basin on the west and parallel the base of the Santa Ana Mountains. The faults within the Basin were simulated using the Horizontal Flow Boundary (HFB) Package in MODFLOW that allows a conductance parameter to be placed between adjacent model cells to limit groundwater flow. Flow across the faults was based on assigned conductance values that ranged from 0.01 ft^2/d in the alluvial sediments in the Prado area to 0.000002 ft^2/d in the sandstone aquifer in the Temescal Basin. The fault locations within the Temescal Basin model are shown on **Figure 14**. For the model, all faults extended across model Layers 1 through 3. The fault hydraulic conductivities were based on an initial estimate that was refined during model calibration.

The HFB Package was also used to assign a low conductance (0.0000003 ft^2/d) to represent the engineered clay core of the Prado Dam that is designed to limit underflow underneath the dam through the unconsolidated sediments in Model Layer 1.

4.2.6. Aquifer Conditions

Groundwater conditions for each model layer can be defined as unconfined, fully-confined, or convertible between confined and unconfined based on the relation of the simulated groundwater level to the top of the model layer. Unconfined conditions exist when groundwater levels are below the top of the physical aquifer layer whereas confined conditions exist when groundwater levels are above the top of the physical aquifer layer. For the Temescal Basin Model, Model Layer 1 is defined as unconfined throughout the model domain. Model Layers 2 and 3 are defined as convertible between confined and unconfined conditions.

Because of the historical changes in groundwater levels, areas within the Basin can be temporarily unsaturated. Prior MODFLOW versions set a dewatered cell to a no-flow condition for the rest of the simulation if the cell is dewatered. An important advantage of using MODFLOW-NWT compared to previous MODFLOW versions is that unsaturated groundwater heads will be calculated for dry cells, whereas standard MODFLOW excludes these calculations (Niswonger et. al., 2011). This resaturation capability of MODFLOW-NWT was utilized for the Temescal Basin Model.

In MODFLOW-NWT, head is simulated continuously from saturated to unsaturated conditions. MODFLOW-NWT will calculate a head in an unsaturated cell while not allowing water to flow out of that cell, which provides a continuous solution for groundwater flow. Inflow to an unsaturated cell, either from adjacent cells, overlying cells, or an external source simulated by one of the stress packages, automatically flows downward to an underlying saturated cell if there are deeper layers. An unsaturated cell has a head below the cell bottom and is considered to have no water in storage, so changes in storage also are zero for these cells. The model accounts for this situation by setting the storage coefficient for an unsaturated cell to zero. This allows for the continuous solution of head not to affect the overall water balance results (Niswonger et. al., 2011).

Because groundwater heads are calculated for unsaturated cells using this approach, it is necessary for the model user to interpret the head in a cell relative to the cell bottom. If the head in a cell is at or below the cell-bottom altitude, then the water table is not contained within this cell (Niswonger et. al., 2011).

4.3. BOUNDARY CONDITIONS

Model boundary conditions represent the hydrologic budget by simulating where groundwater enters and exits the basin. Boundary condition data must be entered for each stress period at each model grid cell where a boundary condition is defined in the model. MODFLOW NWT provides a number of boundary condition options to numerically represent the different physical processes included in the hydrologic budget. The physical distribution and volumes of groundwater inflow and outflow for each budget component need to be accounted for geographically within the model domain. A discussion of each boundary condition of the groundwater budget is provided below.

4.3.1. Surface Recharge

The rainfall-runoff-recharge model outlined in **Section 3** describes the methodology to define both the spatial distribution and monthly volume of surface recharge to groundwater within the Temescal Basin model. The rainfall-runoff-recharge model calculates the monthly contributions from precipitation and return flows to surficial groundwater recharge. The surface recharge is spatially distributed across the model domain using zones that are defined by a combination of geology and land use. This calculated surface recharge is applied using the MODFLOW recharge package.

4.3.2. Streams

The groundwater model dynamically simulates groundwater recharge from stream percolation and groundwater discharge into streams. Percolation from streams is a function of stream flow and—where the water table is equal to or higher than the stream bed elevation—the difference in water level between the creek and water table.

The MODFLOW stream flow routing (SFR2) package is used to simulate these processes. Each stream in the basin is simulated as a sequence of reaches, each of which is a model grid cell along the alignment of the channel. Flow is specified at the upstream end of each stream segment and routed down the reaches, with flow to or from the aquifer calculated on the basis of wetted channel area, channel bed hydraulic conductivity and the difference in elevation between the stream surface and the simulated groundwater level at that reach. By this means conservation of mass is applied concurrently to the stream and the aquifer. Streams can dry up completely as they cross the basin; and conversely, groundwater discharge can create stream flow in a segment that is dry farther upstream. The stream flow routing module allows for a network of channel segments, with multiple inflows or diversions at the start of each segment.

The Temescal Basin model includes a network of 39 stream segments containing a total of 2,688 stream reaches (**Figure 15**). Seventeen segments are used to simulate eight streams that drain watersheds in the Santa Ana Mountains along the west side of the Basin. Streams that flow across the Temescal Basin to Temescal Wash are divided into multiple segments to represent the natural, concrete-lined and unlined engineered streambed conditions present on these streams. Temescal Wash is composed of seven segments that represent varying lined and unlined conditions along Temescal Wash (**Figure 15**). An additional five segments represent the short sections of four streams that drain watersheds from upland areas east of Temescal Wash.

In general, the upland stream reaches are more than 20 feet above the water table and are not hydraulically coupled to groundwater. Percolation from those reaches is independent of groundwater levels and not affected by pumping. Reaches where groundwater appears to be hydraulically coupled to surface water primarily include most of the length of Temescal Wash, Santa Ana River, and the lower ends of some larger tributaries in the Prado wetland area.

In the Chino Basin, the Santa Ana River is represented by five segments (**Figure 15**). The areas upstream of the Prado wetland area were represented by a single long segment, and the other four segments defined areas within the Prado wetland area and downstream of the Prado Dam. Five other segments simulated streams in the Chino Basin. Stream bed permeability was estimated by model calibration. For unlined streams, calibrated values for the stream bed permeability ranged from 0.1 to 25.0 feet per day (ft/d); whereas for concrete-lined streams, the stream bed permeability ranged from 0.00003 to 0.03 ft/d.

To develop estimates of surface and subsurface inflows from these tributary areas to the groundwater basin, a rainfall-runoff-recharge model (**see Section 3**) is used to simulate the entire watershed tributary to the Basin. This model simulates all near-surface hydrologic processes, including rainfall, runoff, infiltration, evapotranspiration, effects of impervious areas and irrigation, soil moisture storage and percolation to stream base flow and deep groundwater recharge. The calculated runoff is included in the SFR2 Package. Inflows for Temescal Wash are coordinated with output from the Bedford-Coldwater numerical model and USGS gauge data as discussed as part of the rainfall-runoff model documentation in **Section 3**.

The lower Temescal Wash and Butterfield Drain in the Prado area along the northern boundary of the Temescal Basin were simulated using the MODFLOW Drain Package. This is because the Prado Area is primarily a groundwater discharge area (**Figure 15)**. During model calibration, these two stream segments experienced numerical instability due to the interaction of two head-dependent boundaries of groundwater-surface water interactions using SFR2 and the high evapotranspiration applied to the Prado Area. During model calibration, the MODFLOW output showed that these areas were principally areas of groundwater discharge to streams or ET, so converting these areas to drains was appropriate to improve the overall model performance.

Similarly, areas in the Norco area include large storm drain channels for drainage and stormwater management (**Figure 15**). Occasional shallow groundwater conditions during high rainfall periods led to numerical instability that was relieved by converting these drainage channels to the MODFLOW Drain Package.

4.3.3. Mountain Front Recharge

Groundwater inflow into the basin from adjacent uplands—also called mountain front recharge (MFR)—were calculated by the rainfall-runoff-recharge model (see **Section 3**). MFR represents subsurface inflow of groundwater from the low-permeability rocks adjacent from the surrounding watershed to the groundwater Basin. The MODFLOW well package was applied along the basin margin in Model Layer 3 which represents the weathered bedrock. The distribution of the cells assigned to represent MFR are shown on **Figure 16.**

The rainfall-runoff-recharge model (see **Section 3**) was used to calculate a monthly subsurface inflow from each watershed based on precipitation recharge in the upstream watershed, with delays and attenuation due to long travel times through bedrock fractures. A set of cells in the well package were assigned to each watershed and the monthly inflow was distributed evenly to those cells assigned to that watershed. Therefore, the distribution of inflow incorporates the size and rainfall for each of the defined watersheds that contribute flow to the Basin.

4.3.4. Evapotranspiration

Evapotranspiration (ET) represents groundwater outflow from evaporation to the atmosphere and uptake by plants from the saturated zone. This is distinct from ET associated with soil moisture before it reaches the groundwater aquifer that is sustained by the total available precipitation not accounted for by runoff or recharge (see **Section 3**).

The MODFLOW evapotranspiration (EVT) package is used simulate ET directly from the groundwater aquifer. ET is defined over the entire model domain; however, ET only occurs in areas of shallow groundwater. In the Basin, this is generally limited to riparian areas adjacent to streams. ET includes uptake from both phreatophytes (plants that require groundwater) and mesophytes (plants that can utilize groundwater) either directly from the saturated zone or from the overlying capillary fringe (Meinzer, 1927; Robinson, 1958; and Lewis and Burgy, 1964). ET from the capillary fringe is replenished with groundwater from the underlying aquifer, so it is also considered a loss of groundwater (Lubczynski, 2011).

In the MODFLOW EVT package, the ET rate decreases with increasing depth to the water table because fewer shrub and tree roots are able to reach the water table and the energetics of withdrawing the water become less favorable. In the groundwater model, the consumptive use of groundwater due to ET decreases from the maximum rate when the water table is at the land surface and diminishes linearly down to zero when the water table reaches the extinction depth for that location.

In the Temescal Basin Model, three ET zones were defined as shown on **Figure 17**. The first zone represents locations where aerial photographs indicate the presence of dense, lush riparian vegetation indicates areas of shallow groundwater where the plants (phreatophytes) can regularly uptake water directly from the water table to meet evaporative demand. These primarily occur in the Prado wetland area, along the Temescal Wash, Santa Ana River and in some of the upland canyons along the basin margin. The extinction depth for these locations was set at 20 feet below the ground surface. Over most of the remaining model domain, the extinction depth was set at the ground surface. The third area represents areas the Norco area where the extinction depth was set at 1.0 feet below the ground surface to better control periods of high groundwater. ET rates applied in the Temescal Basin Model use the ET data from the rainfall-runoff-recharge model (see **Section 3**).

4.3.5. Groundwater Pumping

Groundwater pumpage is the largest groundwater outflow from the Basin. Corona is the primary producer of groundwater in the Basin. Corona has 18 wells that extract water from the Basin for the purpose of potable water supply (Michael Baker 2021). Norco has four active wells but they are located in the unadjudicated portion of the Chino Subbasin not the Basin. Thirty-eight wells within the Basin produced groundwater in one or more years during 1990-2018, and the reported annual pumping amounts were obtained from WMWD.

A number of private wells were historically installed in the Basin. There are no records of which of these wells are currently active. However, the GSA agencies searched for existing active wells within the Basin. This search included reviewing water use records and contacting owners of large private properties (domestic, commercial, and industrial), inquiring about private wells in discussions with knowledgeable local residents and community leaders, and polling interested parties during public meetings. This effort indicated that the only private pumpers in the Basin are All American Asphalt, Dart Corporation, and 3M. No active private domestic wells were identified in this search. **Figure 18** shows the locations of wells with measured pumping rates in the Basin by Corona, Norco and private pumpers.

Citrus orchards irrigated with groundwater were common in the Basin in the early 1990s, but except for one small grove those have all been replaced by urban development. Agricultural irrigation pumping of the orchards was estimated by the rainfall-runoff-recharge model, with pumping assigned to a hypothetical irrigation well at the center of each irrigated recharge zone. This pumping was phased out over time as urban development occurred. Urban irrigation is supplied by the municipal water system, which uses imported water and local wells. Locations of agricultural pumping are distributed based on the estimated agriculture pumping requirements calculated using the rainfall-runoff model (**Figure 19**).

Municipal well extractions are measured and these data are entered directly into the model. Annual production by municipal wells is shown in **Figure 20**. All pumping wells are included as analytical elements that are simulated by the MODFLOW well package in the model. **Table 1** summarizes the average annual groundwater pumping for each well over the simulation period along with the assigned model layer.

4.3.6. Recycled Water Recharge Ponds

Wastewater is treated at three Corona-owned and operated Water Reclamation Facilities (WRF-1, WRF-2 and WRF-3). The average annual production of treated wastewater (effluent) from these sources is approximately 11.35 mgd, or 12,700 acre-feet per year (AFY). Supply is anticipated to increase incrementally due to population growth by an additional 0.88 mgd through 2040 (about 7.8 percent).

WRF effluent is allocated to three end uses: 1) discharge to Temescal Wash or the Santa Ana River (SWRCB 2021), 2) reuse via the reclaimed water distribution system, and 3) discharge to offsite percolation ponds. WRF-1 and WRF-2 both contribute effluent to all of these end uses while WRF-3 only contributes effluent to the reclaimed water system.

The MODFLOW Well Package was used to simulate recharge at the WRF recharge pond as recharge wells. The volume of flow for each recharge pond was distributed evenly over the area of the ponds. The three offsite percolation ponds overlie the Basin and allow for recharge. One of the ponds is located along Lincoln Avenue and the other two at the end of Rincon Street near Cota Street, as shown in **Figure 21**. Average annual WRF discharge to the recharge ponds from 2016 through 2020 ranged from 1,364 to 5,273 AFY at WRF-1, and 734 to 1,462 AFY at WRF-2.

4.3.7. Subsurface Flow with Adjacent Groundwater Basins

To simulate potential subsurface groundwater and outflow with adjacent groundwater basins, either a specified head or general head boundary was defined using MODFLOW. Constant head boundaries allow sufficient inflow or outflow at that model cell to achieve the specified head. Head boundaries were defined at the locations shown on **Figure 22** at the following areas:

- **Arlington Gap** - The Basin margin with the Upper Santa Ana Valley – Riverside-Arlington Basin at the location known as the Arlington Gap.
- **Santa Ana River Flow Boundary** - The Basin margin with the Coastal Plain of Orange County Groundwater Basin near the outflow of the Santa Ana River from the Temescal Basin.
- **Bedford-Coldwater Flow Boundary** - The basin margin along the far southeastern corner of the Basin to coordinate with a similar boundary condition applied in the groundwater model for the Bedford-Coldwater Basin.
- **Chino Basin Interior Flow Boundary** - The northern model domain boundary located within the Chino Basin.

At the Arlington Gap, a MODFLOW General Head Boundary (GHB) package was applied along the basin margin. The distribution of the GHB cells is shown on **Figure 22.** The MODFLOW general head boundary (GHB) package allows for a more flexible simulation of the groundwater elevation at the cell by calculating the inflow or outflow at that model cell based on a conductance and a specified head at a user-defined distance on the external side of the boundary. The GHB boundary was defined based on an earlier groundwater flux calculation for the Arlington Gap (Todd and AKM 2008). The GHB parameters were varied during calibration to better match measured groundwater levels in the area.

The boundary with the Coastal Plan of Orange County Basin is a narrow canyon where the Santa Ana River exits the Temescal Basin. A MODFLOW constant head boundary was applied at this location. The specified head at this boundary was set at a comparable level with the stage of the Santa Ana River to simulate subsurface flow towards the Coastal Plan of Orange County Basin.

The Bedford-Coldwater Basin boundary is generally considered have little to no groundwater flow except where the alluvium along Temescal Wash thins as the wash leaves the subbasin and traverses northward through bedrock (a reach referred to as Temescal Canyon) before entering Temescal Basin. A MODFLOW constant head was applied at this location at a comparable level with the stage as was applied in the Bedford-Coldwater Basin to allow for groundwater flow through the channel deposits of Temescal Wash.

The Chino Basin interior flow boundary is located along the northern model domain. A portion of the Chino Basin was included in the Temescal Basin Model domain to allow for a more natural boundary along the Santa Ana River and Prado wetlands area. As a result, a boundary condition was defined within the Chino Basin. This northern boundary was set at a distance sufficiently far from the Santa Ana River that the assigned boundary condition would not affect simulated river-aquifer interactions or simulated groundwater conditions in the Temescal Basin. A MODFLOW constant head was applied to represent the general groundwater elevation pattern in the Chino Basin based on available groundwater elevations with some minor adjustments during model calibration. The objective of this boundary condition is to provide a realistic representation of groundwater conditions within the Chino Basin with respect to understanding the water balance for the Temescal Basin.

4.4. AQUIFER PROPERTIES

Aquifer properties represent the physical and hydrogeologic characteristics of the aquifers within the Basin that control groundwater flow. Aquifer properties must be assigned to each active grid cell in the model. The conceptual model provides the framework necessary to define aquifer properties.

4.4.1. Aquifer Characteristics

The groundwater model represents the basin fill materials in terms of their ability to store and transmit groundwater. Horizontal and vertical hydraulic conductivity define the permeability of the aquifer, which is its ability to transmit groundwater flow. The ability to store water consists of two components. At the water table, storage of water associated with filling or draining the empty (air-filled) interstices between mineral grains is represented by the specific yield of the aquifer. In deep aquifers, there is a much smaller ability to store and release groundwater that derives from the compressibility of the water and aquifer materials (specific storativity). Thus, the initial response to pumping from a deep aquifer is a large drop in water level (head) within that aquifer. With sufficient time, however, the decrease in head creates downward movement of groundwater that eventually accesses the storage capacity at the water table. In other words, the storage response of the aquifer depends partly on the duration of pumping and observation. For groundwater management purposes, storage responses over periods of months to decades are usually the most relevant.

Aquifer characteristics can be estimated in two ways. The first is by means of an aquifer test in which one well is pumped while water levels are measured at a nearby well. This approach typically measures horizontal hydraulic conductivity over distances of tens to hundreds of feet and storage responses over periods of 1 to 3 days. The second approach is to calibrate a groundwater flow model such that the aquifer characteristics reproduce measured historical water levels throughout the basin given estimates of historical recharge and pumping. The latter approach produces estimates of aquifer characteristics averaged over spatial scales of thousands to tens of thousands of feet and time scales of months to decades. The estimates account for preferential flow through localized sand and gravel lenses in the basin fill materials and for delayed water-table responses to deep pumping. Also, model calibration provides estimates of vertical hydraulic conductivity across the layers of alluvial deposits, which is rarely measured by aquifer tests. The temporal and spatial scales represented by the model calibration approach are better for addressing most long-term groundwater management questions.

4.4.2. Zone Approach

Because of the limited data for aquifer properties for the Basin, a zoned distribution pattern was used that applied aquifer properties over subregional areas with similar geologic conditions. Although the units are heterogeneous, the approach was to get a representative average value for each aquifer property for limited number of zones around the basin. This was to avoid the patchwork quilt type of aquifer property distribution that does not show any relation to the underlying geologic conditions that define the aquifer property. **Figure 23** shows the distribution of aquifer characteristics after calibration of hydraulic conductivity and specific storage, respectively. The initial estimates of hydraulic conductivity and specific yield were from available local data, which incorporated major geologic features such as relatively permeable sediments in the upper parts of alluvial fans.

4.4.3. Hydraulic Conductivity

Hydraulic conductivity represents the ability of the water to flow through the aquifer, and is defined horizontally within a model layer to represent groundwater flow through the aquifer and vertically between adjacent model layers to represent groundwater exchange between aquifers. The determination of the horizontal hydraulic conductivity is based on an assessment of lithologic description, available aquifer test data and model calibration. Since each model layer represents a thick interval composed of varying lithologies, the horizontal hydraulic conductivity represents an average value over the entire vertical thickness that includes the finer-grained layers in addition to any specific sand and gravel zone. For the Temescal Basin model, horizontal hydraulic conductivity is defined using regionalized blocks based on the geologic character of the unit and refined during calibration. The hydraulic conductivity used in the Temescal Basin model varies within a reasonable value range for the aquifer characteristics for each aquifer to achieve the model calibration. The final simulated horizontal hydraulic conductivities are listed in **Table 2.**

4.4.4. Vertical Conductance

In general, groundwater flow within an aquifer is dominantly horizontal whereas flow between adjacent aquifers is essentially vertical. The application of vertical hydraulic conductivity recognizes the inherent anisotropy present in natural geologic formations. Vertical groundwater flow is equivalent to Ohm's Law for serial electrical flow through different resistivity layers. Based on this analogy, vertical groundwater flow, similar to serial electrical flow, is limited by the lowest conductivity (or highest resistivity) layer encountered. Therefore, vertical groundwater flow is defined by the lowest-permeability, areally extensive layer that controls the exchange of groundwater between aquifer or model layers. MODFLOW requires the input of a vertical hydraulic conductivity (Kz) for each layer. The vertical hydraulic conductivity values used in the model to calculate the VCONT are summarized in **Table 2**.

4.4.5. Specific Yield and Specific Storage

Aquifer storage defines the ability of the aquifer to take in or release water. Under unconfined conditions, water released from or put into aquifer storage represents the physical draining of groundwater from interstitial pore space within the aquifer. Unconfined storage is defined by specific yield. Under confined conditions, water released from or put into aquifer storage is derived from the compressibility of water as a result of changes in the aquifer pressure within the interstitial pore space. MODFLOW NWT requires the use of specific storage, which is in the units of $feet^{-1}$. Reasonable ranges for the specific yield and specific storage were varied within a reasonable range during the model calibration and the values are listed in **Table 2**, respectively.

4.5. INITIAL CONDITION

The model also requires that groundwater levels be specified at the start of the simulation. They were estimated based on contouring of available water level data. As the initial heads may not be representative of stable initial conditions, the first stress period representing pre-1990 conditions was run as steady-state condition to facilitate the calculation of a stable hydrologic system. In addition, initial conditions for the earlier groundwater model (Todd and AKM 2008), and simulated groundwater conditions for September 1989 from the Chino Model (WEI, 2015, 2020) were included to help guide the contouring. **Figure 24** provides the starting head used to provide a reasonable representation of the September 1989 groundwater conditions for Layers 1, 2 and 3.

5. HISTORICAL MODEL RESULTS

The Temescal Basin model was calibrated to reduce uncertainty by matching model results to observed data. An extensive calibration process was designed to better constrain the range of aquifer properties and boundary conditions for the model, thereby reducing uncertainty in the results.

5.1. CALIBRATION METHODOLOGY

For the Temescal Basin model, the calibration simulation uses a 29-year period that covers water year (WY) 1990 to WY2018. This aspect of the calibration is important to demonstrate that the model has the capability to simulate historical changes in groundwater elevations, and is therefore capable of forecasting future changes in groundwater elevations. This capability is necessary for the model to serve as a useful groundwater management tool.

5.1.1. Approach

The transient calibration is a process that compares the simulated groundwater levels from the model to observed groundwater level measurements. During calibration, boundary condition parameters and aquifer properties are varied within the reasonable range defined by the hydrogeological conceptual model. Different combinations are tested to determine the set of parameters and properties that produce an acceptable correlation between simulated and measured groundwater elevations. Other data sets, such as key water budget components, surface water conditions, or hydrogeological conceptual model, were also used to further constrain the calibration.

There are multiple combinations of aquifer properties and boundary conditions that can be used to match a single set of groundwater elevation data. Calibrating to multiple data sets under differing stresses (i.e. recharge and discharge rates) reduces this “non-uniqueness”, thereby reducing the uncertainty. Performing a comprehensive calibration over a 29-year base period infers the calibration has been performed over wet, dry, and normal years with varying degrees of pumping. To that end, the Temescal Basin model was primarily calibrated using groundwater levels. The measures of calibration are primarily from a statistical analysis along with a visual assessment groundwater level trends from hydrographs. The groundwater elevation maps and water budget data considered during the model calibration are assessed in context with the model results, so are discussed in the next section.

5.1.2. Calibration Methodology

Joint calibration of the rainfall-runoff-recharge model, the surface water budget models and the groundwater flow model applied heuristic methods (i.e. trial-and-error adjustments) to selected variables, as informed by the timing and location of model residuals. In accordance with the principle of parsimony in modeling (DWR 2016a), calibration began with a small number of broad zones for hydraulic conductivity and storage. Zones were subdivided during calibration if a pattern of residuals at multiple wells warranted it. Although storage and hydraulic conductivity are not necessarily correlated, in practice they often are to some degree. Thus, for simplicity, similar zonation patterns were used for both variables.

In practice, most of the calibration effort focused on adjustments to horizontal and vertical hydraulic conductivity, the locations and conductances of faults, stream bed vertical hydraulic conductivity, and several tributary watershed parameters: root depths of natural vegetation, rainfall-runoff thresholds and slopes, and the leakage and recession rates for shallow groundwater. Variables that were not adjusted during calibration include land use, crop root depths, pumping locations, and groundwater pumping.

The model calibration process was also evaluated using a statistical comparison of differences (or residuals) between measured and simulated groundwater elevations. An initial sensitivity analysis was performed using an automated parameter estimation process to provide an initial estimate of hydraulic parameter values and zonation. During the final model calibration, adjustments were made to model inputs and parameters in areas based on the degree and pattern of discrepancies between measured and simulated water levels. Water levels for some wells were easy to reproduce with the model, while others were more difficult. Additionally, a visual inspection of superimposed measured and simulated water-level hydrographs was used to verify consistency with long-term trends. This process of manually calibrating a groundwater model also produced considerable insight into the groundwater flow system and the factors that influence it.

5.2. SENSITIVITY ANALYSIS

The sensitivity analysis was used to determine which model parameters should be calibrated. The model parameters include the hydraulic properties of the aquifer, boundary conditions, as well as any other aspect of the model that can be parameterized. The objective of the sensitivity analysis was to identify those model parameters with a high sensitivity with respect to simulation of groundwater elevations. For the sensitivity analysis, PEST (Doherty, 2004) was selected due to its robust capabilities to automate the parameter estimation and further evaluate the model.

Parameter sensitivity measures the impact of a small parameter change on the calculated system response. If a small model parameter changes results in a large change in the simulated water levels of the model domain, the parameter is regarded as highly sensitive. For the initial sensitivity analysis, all model parameters were included. The purpose was to exclude insensitive parameters from the final adjusted parameter set. During these processes, the covariance matrix from sensitivity analysis was used as the basis for eliminating insensitive parameters from the final test. A total of 21 hydraulic parameters were included in the initial sensitivity analysis. The results indicated that results are relatively sensitive to the hydraulic conductivities and specific yield of layer 1, and also to the hydraulic conductivity of Layer 2 in some areas.

5.3. STATISTICAL CALIBRATION

Model calibration was based on observed groundwater elevations from 3,166 measurements in 29 wells over the 29-year base period from October 1989 through September 2018 (WY1990-2018). The locations of these wells are shown on **Figure 25**.

The statistical calibration consists of a rigorous analysis comparing the difference, or residual, between measured and simulated groundwater elevations. An initial assessment of the model calibration is a comparison of observed versus simulated groundwater elevations of the entire calibration data set using a scatter plot (**Figure 26**). As indicated on **Figure 26**, the scatter along the correlation line is minor in comparison to the range of the data. The correlation coefficient for the data on this graph is 0.934, which indicates a strong correlation between simulated and observed groundwater elevations.

A more detailed tabulation of the statistical analysis for the model calibration is presented in **Table 3**. A summary of the key statistical measures shown on **Table 3** are provided below:

- The residual mean is computed by dividing the sum of the residuals by the number of residual data values. If the mean is significantly higher or lower than zero, it indicates overall model bias toward high or low water levels. The residual mean is -1.7 feet, which is close to zero.
- The absolute residual mean is the arithmetic average for the absolute value of the residual so it provides a measure of the overall error in the model. The absolute residual mean is 11.1 feet.
- The residual standard deviation evaluates the scatter of the data. A lower standard deviation indicates a closer fit between the simulated and observed data. The standard deviation for the calibrated model is 8.7 feet.
- The Root Mean Square (RMS) Error is the square root of the arithmetic mean of the squares of the residuals is provides another measure of the overall error in the model. The RMS Error for the calibrated model is 11.3 feet.
- The scaled absolute residual the ratio of the absolute residual mean is divided by the range of observed groundwater elevations. This ratio helps to put the variation of the residuals into perspective with respect to the scale of the groundwater basin. This ratio for the Temescal Basin Model is 0.024, which puts the statistical variability at less than 2.5 percent of the range. A ratio below 0.10 is generally considered a well calibrated (ESI 2020).

The statistical comparison is also consistent when evaluated by aquifer as shown on **Table 3**, which summarizes the statistical parameters for calibration wells screened primarily in the Channel Aquifer and the Secondary Aquifers (combined Alluvial Fan Aquifer and Sandstone Aquifer). The variability is primarily attributed to the greater number of groundwater levels from active pumping that increases the variability of the observed data over the calibration period. The statistical results are of high quality and are one indication that each aquifer is well calibrated. **Table 4** provides a summary statistics for each of the 29 wells used in the calibration process. The statistical parameters are considered reasonable, indicating that the model is well calibrated.

It should be noted that some degree of difference (or residual) between the observed and simulated groundwater elevations is expected. Residuals may be due in part to localized effects or data quality issues. Therefore, a limited outlier analysis was applied to remove groundwater elevations that did not reflect groundwater conditions in the aquifer. For example, data quality issues, which typically look like isolated spikes along an otherwise consistent long-term trend, were removed. Elevated residuals can result from using groundwater elevations from pumping wells as calibration targets due to excessive drawdown due to a low well efficiency of the pumping well. Pumping well groundwater levels used for the calibration data set except those where the drawdown highly deviated from the long-term trend that were interpreted to be represent well efficiency issues within the pumping well.

5.4. GROUNDWATER LEVEL TRENDS

Hydrographs provide a detailed time history of groundwater elevations for specific wells. This time history data includes the impact of varying climatic and pumping stresses on the groundwater basin. Comparing hydrographs of model results versus observed data provides another measure of model accuracy. For calibration purposes, the hydrographs were inspected to evaluate how well the model results matched the overall magnitude and trend of the observed groundwater elevation data over time. For the transient model, it was considered more important to honor the overall trend of the data. A hydrograph was considered a good match if the model simulated the trend, even if the simulated groundwater elevations were consistently offset from the measured ones.

Groundwater elevation data for 28 hydrographs from different parts of the basin are included on **Figures 27 through 33**. Locations of the wells used for the hydrographs are shown on **Figure 25**. To facilitate a comparison of the relative groundwater trends observed in these wells, a consistent vertical scale of 200 feet is used on **Figures 27 through 33**. The vertical scale on the hydrographs ranges from 450 to 650 feet, except for Corona 27 well, which is located in the upland areas and has groundwater elevations outside of that range.

The majority of the hydrographs are from wells completed in the Channel Aquifer and adjacent Secondary Aquifers located in the northern portion of the Temescal Basin. The hydrographs from wells in this area show several trends that can be summarized as follows:

- From 1990 through 2000, groundwater elevations typically showed a stable to increasing trend with cumulative groundwater changes ranging from near zero to increases of over 20 feet.
- From 2001 through 2009, groundwater elevations showed a general declining trend of 20 to 40 feet of cumulative decline over this period.
- From 2010 through 2018, groundwater levels showed a variable, but overall stable trend, with groundwater levels fluctuating by plus or minus 10 to 20 feet.

During these periods, the average groundwater recharge was roughly similar, with a mixture of wet, normal and dry water year types. From 1990 to 2000, the average annual groundwater pumping in the Channel Aquifer area was at its lowest levels for the simulation period. Groundwater pumping in the Channel Aquifer area peaked during 2001 through 2009, then declined from 2010 to 2018. Based on this, the primary factor affecting the groundwater levels in the Channel Aquifer area is the amount of groundwater pumping.

In summary, trends in simulated groundwater elevations are similar to trends in the measured groundwater level data, indicating good model calibration. As noted above, most of the differences are due to using groundwater level data from active production wells. Groundwater elevations near active production wells can be chronically lower than in nearby surrounding areas due to residual pumping drawdown. MODFLOW calculates the average groundwater elevation over the entire area of each model cell rather than the elevation at the well location itself. It does not simulate localized pumping drawdown around the well.

5.5. EVALUATION OF GROUNDWATER FLOW

The Temescal Basin Model simulates monthly groundwater elevations for 348 months from October 1989 through September 2018. In general, the overall groundwater flow directions remained generally consistent over this period with some variations observed near the major groundwater pumping centers. To evaluate the range of groundwater elevations, we have selected a few key time periods. These include:

- **Figure 34** – September 2018 for Model Layer 1 – End of Historical Simulation Period
- **Figure 35** – September 2018 for Model Layer 3 – End of Historical Simulation Period
- **Figure 36** – January 1997 for Model Layer 1 – Period of consistently high groundwater levels
- **Figure 37** – January 1997 or Model Layer 3 – Period of consistently high groundwater levels
- **Figure 38** – August 2014 for Model Layer 1 – Period of consistently low groundwater levels
- **Figure 39** – August 2014 or Model Layer 3 – Period of consistently low groundwater levels

The high and low conditions represent a combination of climatic conditions and groundwater pumping demands. For the purposes of evaluating groundwater flow directions, we have selected Layers 1 and 3 as representative of the three layers. In general, the groundwater map for Layer 1 is representative of groundwater conditions in the Channel Aquifer, the upper part of the Alluvial Aquifer in the Temescal Basin, and the shallow aquifer in the Chino Basin. The groundwater map for Layer 3 is representative of groundwater conditions in the Secondary Aquifers.

Figure 34 shows the groundwater level contours and flow directions for Layer 1 at the end of the historical simulation period representing September 2018 conditions Groundwater flow in the Channel Aquifer was from east to west, generally following Temescal Wash. In the Norco area, groundwater flow in Layer 1 was localized to internal drainage and downward percolation. In the Chino Basin, groundwater flow was from northeast to southwest generally following the Santa Ana River. For much of the southern Temescal Basin and areas in the Norco area, Layer 1 is unsaturated, shown on the figures by the purple areas.

In the Secondary Aquifers, groundwater flow was generally from the basin margins towards the Santa Ana River and the Prado wetlands area in September 2018 (**Figure 35**). Underneath the Channel Aquifer, groundwater flow in the Secondary Aquifers flowed from southeast to northwest generally parallel to Temescal Wash. In the Norco area, groundwater flow was generally southwest along the long axis of the valley where it then converged with groundwater flowing northwest toward the Santa Ana River. In the Chino Basin, groundwater flow is from northeast to southwest along the Santa Ana River.

In the southern Temescal Basin, the groundwater gradient in September 2018 was steeper due to the geology of the area. The fault zone along the western margin is configured to be a groundwater barrier limiting flow across the fault. This is based on the HCM and groundwater levels from the Corona 27 well. Groundwater flow in the faulted area flowed to the north where it reached the Santa Ana River downstream of Prado Dam. Below Prado Dam, groundwater flow is towards the Coastal Plain of Orange County Groundwater Basin through either discharge to the Santa Ana River or subsurface flow.

Figure 36 shows simulated groundwater elevation contours for January 1997 in Layer 1. During this period, widespread high groundwater levels were observed reflecting a period of high precipitation and below average groundwater pumping rates. In spite of the contrast in hydrologic conditions, the general groundwater flow directions were generally consistent with those in September 2018 (**Figure 34**).

Groundwater elevations in January 1997 in Layer 3 were also generally consistent with September 2018, with groundwater flowing from the basin margins towards the Santa Ana River and the Prado wetlands (**Figure 37**). The most significant difference was lower groundwater elevations with a localized groundwater depression in the southern Temescal Basin as a result of estimated agricultural groundwater pumping at this time.

Figure 38 shows the groundwater elevations in layer 1 for August 2014. During this period, widespread low groundwater levels were observed reflecting several preceding dry years. In general, the groundwater flow directions were similar to those in 1997 and 2018 (**Figures 34 and 36**). The main differences are lower groundwater levels due to groundwater pumping and limited recharge in the Channel Aquifer.

In the Secondary Aquifers (Layer 3), groundwater elevations were also similar to September 2018 and January 1997, with groundwater flowing from the basin margins towards the Santa Ana River and the Prado wetlands area (**Figure 39**). By 2014, agricultural pumping in the Temescal Basin had disappeared due to urbanization. As a result, groundwater pumping in the southern part of Temescal Basin decreased to near zero, and flow was consistently towards the north.

The simulated groundwater flow patterns were consistent with the hydrogeological conceptual model. These maps are included to demonstrate that the model provides reasonable simulation of groundwater elevation and flow direction even during the more extreme climatic periods during the base period. This further demonstrates that the model is well calibrated and can accurately simulate wet and dry weather periods.

5.6. MODEL-BASED HYDROLOGIC BUDGET

GSP regulations (§354.18(c)(2)(B)) indicate a need to identify an average hydrologic study period that cover as least 10 years that includes a range of hydrologic conditions (e.g. wet, normal, dry and critically dry) for purposes of the groundwater analyses in the basin-wide water budgets. In order to select a consistent study period, the Temescal GSA is using a 29-year base period covering the simulation period from WY1990 through WY2018. Water years used for the Temescal Basin Model run from October through to the following September to capture the cause and effect relationship on groundwater levels of wintertime rain and subsequent summertime groundwater pumping. Additional analysis of the historical water budget is provided in **GSP Section 5** ("Water Budget") and tables summarizing the water budget results are presented in **Appendix K**.

6. SIMULATION OF FUTURE CONDITIONS

GSP regulations §354.18(c)(3) require simulation of several future scenarios to determine their effects on water balances, yield and sustainability indicators. The following scenarios to simulate future conditions include:

- **Baseline Scenario** - This represents a continuation of existing land and water use patterns, imported water availability, and climate.
- **Growth Plus Climate Change Scenario** - This scenario implements anticipated changes in land use and associated water use, such as urban expansion, and anticipated effects of future climate change on local hydrology (rainfall recharge and stream percolation) and on the availability of imported water supplies.

The historical period used for model calibration consisted of only 29 years (water years 1990 through 2018). The Sustainable Groundwater Management Act requires that future simulations cover a 50-year period. To obtain 50 years of hydrology, rainfall, reference ET and streamflow were assumed to repeat the 1993 to 2017 sequence twice. Rainfall during that period equaled 99 percent of the long-term average. Surface and subsurface inflows from tributary watersheds simulated using the rainfall-runoff-recharge model were also replicated to obtain 50 years of data. The initial conditions for the future baseline simulation equaled the ending water levels of the calibration simulation, or September 2018. Thus, the future simulation period nominally covers water years 2019 to 2068.

Both of the future simulations assumed that the level of development and related water demand are constant throughout the simulation. That is, development in the growth plus climate change simulation is not phased in over time but rather corresponds to 2068 development throughout the simulation. This is the best way to demonstrate whether 2068 land use is sustainable because it allows for assessment of the effects of variations in climatic conditions (wet and dry cycles) on groundwater conditions, avoids subjective decisions about the concurrent timing of droughts and development, and provides time for the full effect of future conditions on groundwater to become apparent.

Additional details regarding assumptions and inputs for the future scenarios are presented in **GSP Section 5.5.3** "Simulation of Future Conditions". Water budget results for the two future scenarios are described in Section 5 of the main GSP text. Both scenarios showed essentially no net change in groundwater storage from 2018 to 2068 (see **GSP Figure 5-10**). Contours of simulated groundwater elevations in model layers 1 and 3 were also very similar to those in 2018, consistent with the water budget results and with the SMCs for groundwater elevations and storage, which preclude future declines to levels below minimum historical levels.

The future Baseline Scenario and Growth Plus Climate Change Scenario can serve as reference conditions against which to compare alternative management scenarios. Additional data and assumptions used in the future baseline simulation are described in **GSP Section 5.5.3** ("Simulation of Future Conditions"). Inputs and results of other scenarios related to specific management actions recommended in the GSP are also described in **Section 8** ("Management Actions") and water budget results are presented in **Appendix K**.

7. SGMA REQUIREMENTS

As noted in the SGMA Modeling Best Management Practices (BMP) guidelines (DWR 2016a), the description of the model application should include detailed information on the model conceptualization, assumptions, data inputs, boundary conditions, calibration, sensitivity and uncertainty analysis, and there applicable modeling elements such as model limitations. A DWR requirement for using model results in future water budget reporting for Annual Reports is to report the model accuracy. The following information addresses these reporting requirements.

7.1. MODEL DATA GAPS

When evaluating model results, it is important to consider the strengths and limitations of the numerical model. The horizontal and vertical resolution used to construct the model dictates the range of scales that the model can evaluate. The Temescal Basin Model is designed as a regional or basin-wide model to evaluate long-term, regional trends and the overall groundwater inflow and outflow to the basin. Within that scale, conditions are averaged. However, this model may not contain the site-specific details necessary to evaluate some localized conditions due to geologic complexity or unique localized effects. For these areas, a more localized model may be required if such a detailed analysis is necessary. The regional model can provide a broader regional context to support the development of these localized models.

The groundwater flow model is an appropriate tool for evaluating groundwater conditions at the basin and subarea scale over periods of months to decades. Given its reasonable calibration under a wide range of historical hydrologic and water management conditions, it should produce reliable results under a similar range of future conditions. However, some aspects of the model and some types of applications may be less reliable. Limitations in model accuracy and in types of applications include the following:

- As with any regional model, the model cannot simulate details of water levels and flow at spatial scales smaller than one model cell. It cannot, for example, simulate drawdown within a pumping well. It can only simulate the average effect of that pumping on the average water level of the cell in which the well is located.
- The monthly stress periods of the model preclude simulation of brief hydrologic stresses. For example, the model cannot simulate the effects of daily pumping cycles on water levels, or the amount of recharge associated with peak stream flow events.
- Surface and subsurface inflows from tributary watersheds around the perimeter of the basin remain uncertain. The rainfall-runoff-recharge model simulates watershed hydrology explicitly but flows from the watersheds to the groundwater basin are small compared to rainfall and ET. Accurate data for those variables within the watershed areas are not available, and a small error in rainfall or ET can result in a large error in simulated watershed outflow.
- Model calibration is better in some parts of the basin than others. Any future model calibration would benefit from additional groundwater elevation data in areas outside of the Channel Aquifer.

7.2. MODEL ACCURACY

A numerical model mathematically describes the conceptual model by solving the mass balance and motion equations that govern groundwater flow and chemical transport (Bear and Verruijt 1987). To solve these equations, an iterative method is used to solve the matrix equations. For these iterative techniques, the procedure is repeated until the convergence criteria are met. The convergence criteria may be groundwater elevation change, mass balance difference, or both. Convergence defines whether the model is mathematically stable and capable of producing reliable results.

For this model, the Newton (NWT) Solver Package was used (Niswonger et. al., 2011). The convergence criteria for NWT included both a maximum change in groundwater elevation and a maximum mass balance differential for a cell. For this model, the convergence parameter for groundwater elevation was set at 0.1 feet and 5,000 cubic feet per day for mass balance differential. Convergence is evaluated at the grid cell level. If a single cell does not meet the requirement, then the solution procedure is repeated. The model was able to successfully converge using the set convergence parameters.

The primary method to check whether the model is numerically stable is to evaluate the differential in mass balance. Iterative techniques provide an approximate solution for the model; therefore, there is always a mass balance differential. This differential should be small, and typically a differential of less than 1.00 percent is considered as a good solution. The mass balance differential for Temescal Basin Model is 0.02 percent. These values further indicate that numerical model that is accurately simulating the flow of groundwater in the Basin.

The model calibration and comparison of the hydrologic budget results demonstrate that the model is consistent with the conceptual model to produce these results. The calibration correlation coefficient of 0.934 demonstrates a strong comparison between measured and simulated groundwater elevations. Other statistical calibration parameters show that the scaled ratio of the calibration residuals to the range of observed groundwater levels is about 2.5 percent.

Based on these parameters, the accuracy of the Temescal Basin Model in developing SGMA water budgets is conservatively considered to range between 10 to 15 percent when also considering total level of uncertainty resulting from input parameter, assumptions, calibration accuracy and numerical stability. Since the calibration accuracy and numerical stability are well below this range, the input parameter assumptions are the main source of uncertainty with the model results.

7.3. LIMITATIONS TO CALIBRATION

All inputs to a model are estimates that are subject to errors or uncertainty, but some are better known than others. Also, some have relatively pronounced effects on simulation results. For example, the amount of water pumped by municipal wells is metered and is considered highly accurate compared to most model inputs. Accordingly, the amount of municipal pumping was not adjusted during calibration.

Variables were selected for adjustment during calibration based on their relative uncertainty, the sensitivity of results to that variable, and whether the variable might logically be connected to an observed pattern of residuals based on hydrologic processes.

The measured water levels that serve as the basis for calibration are themselves subject to uncertainty stemming from wellhead elevation errors, effects of recent pumping at the measured well, and wells that for unknown reasons have water levels inconsistent with water levels at nearby wells. Almost all of the wells used to monitor water levels are active water supply wells located in or adjacent to the Channel Aquifer. If a well was pumping shortly before the water level is measured, the water level will be much lower (by feet to tens of feet) than if the well had been idle for a day or more. In some hydrographs, pumping-affected water levels stand out as obvious anomalies. A number of those points were removed from the calibration data set. In other cases, water levels fluctuate over a wide range seasonally and between measurements, and pumping effects could not be systematically identified and eliminated.

8. REFERENCES CITED

Bear, J. and A. Verruijt, 1987, Modeling Groundwater Flow and Pollution, D. Reidel Publishing Company, Boston, 414 p.

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigian, A.S., Jr., and Johanson, R.C., 1997, Hydrological Simulation Program--Fortran, User's manual for version 11: U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Ga., EPA/600/R-97/080, 755 .

Blaney, H.F., P.R. Nixon, G.P. Lawless and E.J. Wiedmann. October 1963. ,Utilization of the waters of the Santa Ynez River basin for agriculture in southern Santa Barbara County, California. U.S. Department of Agriculture, Agricultural Research Service., Riverside, CA.

California Department of Water Resources (DWR), 2016a. Management Practices for the Sustainable Management of Groundwater, Modeling BMP, Sacramento, CA: Technical Memorandum.

California Department of Water Resources (DWR), 2016b, California Groundwater, Bulletin 118, Interim update December 22. https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118

Doherty, J. 1994, PEST, Watermark Computing, Corinda, Australia, 122p.

Environmental Simulations Inc. (ESI), 2020. Guide to Using Groundwater Vistas, Version 8. Reinholds, PA.

Geoscience, 2009, Technical Memorandum Geohydrologic Evaluation Of The Riverside North Aquifer Storage And Recovery Project, technical report to the City of Riverside and RBF Consulting, October 23, 2009.

Lewis, D.C. and R.H. Burgy, 1964, The Relationship between oak tree roots and groundwater in fractured rock as determined by tritium tracing, Journal of Geophysical Research, Vol. 69 No. 12, 15 June 1964, p 2579-2588.

Lubczynski, M.W., 2011, Groundwater Evapotranspiration – Underestimated Role of Tree Transpiration and Bare Soil Evaporation in Groundwater Balances of Dry Lands, in Climate Change and its Effects on Water Resources, NATO Science for Peace and Security Series C: Environmental Security Volume 3, 2011, pp 183-190.

Markstrom, S.L., Regan, R.S., Hay, L.E., Viger, R.J., Webb, R.M.T., Payn, R.A., and LaFontaine, J.H., 2015, PRMS-IV, the precipitation-runoff modeling system, version 4: U.S. Geological Survey Techniques and Methods, book 6, chap. B7, 158 p., http://dx.doi.org/10.3133/tm6B7.

Meinzer, O.E., 1927, Plants as indicators of ground water: USGS Water-Supply Paper 577.

Michael Baker International, 2021, City of Corona 2020 Urban Water Management Plan, Volume 1, Draft, June https://www.coronaca.gov/home/showpublisheddocument/20172/637576204172900000.

Natural Resources Conservation Service (NRCS). 2015. SSURGO soil survey on-line map database available at http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx . Downloaded 27 March 2015.

Niswonger, R.G., S. Panday, and M. Ibaraki, 2011, MODFLOW-NWT, A Newton Formulation for MODFLOW-2005, U.S. Geological Survey Techniques and Methods G-A37, 44p.

Rawls, W.J., L.R. Ahuja, D.L. Brakensiek and A. Shirmohammadi. 1993. , Infiltration and Soil Water Movement. Chapter 5 in D.R. Maidment, ed. Handbook of Hydrology, McGraw-Hill, Inc. New York, NY.

Robinson, T.W., 1958, Phreatophytes: USGS Water-Supply Paper 1428.

Todd Engineers and AKM Consulting Engineers (Todd and AKM), 2008, AB3030 Groundwater Management Plan, prepared for City of Corona, June.

United Nations Food and Agriculture Organization (UNFAP). 2006. Crop evapotranspiration. Technical Report No. 56. Rome, Italy.

United States Geological Survey (USGS), 2004, Preliminary Digital Geologic Map of the Santa Ana 30' x 60' Quadrangle, Southern California, Version 2.0 compiled by D.M. Morton, Open-File Report 99-172, http://pubs.usgs.gov/of/1999/of99-172/.

United States Geological Survey (USGS), 2006, Geologic Map of the San Bernardino and Santa Ana 30' x 60' Quadrangles, California, Version 1.0 compiled by Douglas M. Morton and Fred K. Miller, Open-File Report 2006-1217, http://pubs.usgs.gov/of/2006/1217/.

Van Mullen, J.A., D.E. Woodward, R.H. Hawkins, and A.T. Hjelmfelt, Jr., No date (but after 2001), Runoff curve number method: beyond the handbook, Curve-Number Working Group, Natural Resources

Viessman, W., Jr., J.W. Knapp, G.L. Lewis, and T.E. Harbaugh., 1977, Introduction to Hydrology, 2nd edition, Harper & Row, Publishers. New York, NY.

Wildermuth Environmental Inc. (WEI), 2015, 2013 Chino Basin Groundwater Model Update and Recalculation of Safe Yield Pursuant to the Peace Agreement, technical report prepared for Chino Basin Watermaster, October 2015.

Wildermuth Environmental Inc. (WEI), 2020, 2020 Safe Yield Recalculation Final Report, technical report prepared for Chino Basin Watermaster, May 15, 2020.

WRIME, 2011, Riverside-Arlington Groundwater Flow Model (RAGFM) Model Development and Scenarios, technical report prepared for City of Riverside Public Utilities and Western Municipal Water District, June 2011.

WRIME, 2010, Task 4 - Numerical Model Calibration, Validation, and Sensitivity Analysis for Riverside-Arlington Basins Numerical Groundwater Model and Groundwater Management Plans (GWMPs) Development, technical report to t Western Municipal Water District and RBF Consulting, May 25, 2010.

TABLES

Table 1 - Annual Metered Groundwater Pumping Volumes by Well (acre-feet per year)

Well_Name	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AA_Asphalt_#1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	25	25	25	25	25	25	25	25	25	25	0	1
AA_Asphalt_#2	0	0	0	0	0	0	0	0	0	0	0	0	374	515	588	378	204	180	288	330	310	357	344	337	366	184	98	212	265	0	0
Butterfield#1	240	240	205	191	190	51	74	100	100	60	12	0	0	0	0	0	0	12	4	0	0	0	0	0	0	0	0	0	0	0	0
Corona_#01	843	979	1,154	1,515	1,264	1,670	1,309	1,223	1,658	362	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	207
Corona_#02	0	0	209	1,053	1,049	1,143	1,004	858	1,014	211	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	202
Corona_#06	372	560	195	325	374	610	427	450	567	525	372	359	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	169	185
Corona_#07	396	544	306	524	254	578	316	421	751	830	845	860	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	414	278
Corona_#07A	0	0	0	0	0	0	0	0	0	0	0	0	0	830	1,276	1,244	1,242	1,215	1,262	713	752	720	749	785	1,146	990	1,144	617	1,197	243	380
Corona_#08	1,164	76	2,117	1,603	1,389	1,743	1,352	1,156	1,420	1,333	1,513	1,598	1,307	559	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corona_#08A	0	0	0	0	0	0	0	0	0	0	0	0	0	1,094	2,196	1,542	1,598	1,968	2,102	1,875	2,164	1,886	2,004	2,031	1,919	2,019	1,771	2,047	1,657	0	0
Corona_#09	443	703	552	639	507	459	242	544	531	535	507	755	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corona_#09A	0	0	0	0	0	0	0	0	0	0	0	0	0	1,162	2,554	2,159	1,266	1,455	1,622	1,487	1,512	1,519	1,612	1,547	1,550	1,495	1,227	1,419	1,327	0	0
Corona_#10thSt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corona_#11	209	456	423	407	153	422	295	361	143	632	490	403	119	297	511	582	589	575	600	243	143	34	0	0	0	0	0	0	0	385	410
Corona_#11A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	511	948	913	811	789	781	417	515	804	0	0
Corona_#12&12A	130	4	0	0	0	0	0	0	0	0	0	0	432	660	607	564	545	359	551	1,087	924	377	619	884	1,228	1,041	458	677	792	354	425
Corona_#13	701	429	3	70	272	1	0	55	334	31	0	0	0	120	278	529	544	772	701	598	574	381	527	498	345	257	0	0	0	324	205
Corona_#14L1	65	59	25	289	386	238	243	427	342	631	495	351	387	578	483	332	626	452	249	360	331	360	360	240	300	360	356	360	360	174	96
Corona_#14L2	10	6	4	62	93	54	50	107	81	153	119	80	92	141	120	83	152	110	604	854	775	798	1,025	455	550	602	431	573	482	0	0
Corona_#15	573	977	1,034	1,331	1,287	1,219	916	145	1,303	1,357	1,595	1,218	586	681	1,543	1,404	1,730	1,099	1,764	1,695	1,713	1,667	1,568	1,242	810	1,423	1,087	1,214	939	0	0
Corona_#17	1,030	211	1,045	1,087	1,223	1,360	995	863	1,003	1,142	976	331	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corona_#17A	0	0	0	0	0	0	0	0	0	0	0	0	304	1,285	706	826	1,518	1,706	1,465	1,215	1,055	1,101	1,191	1,231	1,027	1,212	1,230	1,074	1,019	0	0
Corona_#19	0	0	0	13	12	0	596	2,500	3,009	3,093	2,291	2,686	2,289	1,365	539	1,461	1,794	1,702	1,687	1,373	1,379	1,292	973	1,578	9	0	0	0	1,056	0	0
Corona_#22	0	0	0	0	0	0	0	0	0	0	0	0	4,658	4,044	3,016	2,014	2,362	2,309	1,950	1,269	769	1,450	2,250	2,698	2,570	2,687	1,921	2,272	2,169	178	0
Corona_#23	0	0	0	0	0	0	0	0	0	0	0	0	51	0	0	211	0	0	0	19	201	0	0	0	0	0	0	0	0	0	0
Corona_#24	0	0	0	0	0	0	0	0	0	0	0	191	652	315	200	384	497	283	56	163	0	0	94	109	26	0	0	0	0	0	0
Corona_#25	0	0	0	0	0	0	0	0	0	0	0	0	3,833	2,632	2,408	2,454	2,259	1,425	2,137	1,195	1,268	1,184	981	609	615	769	1,522	1,894	1,110	174	748
Corona_#26	0	0	0	0	0	0	0	0	0	0	0	347	1,419	1,365	1,009	1,055	819	813	317	102	420	109	8	501	603	545	42	0	0	565	522
Corona_#27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	209	408	414	224	658	633	677	684	584	643	565	494	364	306	375	45	45
Corona_#28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	807	2,388	2,270	2,369	2,440	2,009	1,842	1,643	1,703	1,379	1,195	1,115	612	814	1,048	9	8
Corona_#29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	823	831	523	783	793	974	89	7	0	0	0	0
Corona_#31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	915	752	5	0	0	855	0	0
Corona_LINCOLN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corona_Main#3	1,433	1,197	1,194	1,206	542	377	357	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corona_Main#4	75	491	1,004	1,190	1,195	765	175	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	175
Dairy_New_Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	533	227	329	175	90	105	106	114	119	115	29	0	0	0
Dart#1	84	91	95	114	120	122	123	123	123	129	165	171	159	154	53	128	205	238	224	195	140	124	110	98	99	101	102	102	112	56	57
Dart#2	0	0	0	0	0	0	0	0	0	4	7	11	13	18	146	75	18	4	0	0	0	7	2	0	0	1	1	1	1		
EVWMD-Kampling	411	284	157	40	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
HGCWD_#1	1	1	1	1	2	1	1	1	1	2	2	3	3	2	2	2	1	1	2	1	1	1	2	1	1	1	1	0	0		
HGCWD_#5	0	0	0	88	194	238	242	155	131	163	162	148	156	149	136	137	131	125	128	128	116	116	91	29	3	0	0	0	0		
JoyWC_10thSt	143	137	135	139	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
JoyWC_Lincoln	0	0	0	0	70	97	101	77	72	82	56	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Norch_#5	949	146	22	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Norco_#14	0	0	0	0	0	859	155	1,049	1,219	1,196	1,134	1,126	978	837	1,017	1,060	1,062	992	983	970	699	763	891	880	833	791	559	631	471		
Norco_#15	0	0	0	0	0	0	0	195	746	1,178	932	713	1,115	1,263	875	496	449	300	429	127	24	103	18	0	0	0	0	0	0		
Subtotals																															
Total	9,273	7,589	9,879	11,890	10,614	12,007	8,973	10,905	14,550	13,649	11,672	11,362	19,216	20,066	21,279	21,914	22,294	21,221	22,468	19,816	19,331	18,263	19,532	20,426	18,414	17,104	13,488	14,781	16,063	3,169	3,944

Table 2 - Annual Metered Groundwater Pumping Volumes by Well (acre-feet per year)

Horizontal Hydraulic Conductivity (feet/day)					
Zone	**Name**	**Basin**	**Model Layer 1**	**Model Layer 2**	**Model Layer 3**
1	Outer Channel	Temescal	60	7.5	2
2	Deep Channel	Temescal	125	10	3
3	Channel Margin	Temescal	45	7.5	2
4	South Basin	Temescal	20	2	1
5	Norco	Temescal	10	2	1
6	Fault South	Temescal	10	2	1
7	Fault North	Temescal	10	2	1
8	Upper Santa Ana	Chino	5	0.5	0.5
9	Chino	Chino	5	1	3
10	Prado	Chino	5	1	3
Vertical Hydraulic Conductivity (feet/day)					
Zone	**Name**	**Basin**	**Model Layer 1**	**Model Layer 2**	**Model Layer 3**
1	Outer Channel	Temescal	6	0.75	0.2
2	Deep Channel	Temescal	12.5	1	0.3
3	Channel Margin	Temescal	4.5	0.75	0.2
4	South Basin	Temescal	10	0.2	0.1
5	Norco	Temescal	1	0.2	0.1
6	Fault South	Temescal	10	2	0.1
7	Fault North	Temescal	10	0.2	0.1
8	Upper Santa Ana	Chino	0.5	0.025	0.025
9	Chino	Chino	0.5	0.1	0.3
10	Prado	Chino	0.5	0.1	0.3
Specific Storage (1/feet)					
Zone	**Name**	**Basin**	**Model Layer 1**	**Model Layer 2**	**Model Layer 3**
1	Outer Channel	Temescal	2.0E-04	2.0E-04	1.0E-05
2	Deep Channel	Temescal	1.0E-03	2.0E-04	1.0E-05
3	Channel Margin	Temescal	2.0E-04	2.0E-04	1.0E-05
4	South Basin	Temescal	1.0E-04	2.0E-05	1.0E-05
5	Norco	Temescal	1.0E-04	2.0E-05	5.0E-06
6	Fault South	Temescal	1.0E-04	2.0E-05	5.0E-06
7	Fault North	Temescal	1.0E-04	2.0E-05	5.0E-06
8	Upper Santa Ana	Chino	1.0E-04	2.0E-07	2.0E-07
9	Chino	Chino	1.0E-04	1.0E-06	2.0E-06
10	Prado	Chino	1.0E-04	1.0E-06	2.0E-06
Specific Yield (percentage)					
Zone	**Name**	**Basin**	**Model Layer 1**	**Model Layer 2**	**Model Layer 3**
1	Outer Channel	Temescal	0.10	0.06	0.02
2	Deep Channel	Temescal	0.15	0.08	0.02
3	Channel Margin	Temescal	0.10	0.08	0.02
4	South Basin	Temescal	0.08	0.03	0.02
5	Norco	Temescal	0.08	0.03	0.02
6	Fault South	Temescal	0.08	0.03	0.02
7	Fault North	Temescal	0.08	0.03	0.02
8	Upper Santa Ana	Chino	0.06	0.02	0.03
9	Chino	Chino	0.06	0.02	0.03
10	Prado	Chino	0.06	0.02	0.03

Table 3 - Temescal Model Calibration Statistics

Statistical Measure	Result	Explanation
Residual Mean	-1.73	Average error from residual for each point in calibration data set
Absolute Residual Mean	8.66	Total error from average for the absolute value of the residuals
Residual Standard Deviation	11.12	Average deviation of residual relative to the "residual mean"
Sum of Squares	458,178	Sum of squared value of residual for each calibration data point
RMS Error	11.26	Square root of the "Sum of Squares"
Maximum Residual	51.0	Highest residual during simulation
Minimum Residual	-59.0	Lowest residual during simulation
Number of Observations	3616	Number of GWEL measurements in calibration data set
Range in Observations	367	Difference of highest and lowest observed GWEL
Scaled Residual Mean	-0.0047	Residual Mean divided by "Range of Observations"
Scaled Absolute Residual Mean	0.0236	Absolute Residual Mean divided by "Range of Observations"
Scaled Residual Standard Deviation	0.0303	Residual Std. Deviation divided by "Range of Observations"
Scaled RMS Error	0.0306	RMS Error divided by "Range of Observations"
Correlation Coefficient	93.4%	Strength of relationship between observed and simulated GWEL

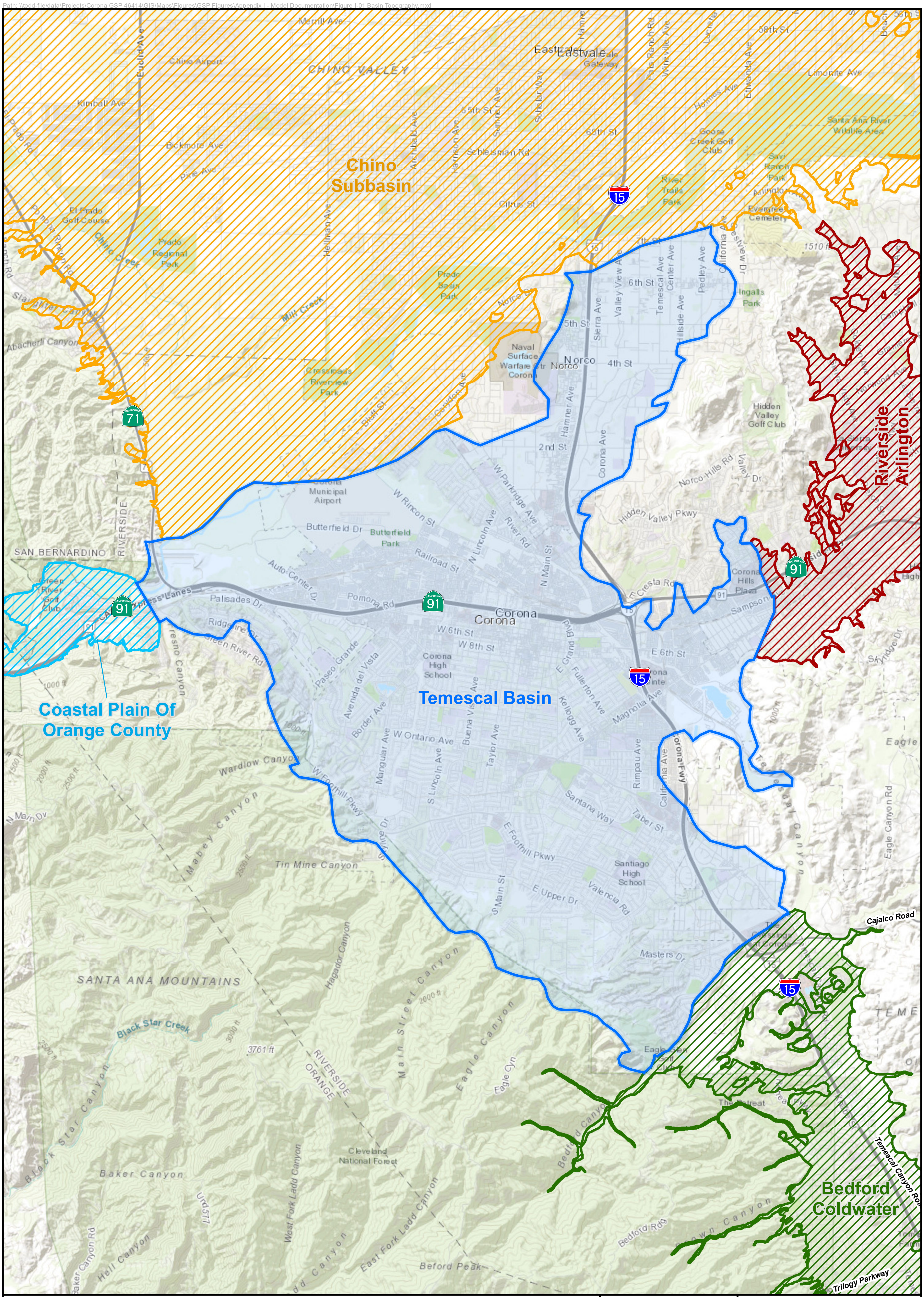
Notes: GWEL - groundwater elevation

Residual is the observed GWEL minus the simulated GWEL

Table 4 - Statistical Calibration by Well

Well ID	Model Layer	Number of Measured Data	Residual Mean (feet)	Absolute Residual Mean (feet)	Standard Deviation (feet)
3S7W27F6	1	66	-11.7	11.7	4.9
Butterfield	1	51	-0.7	3.3	4.2
Corona_11	1	307	-0.6	4.7	5.9
Corona_12	1	144	-5.3	6.1	5.1
Corona_12A	1	169	4.4	7.8	9.1
Corona_13	1	275	15.7	16.3	8.4
Corona_14	2	191	9.6	10.3	7.4
Corona_15	1	310	-4.8	7.6	8.5
Corona_16	2	112	-8.6	8.6	4.6
Corona_17	1	15	-1.2	1.9	2.4
Corona_17A	1	160	-5.4	9.4	10.6
Corona_19	1	251	-5.6	8.1	9.4
Corona_22	1	180	-1.6	8.1	10.0
Corona_23	1	35	-6.3	6.6	4.3
Corona_24	3	74	-1.9	6.6	8.4
Corona_25	1	134	0.6	5.9	7.3
Corona_26	2	61	-8.7	8.7	4.7
Corona_27	3	15	-13.0	43.2	45.5
Corona_28	1	102	-0.2	5.9	7.1
Corona_29	1	113	-7.9	9.0	6.9
Corona_31	1	97	4.8	6.3	6.3
Corona_6	1	60	-0.7	3.8	5.0
Corona_7	1	59	0.9	4.6	5.9
Corona_7A	1	111	-15.6	15.7	8.2
Corona_8	1	181	-10.7	11.2	9.0
Corona_8A	1	157	-1.0	4.8	6.1
Corona_9	1	147	-8.9	11.6	9.8
HG-01	1	27	3.4	4.8	4.2
Joy-Street	2	12	9.6	14.6	13.6
Grand Total	**3**	**3616**	**-1.73**	**8.7**	**11.12**

FIGURES



- Temescal Basin
- Bedford-Coldwater
- Chino Subbasin
- Coastal Plain Of Orange County
- Riverside-Arlington

N

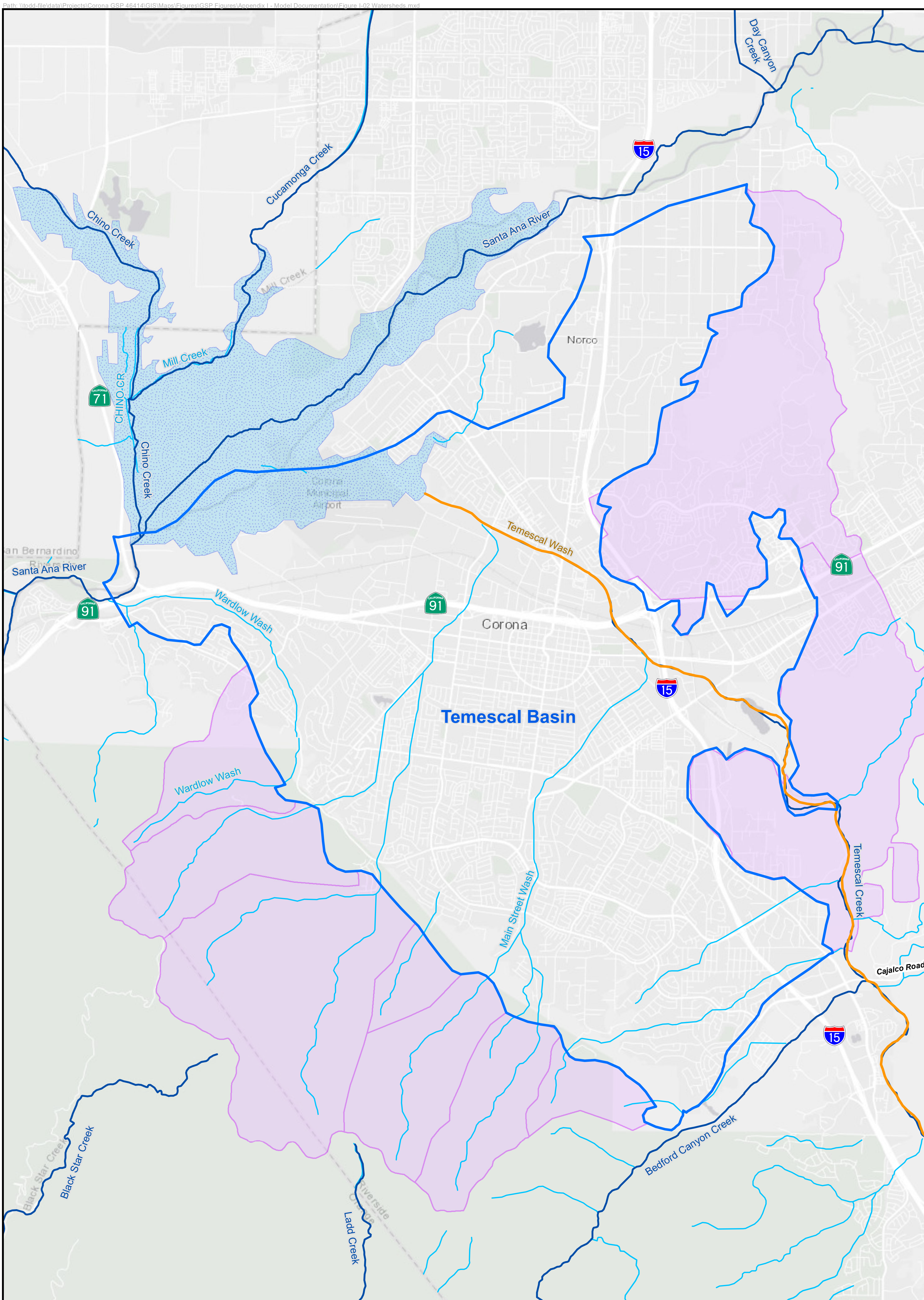
0 0.5 1

Miles

Figure 1
Location and Topography of the Temescal Basin

carollo
Engineers...Working Wonders With Water®

TODD GROUNDWATER



Temesal Basin
Temescal Wash
Rivers and Large Streams
Streams
Tributary Watersheds
Prado Wetlands

N

0 0.5 1
Miles

Figure 2
Rivers, Streams, Wetlands and Tributary Watersheds

carollo
Engineers...Working Wonders With Water®
TODD GROUNDWATER

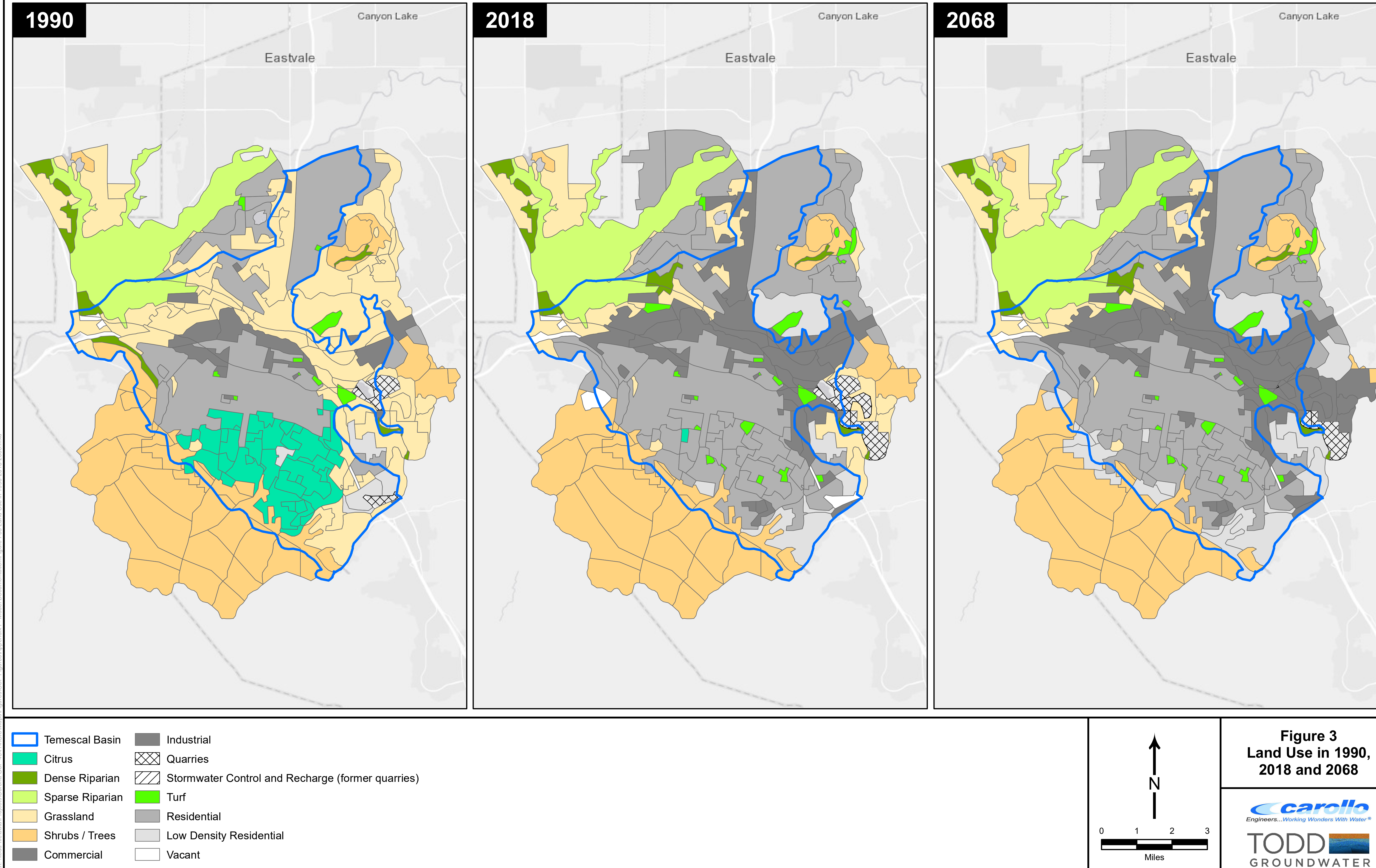
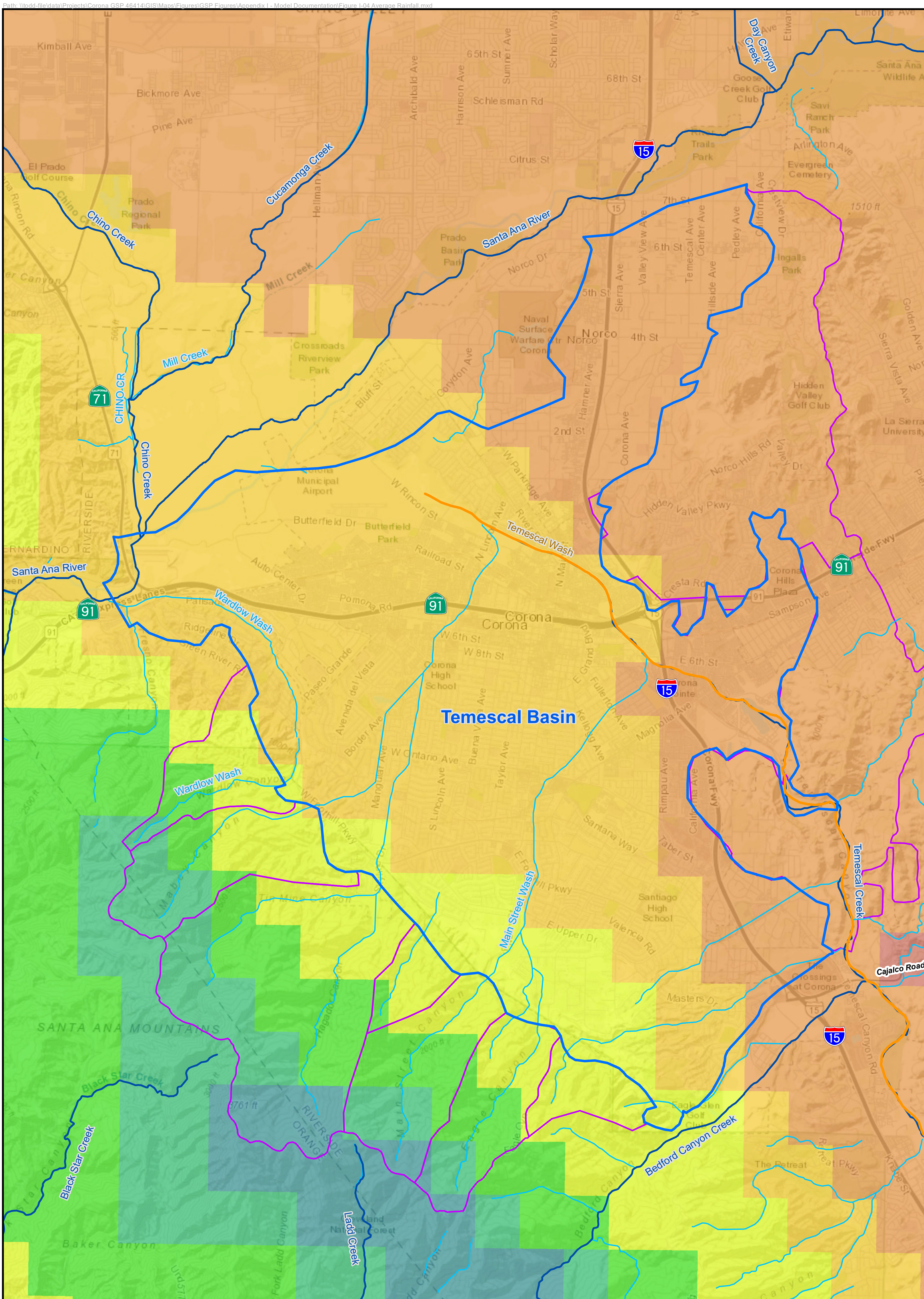


Figure 3
Land Use in 1990, 2018 and 2068

carollo
Engineers...Working Wonders With Water®
TODD GROUNDWATER

Path: \\todd-file\data\Projects\Corona GSP 46414\GIS\Maps\Figures\GSP Figures\Appendix I - Model Documentation\Figure I-04 Average Rainfall.mxd



Legend	
Temesal Basin	
Temescal Wash	
Rivers and Large Streams	
Streams	
Tributary Watersheds	

Average 1981-2010

0 - 10	16 - 18
10 - 12	18 - 20
12 - 14	20 - 22
14 - 16	22 - 24

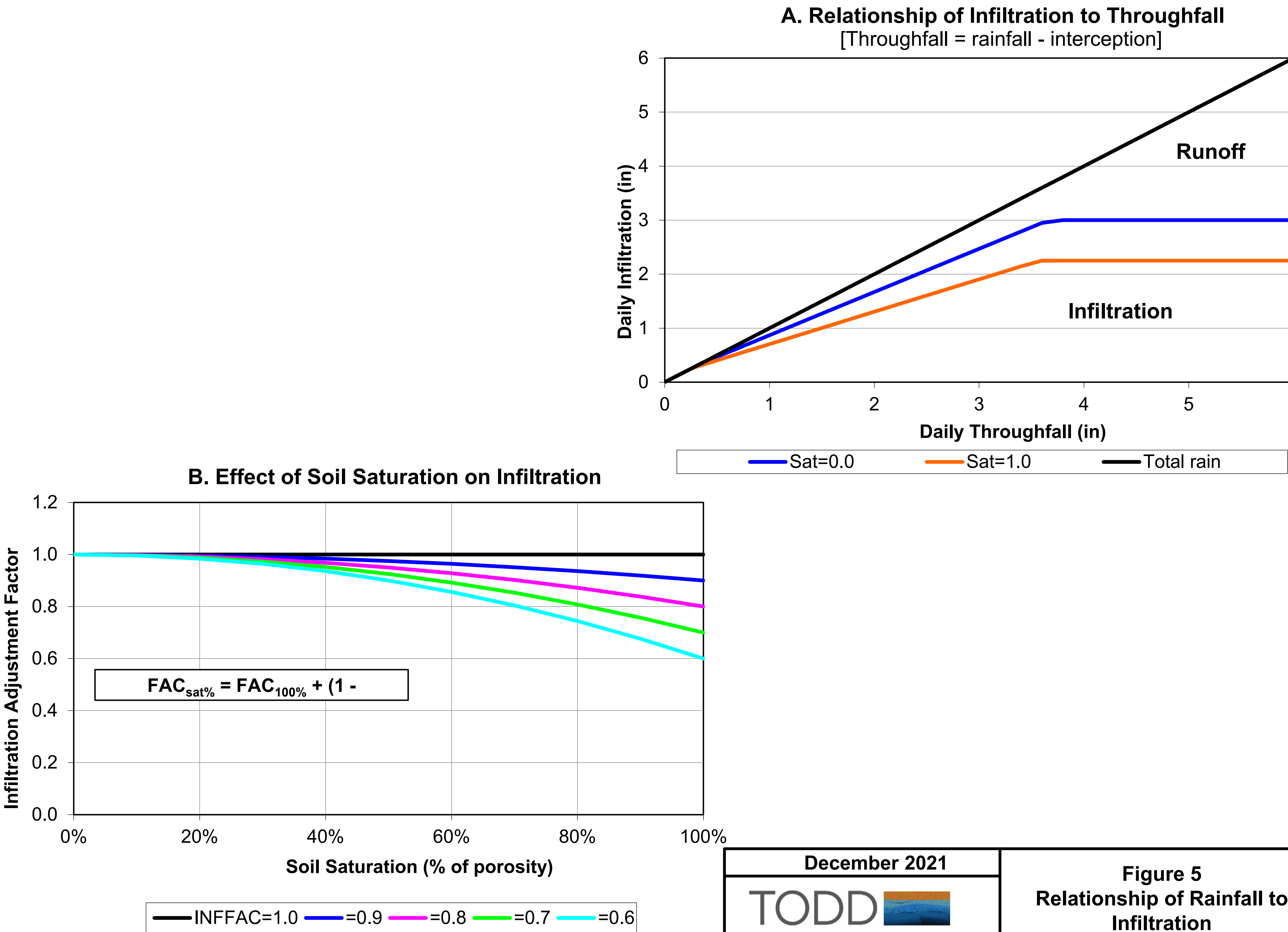
N

0 0.5 1
Miles

Figure 4
Average Annual Rainfall

Engineers...Working Wonders With Water®

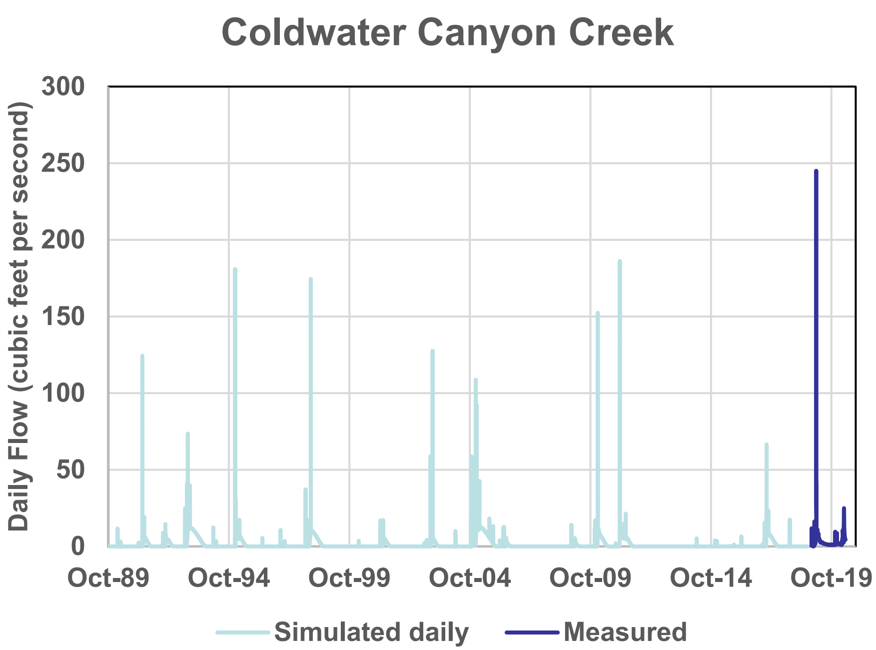
TODD GROUNDWATER

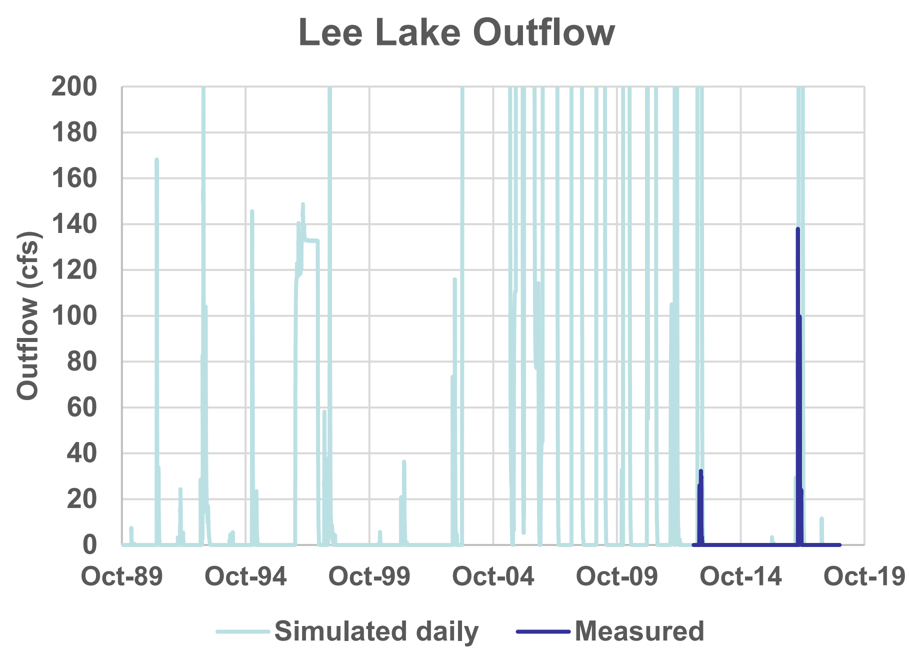


December 2021

TODD GROUNDWATER

Figure 5
Relationship of Rainfall to Infiltration





December 2021	Figure 6 Rainfall to Runoff Calibration
TODD GROUNDWATER	

Path: \\todd-file\data\Projects\Corona GSP 46414\GIS\Maps\Figures\GSP Figures\Appendix I - Model Documentation\Figure I-07 Model Domain.mxd

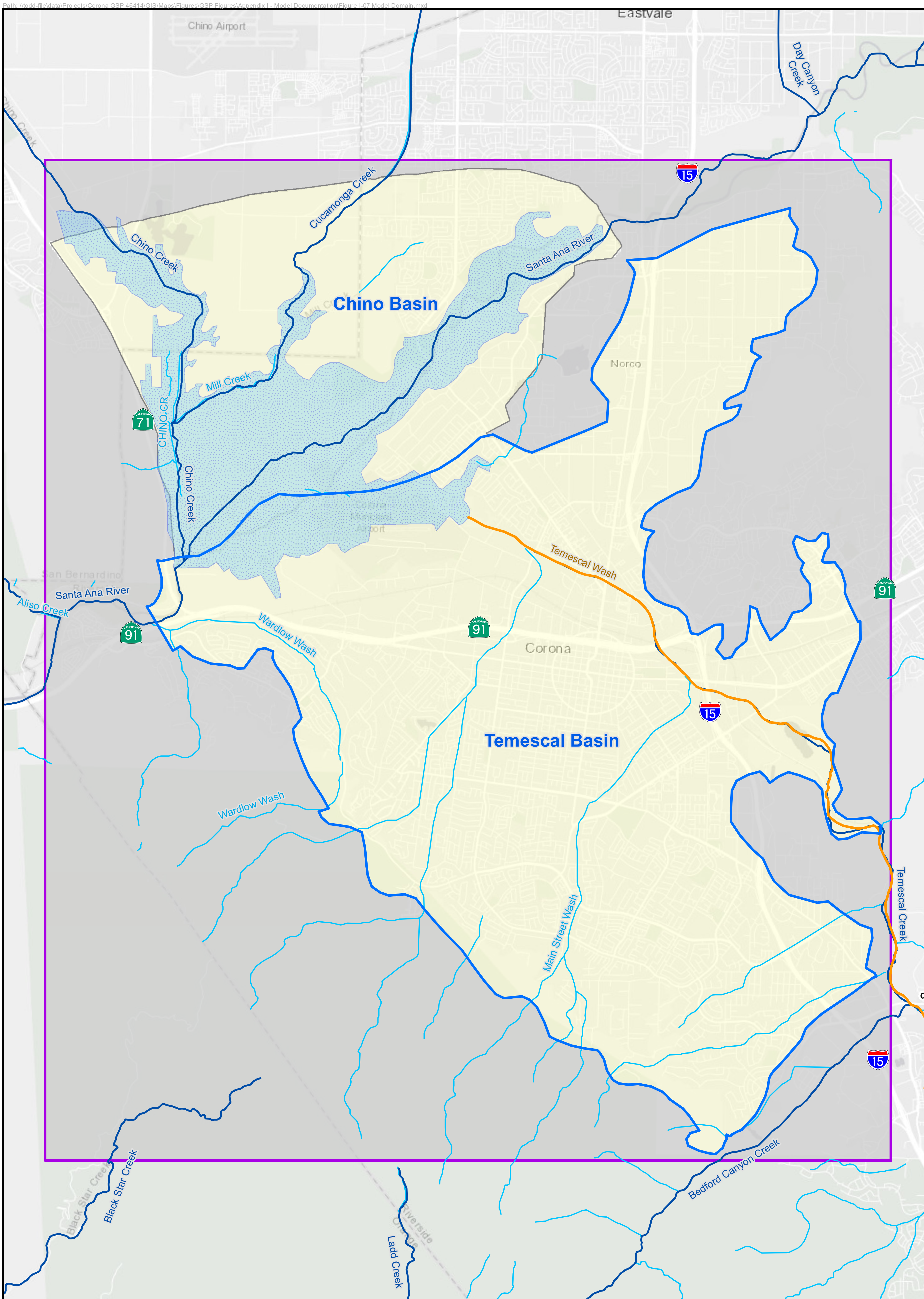


Figure 7
Extent of MODFLOW Model Domain

- Temesal Basin
- Temescal Wash
- Rivers and Large Streams
- Streams
- Prado Wetlands
- Model Domain
- Active Model Cells
- No Flow Model Cells

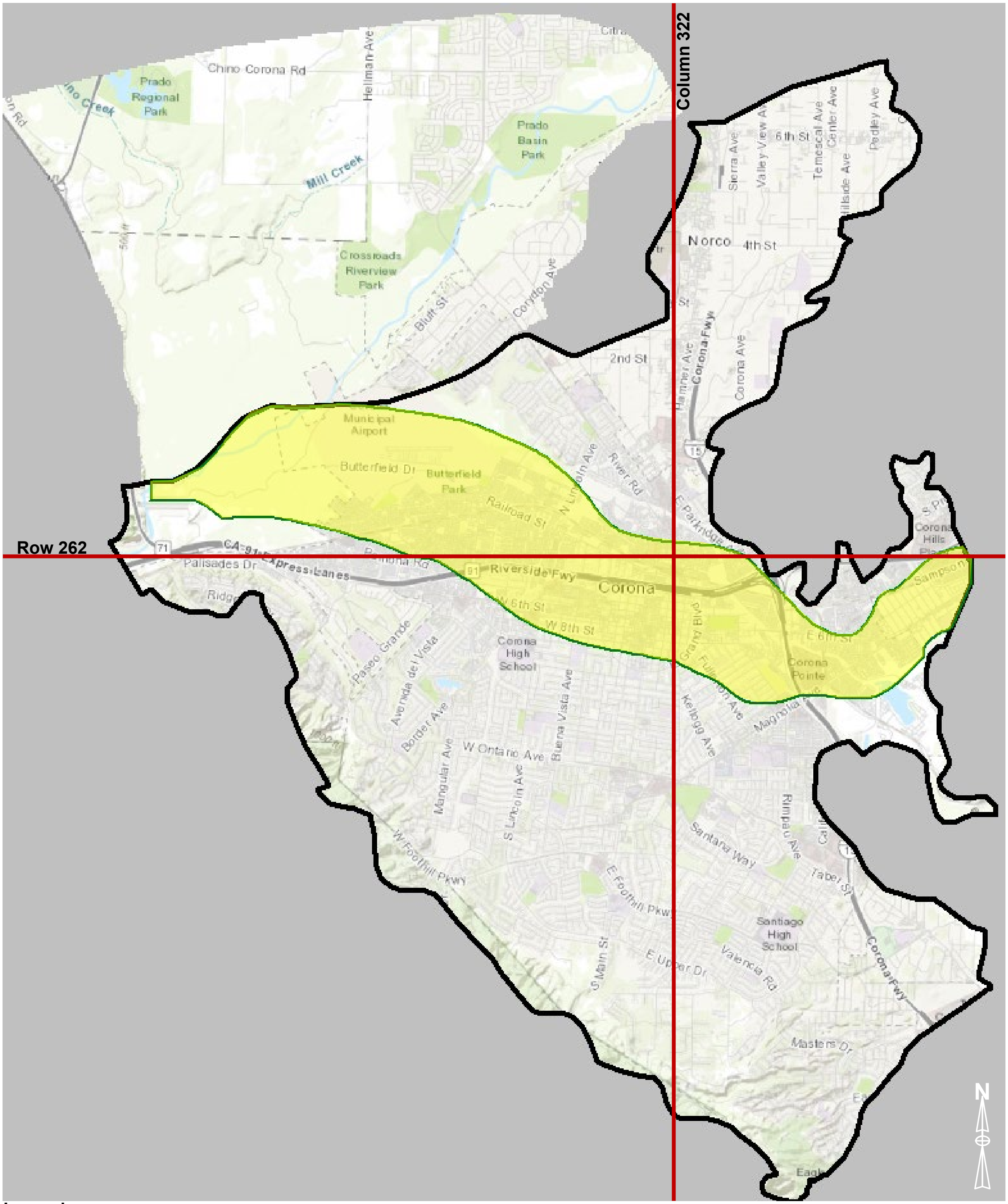
N

0 0.5 1

Miles

Engineers...Working Wonders With Water®

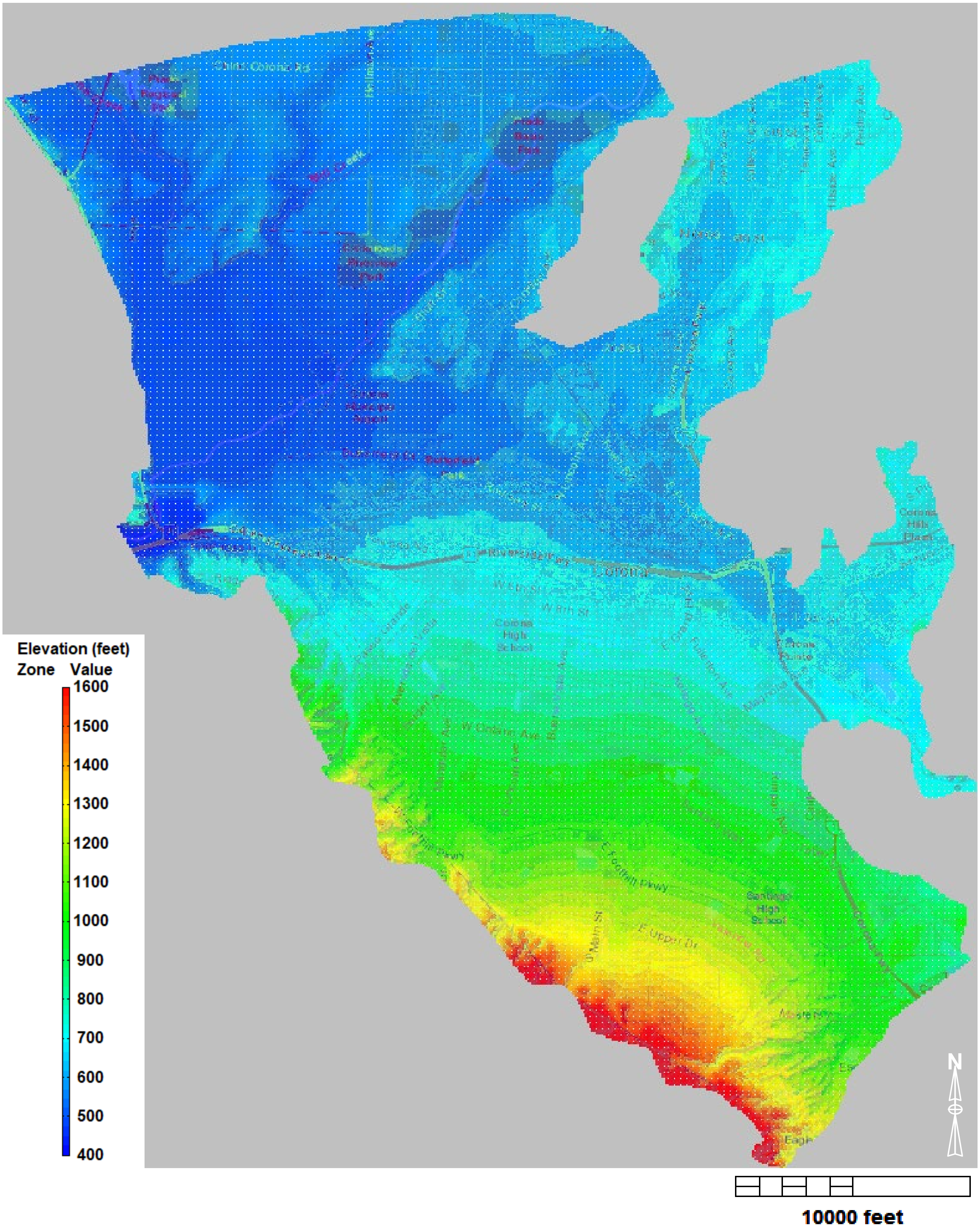
GROUNDWATER



December 2021

TODD GROUNDWATER

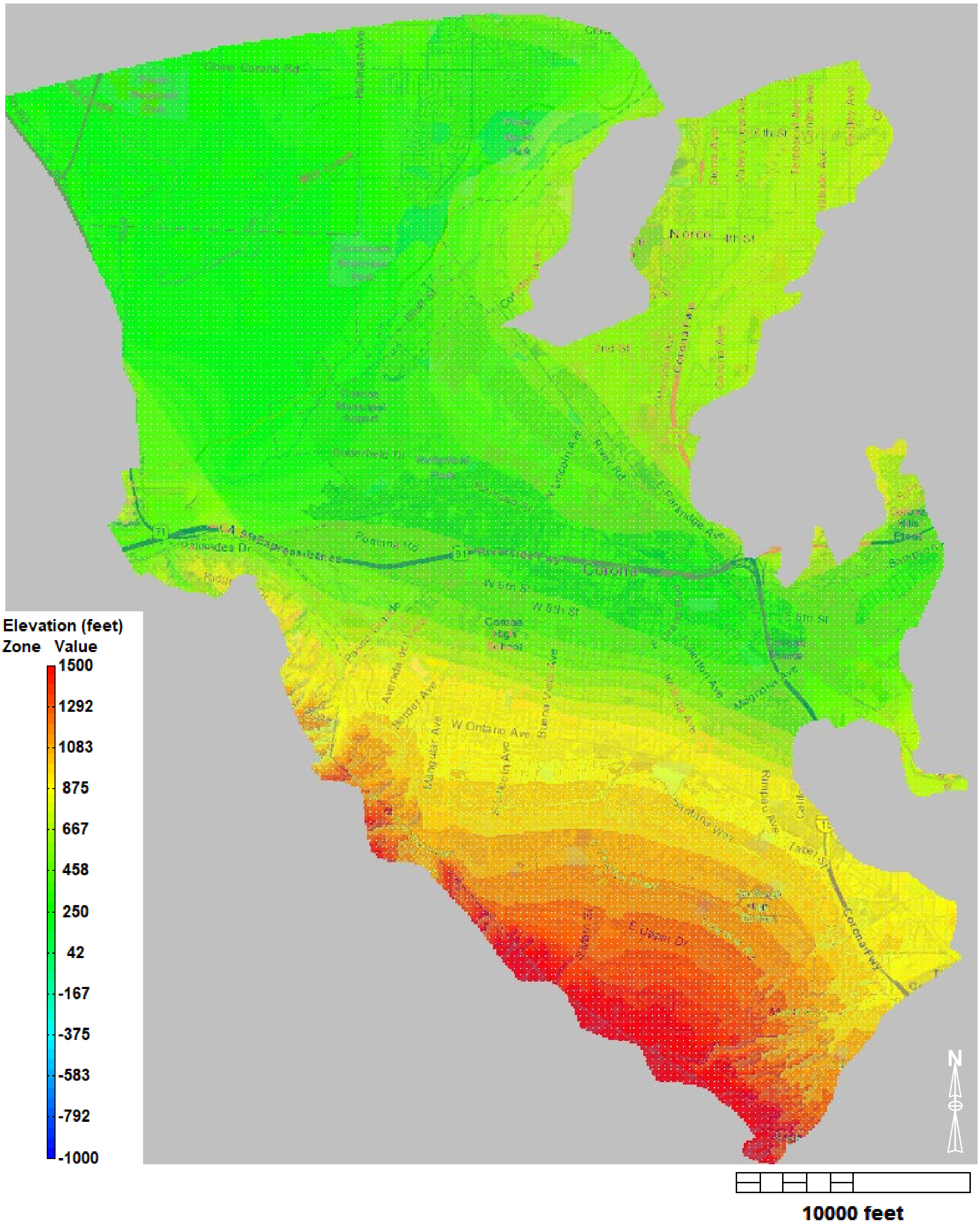
Figure 8
Location of Channel Aquifer



December 2021

TODD GROUNDWATER

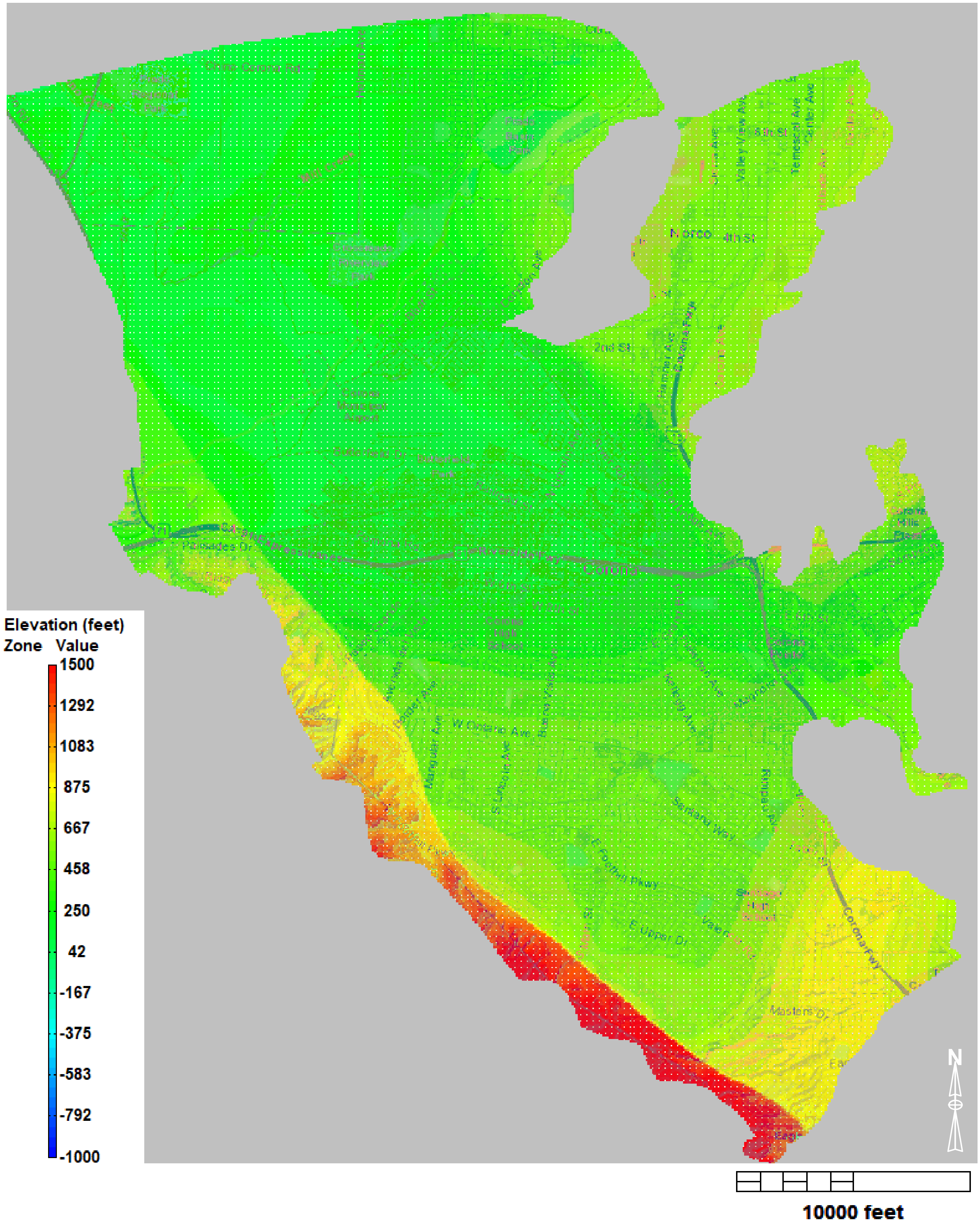
Figure 9
Topographic Elevation of Top of Model Layer 1



December 2021

TODD GROUNDWATER

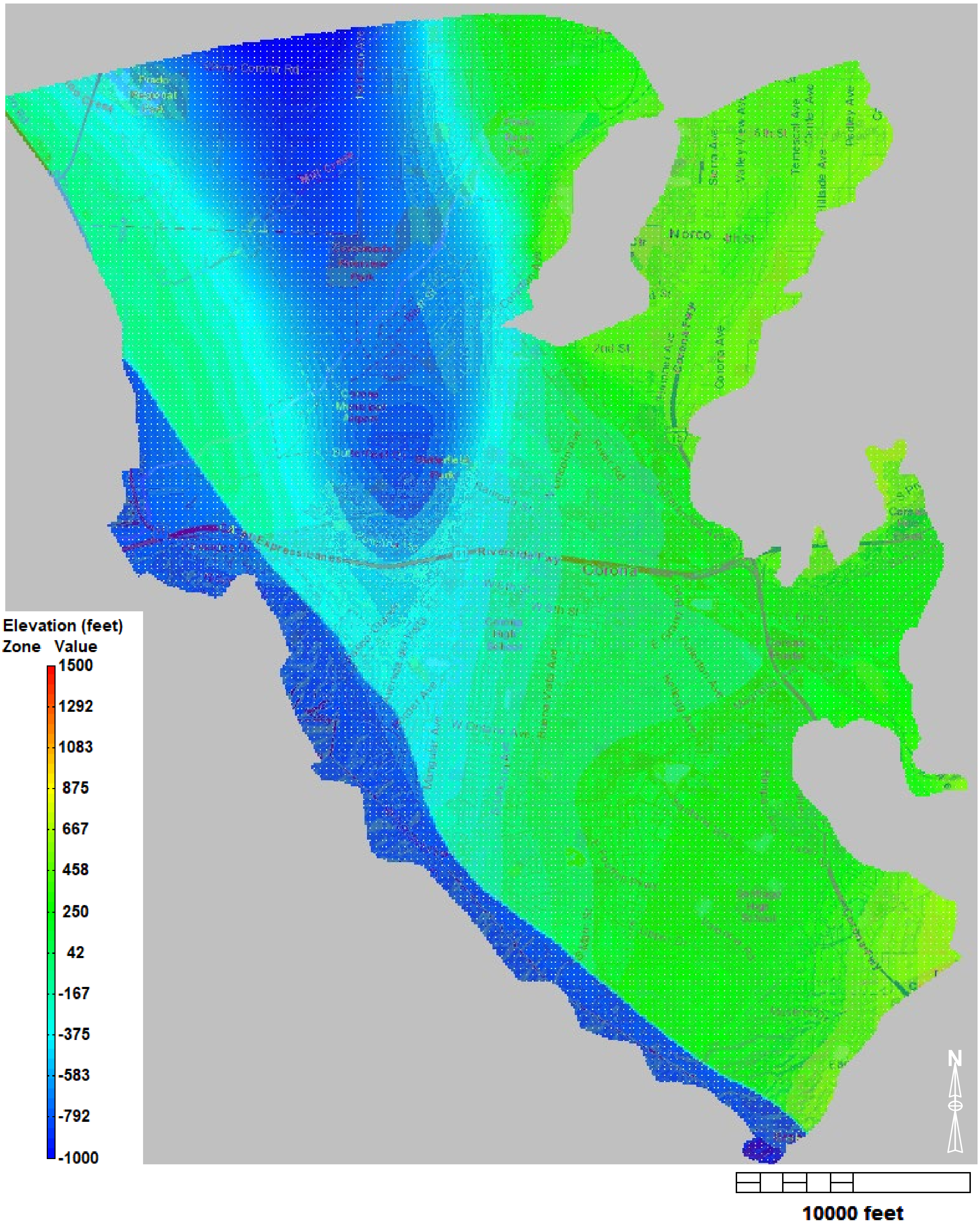
Figure 10
Bottom Elevation Distribution for Model Layer 1



December 2021

TODD GROUNDWATER

Figure 11
Bottom Elevation Distribution for Model Layer 2

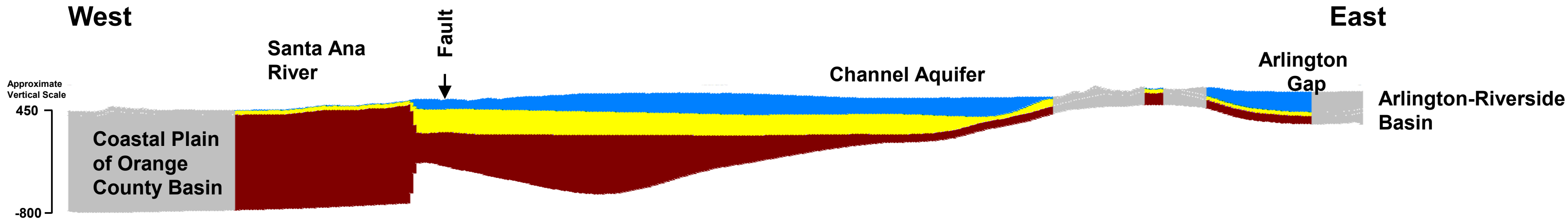


December 2021

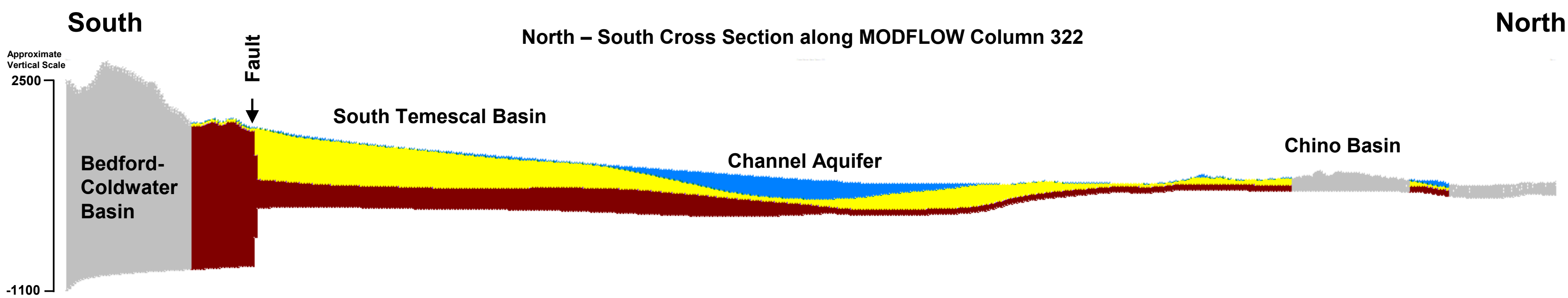
TODD GROUNDWATER

Figure 12
Bottom Elevation Distribution for Model Layer 3

East – West Cross Section along MODFLOW Row 262

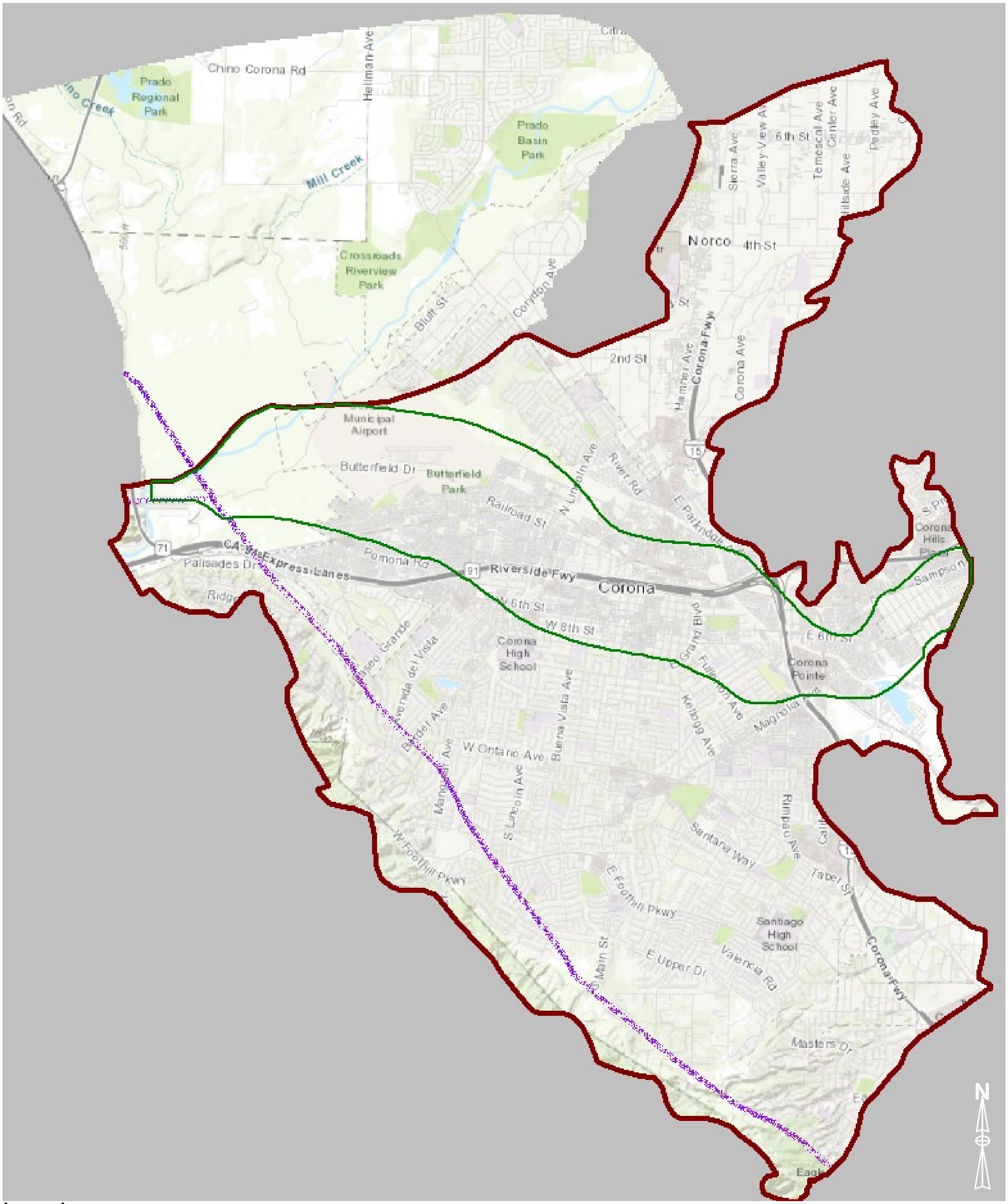


North – South Cross Section along MODFLOW Column 322



Note: The locations of these schematic cross sections are shown on Figure 8

December 2021	Figure 13 Schematic Cross Sections to Illustrate Relative Model Layer Thicknesses
TODD GROUNDWATER	



Legend

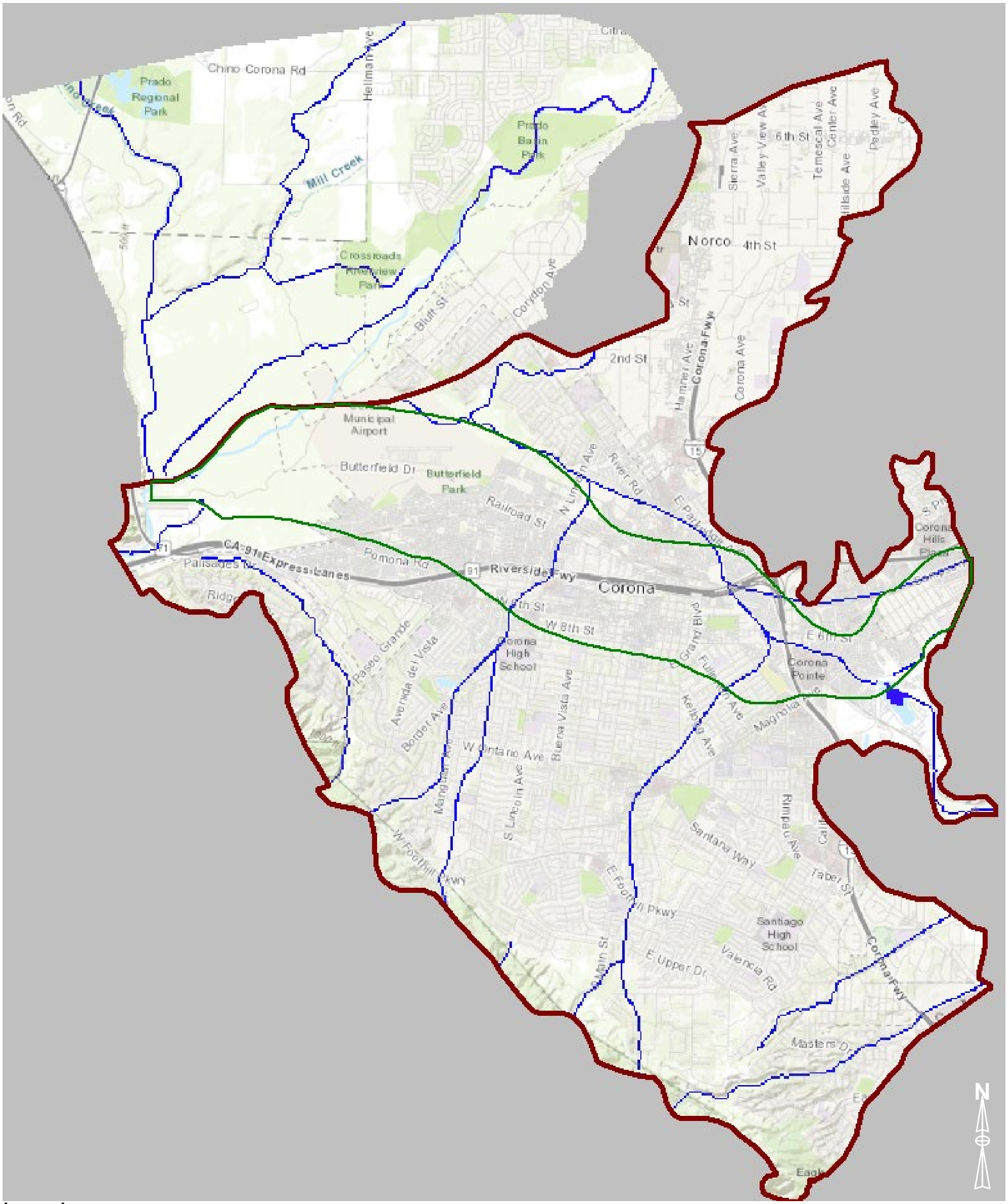
- Simulated Fault Location
- Temescal Subbasin
- Channel Aquifer Outline

10000 feet

December 2021

TODD GROUNDWATER

Figure 14
Location of Faults Applied in the MODFLOW Model



Legend

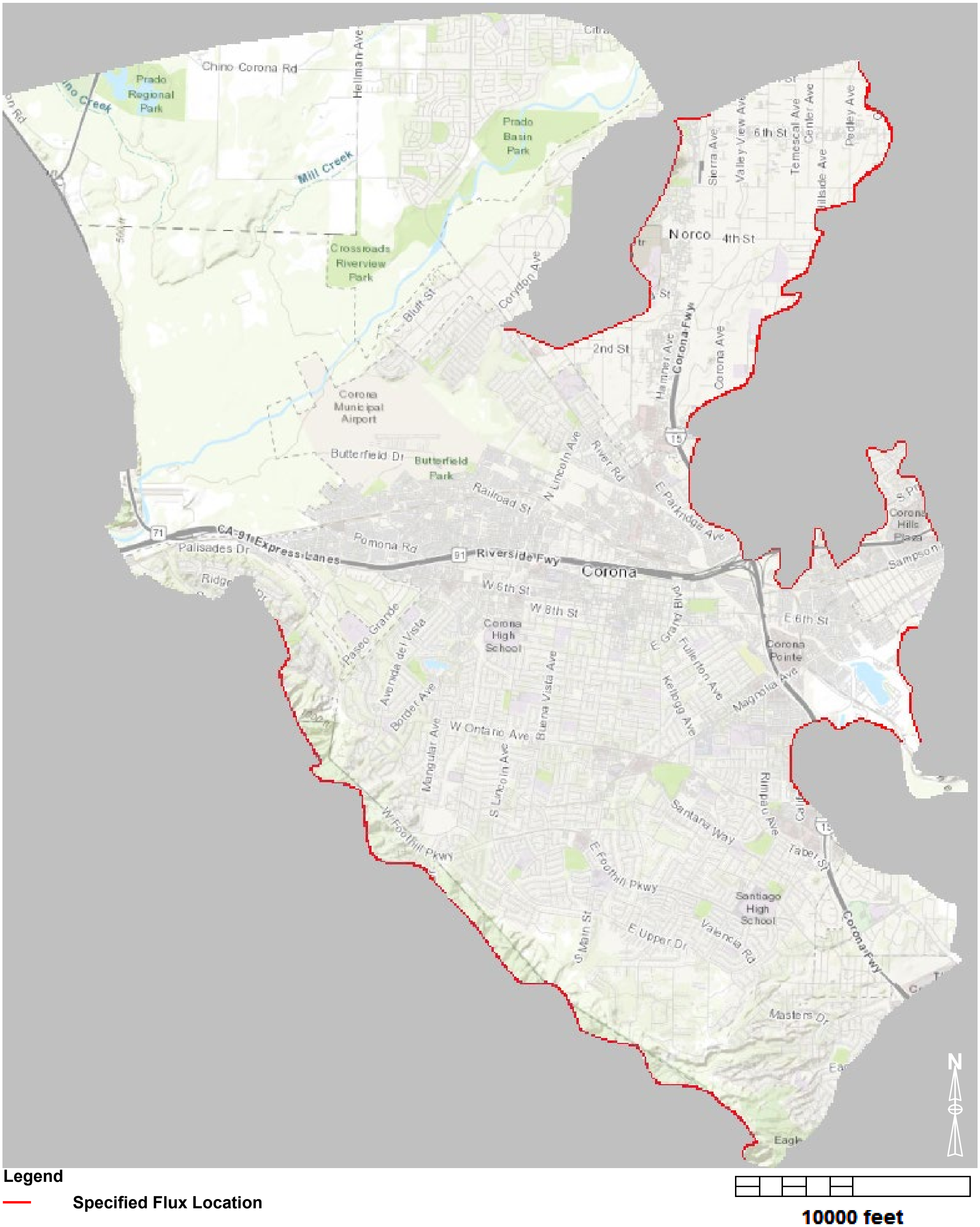
- Simulated Stream Location
- Temescal Subbasin
- Channel Aquifer Outline

10000 feet

December 2021

TODD GROUNDWATER

Figure 15
Locations of Streams Applied in the MODFLOW Model



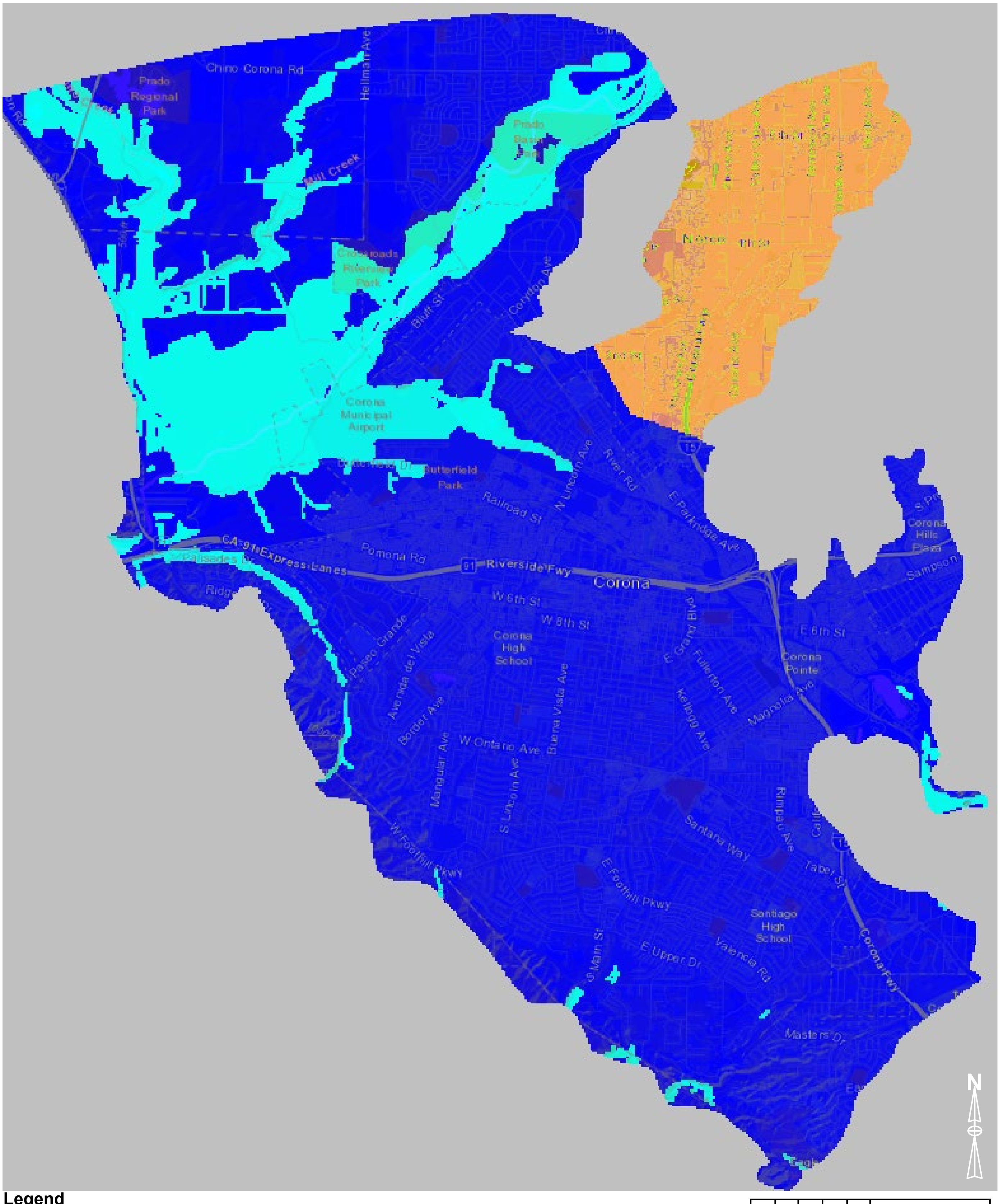
Legend

Specified Flux Location

December 2021

TODD GROUNDWATER

Figure 16
Distribution of Specified Flux Boundary for Mountain Front Recharge



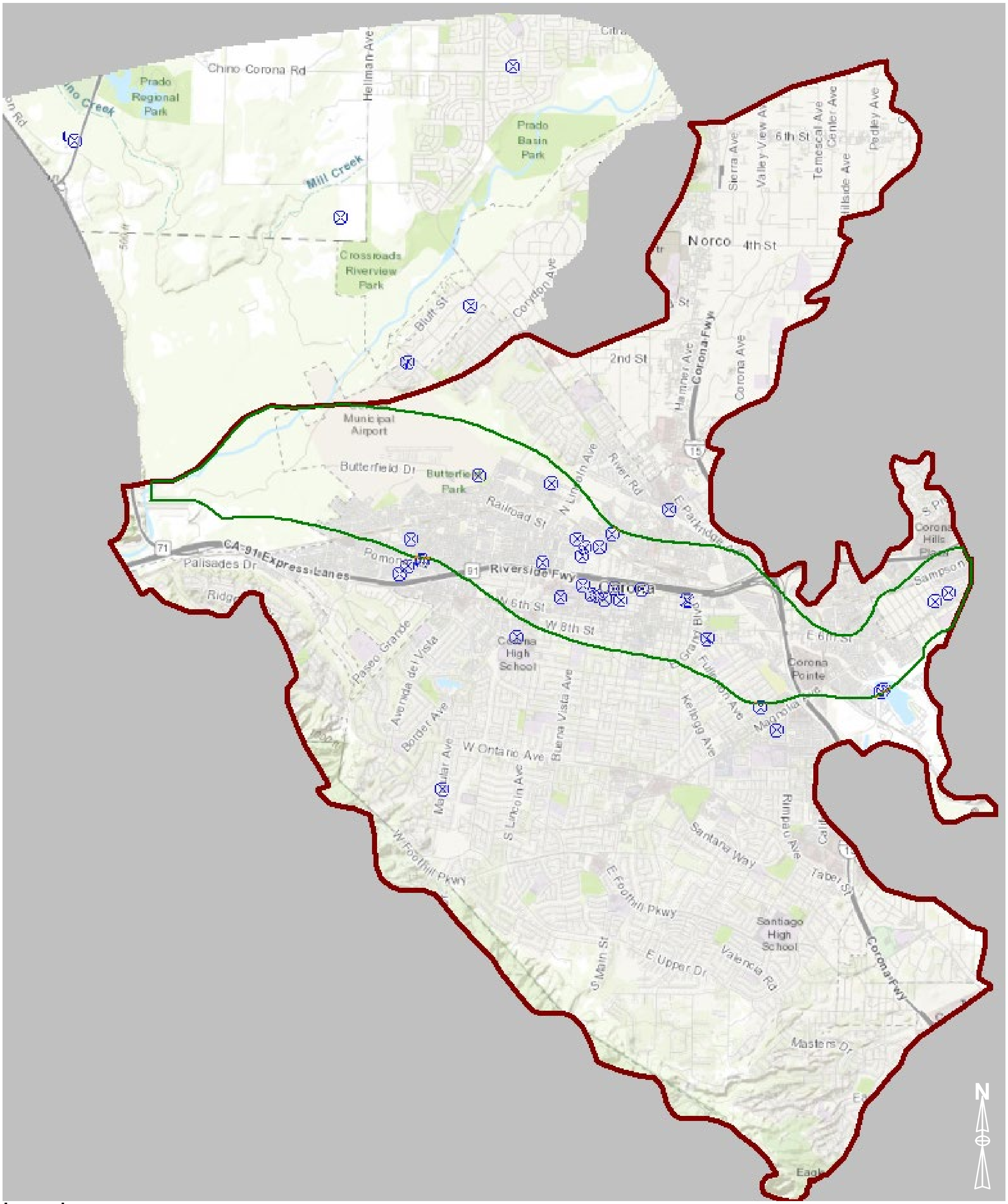
Legend

- Riparian ET Zone
- Basin ET Zone
- Norco ET Zone

December 2021

TODD GROUNDWATER

Figure 17
Distribution of Evapotranspiration (ET) Zones



Legend

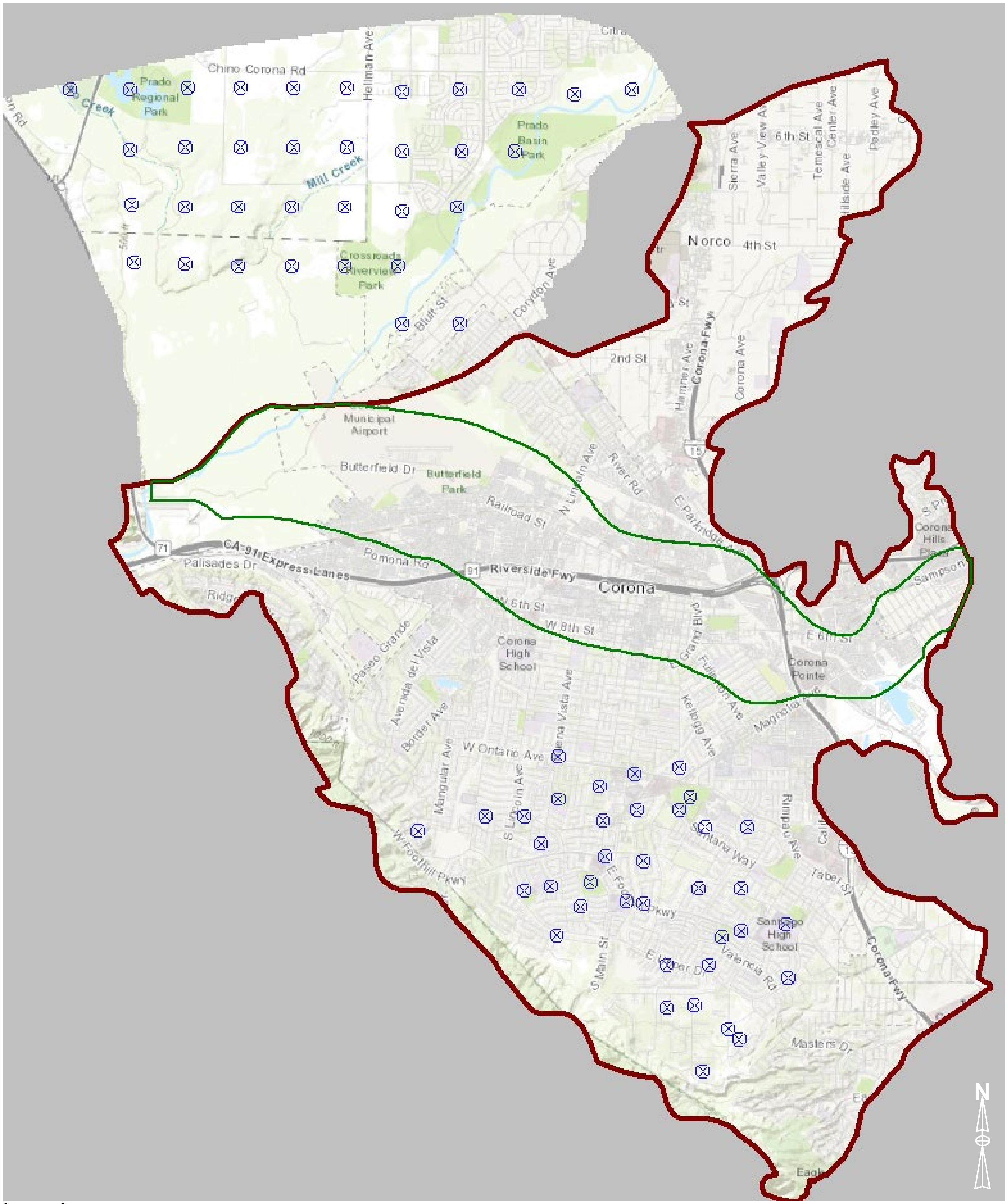
- Location of Metered Municipal or Industrial Well
- Temescal Subbasin
- Channel Aquifer Outline

10000 feet

December 2021

TODD GROUNDWATER

Figure 18
Locations of Metered Municipal or Industrial Well Applied in MODFLOW Model



Legend

Location of Estimated Agricultural Pumping

Temescal Subbasin

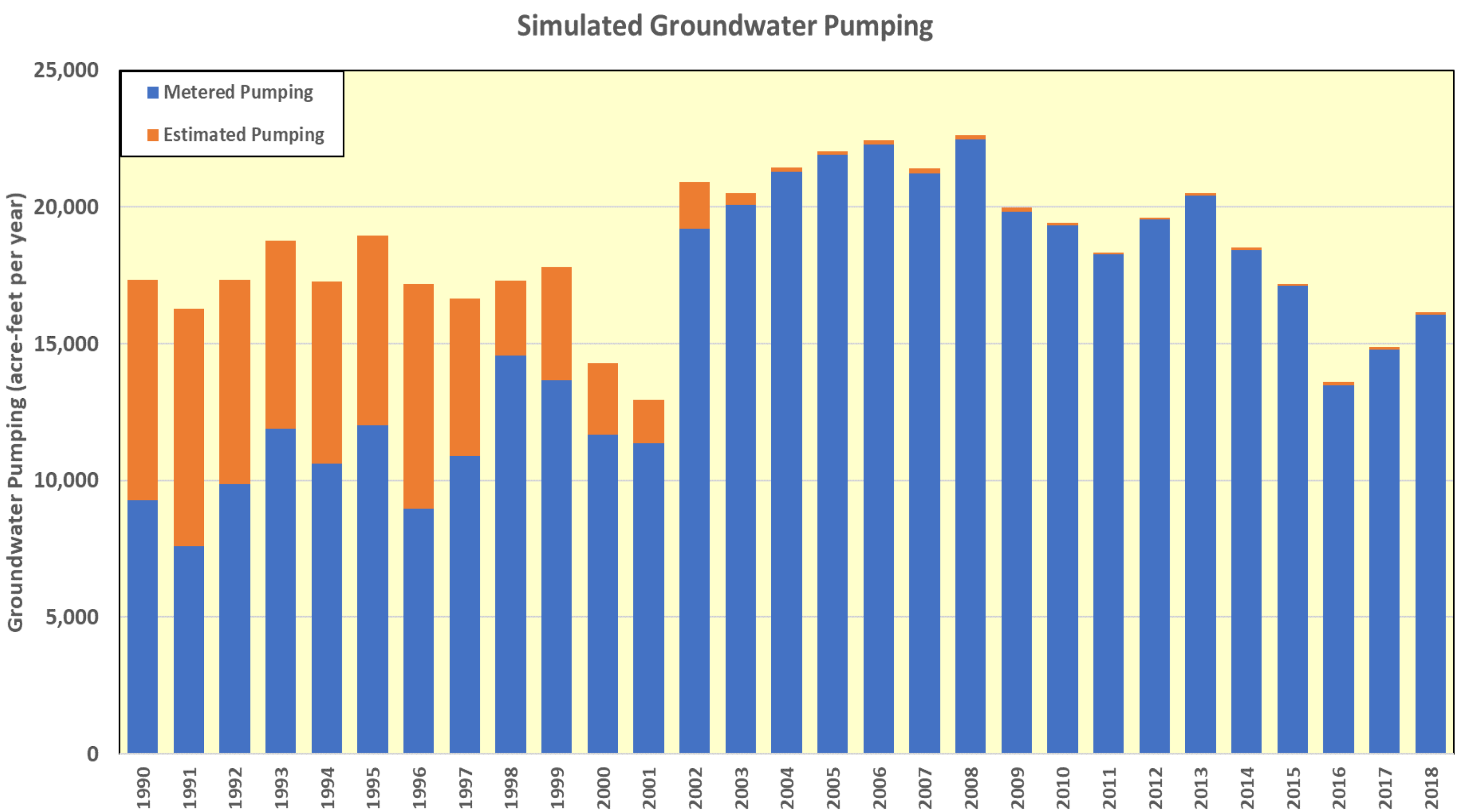
Channel Aquifer Outline

10000 feet

December 2021

TODD GROUNDWATER

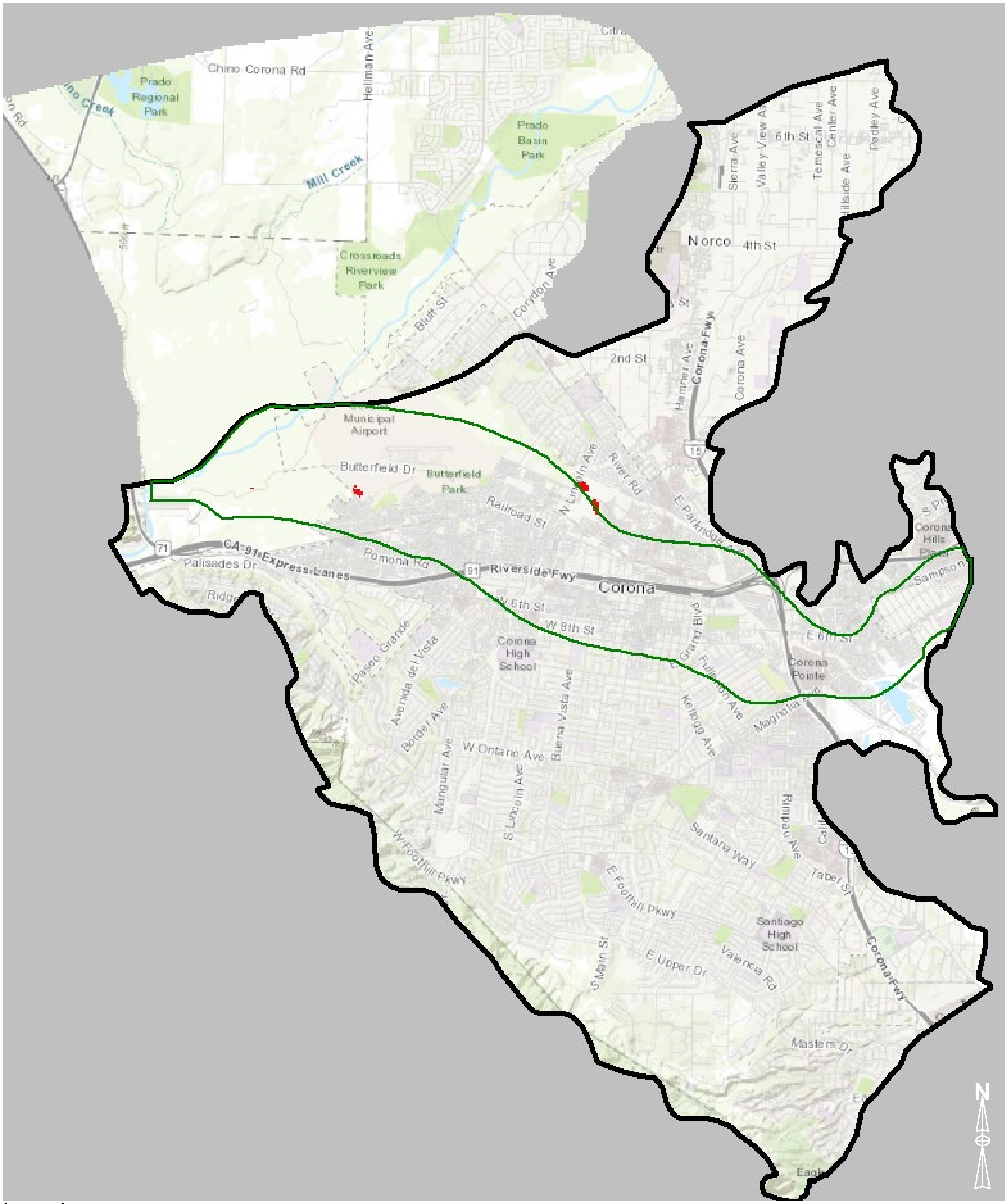
Figure 19
Approximated Locations of Agricultural Pumping Wells Applied in MODFLOW Model



December 2021

TODD GROUNDWATER

Figure 20
Annual Groundwater Pumping Applied in MODFLOW Model



Legend

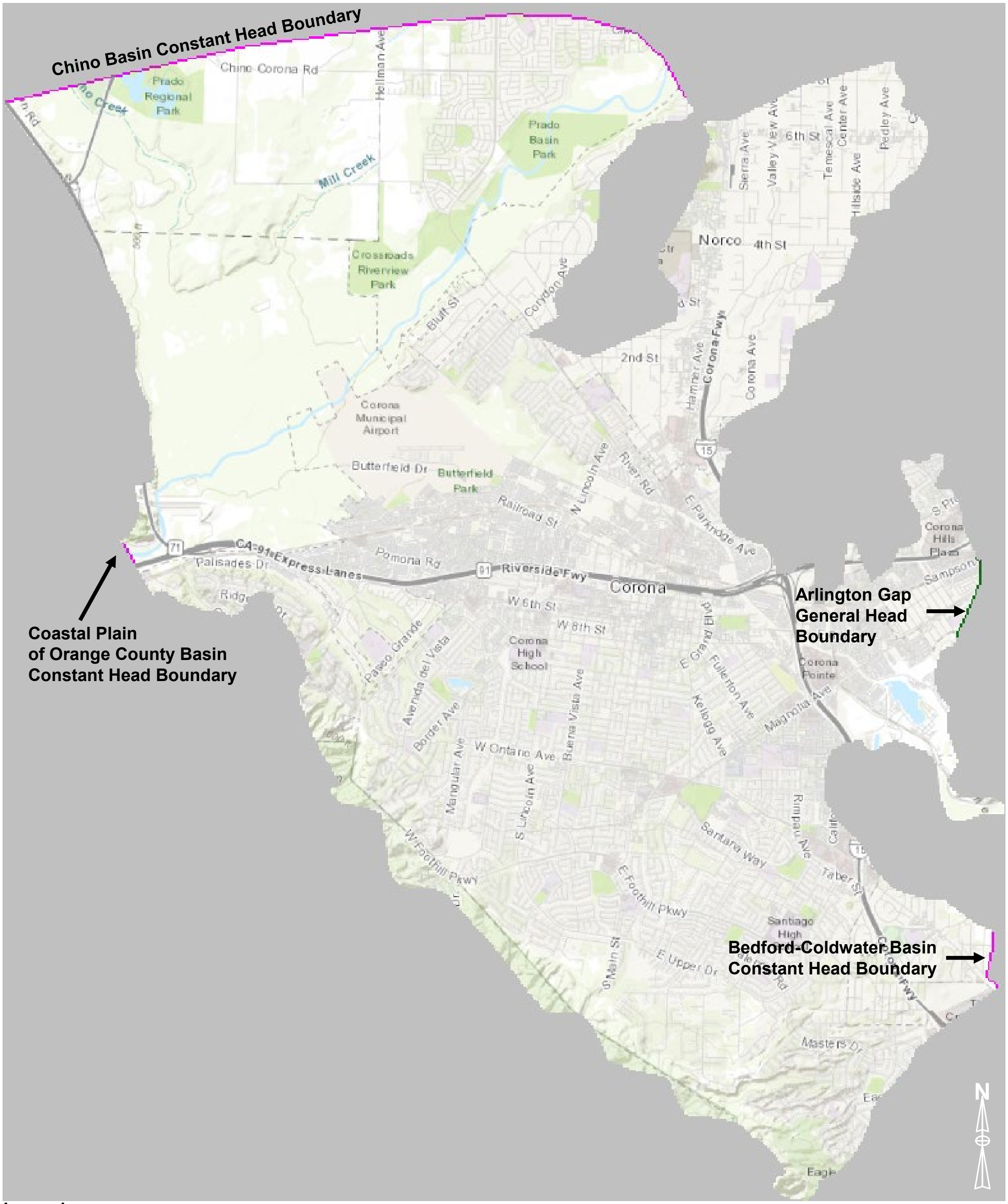
- Recycled Water Percolation Pond
- Temescal Subbasin
- Channel Aquifer Outline

10000 feet

December 2021

TODD GROUNDWATER

Figure 21
Location of Recycled Water Recharge Ponds



Legend

Simulated Constant Head Boundary

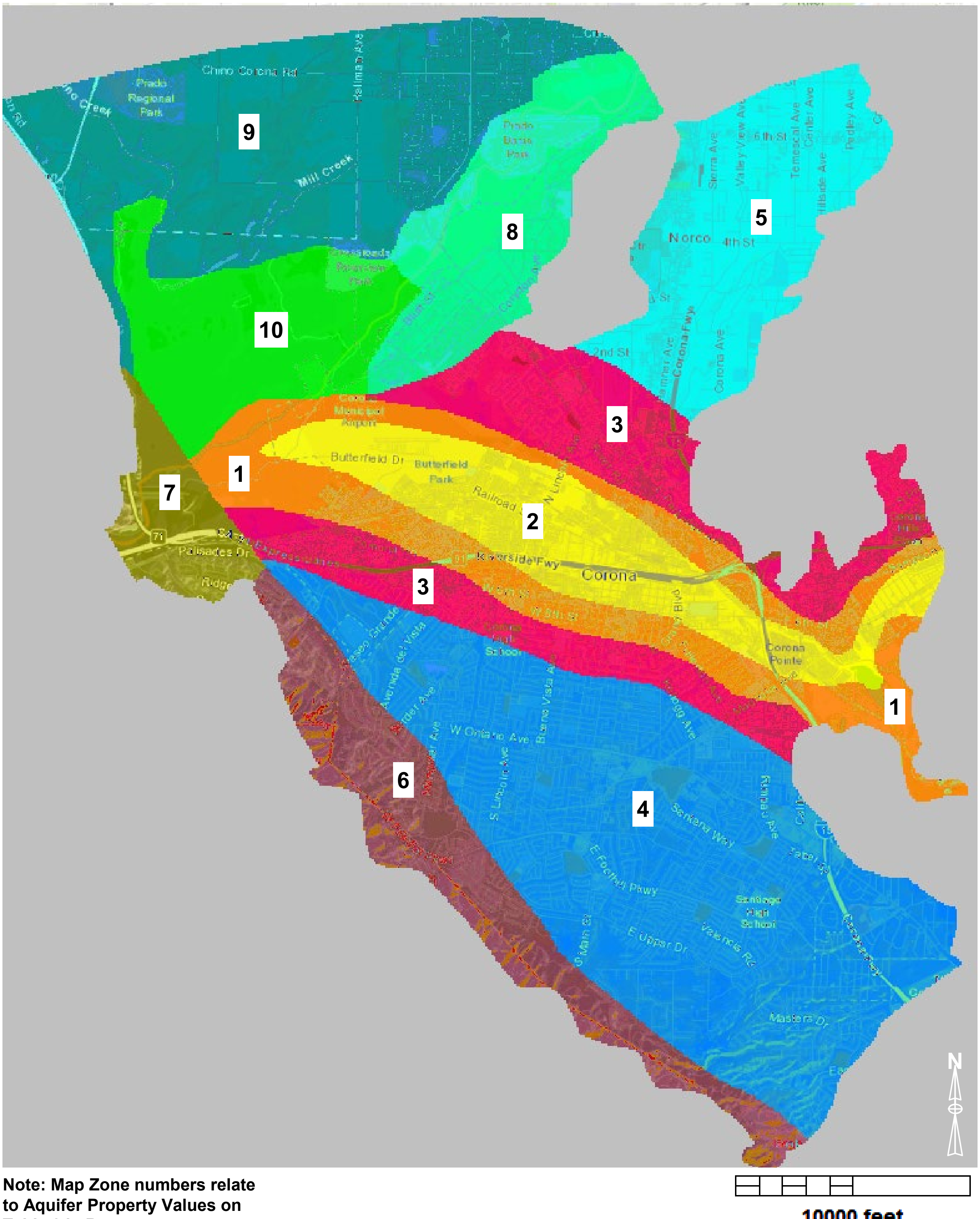
Simulated General Head Boundary

10000 feet

December 2021

TODD GROUNDWATER

Figure 22
Boundary Conditions Applied at the Basin Margins in the MODFLOW Model

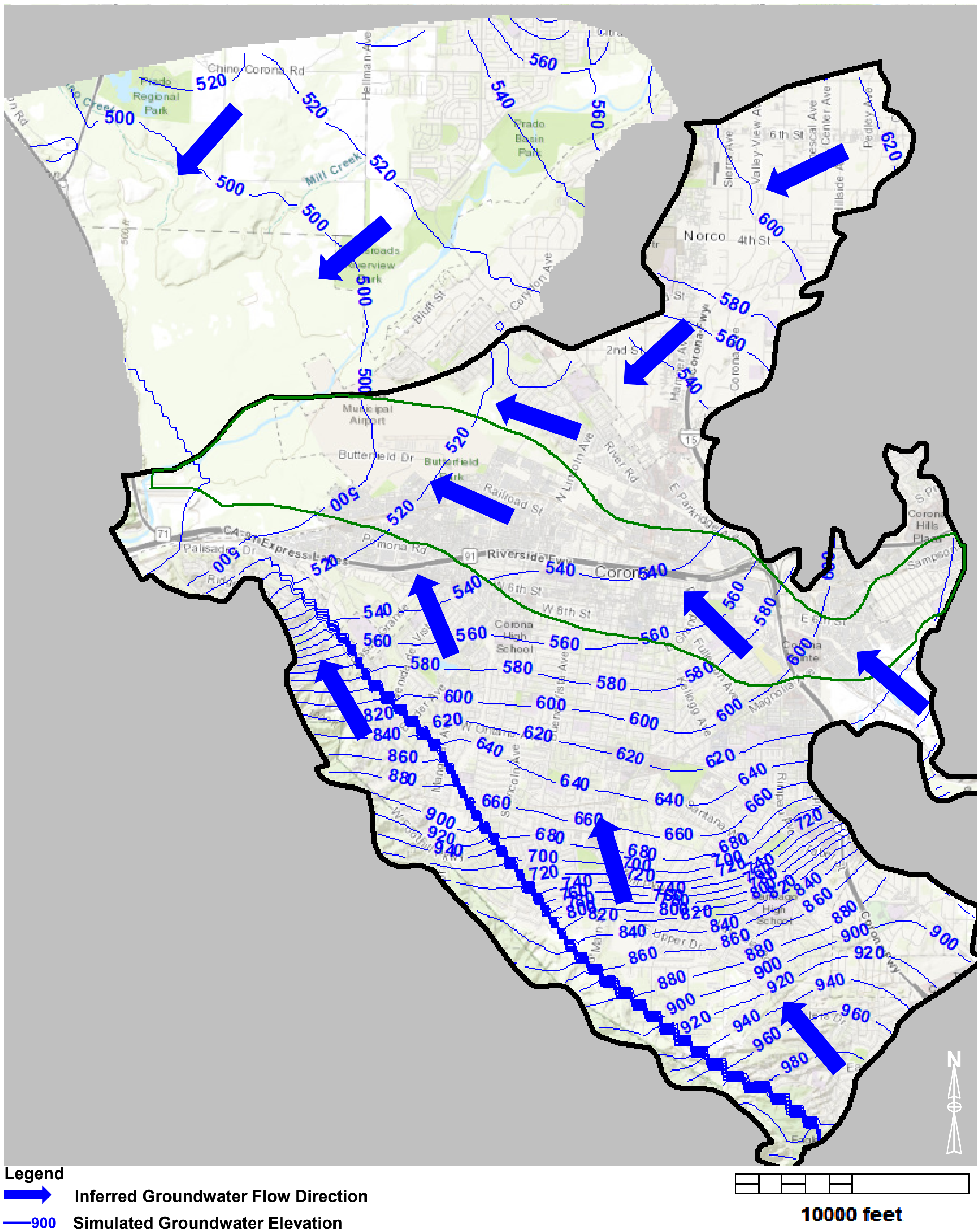


Note: Map Zone numbers relate to Aquifer Property Values on Table 2 in Report

December 2021

TODD GROUNDWATER

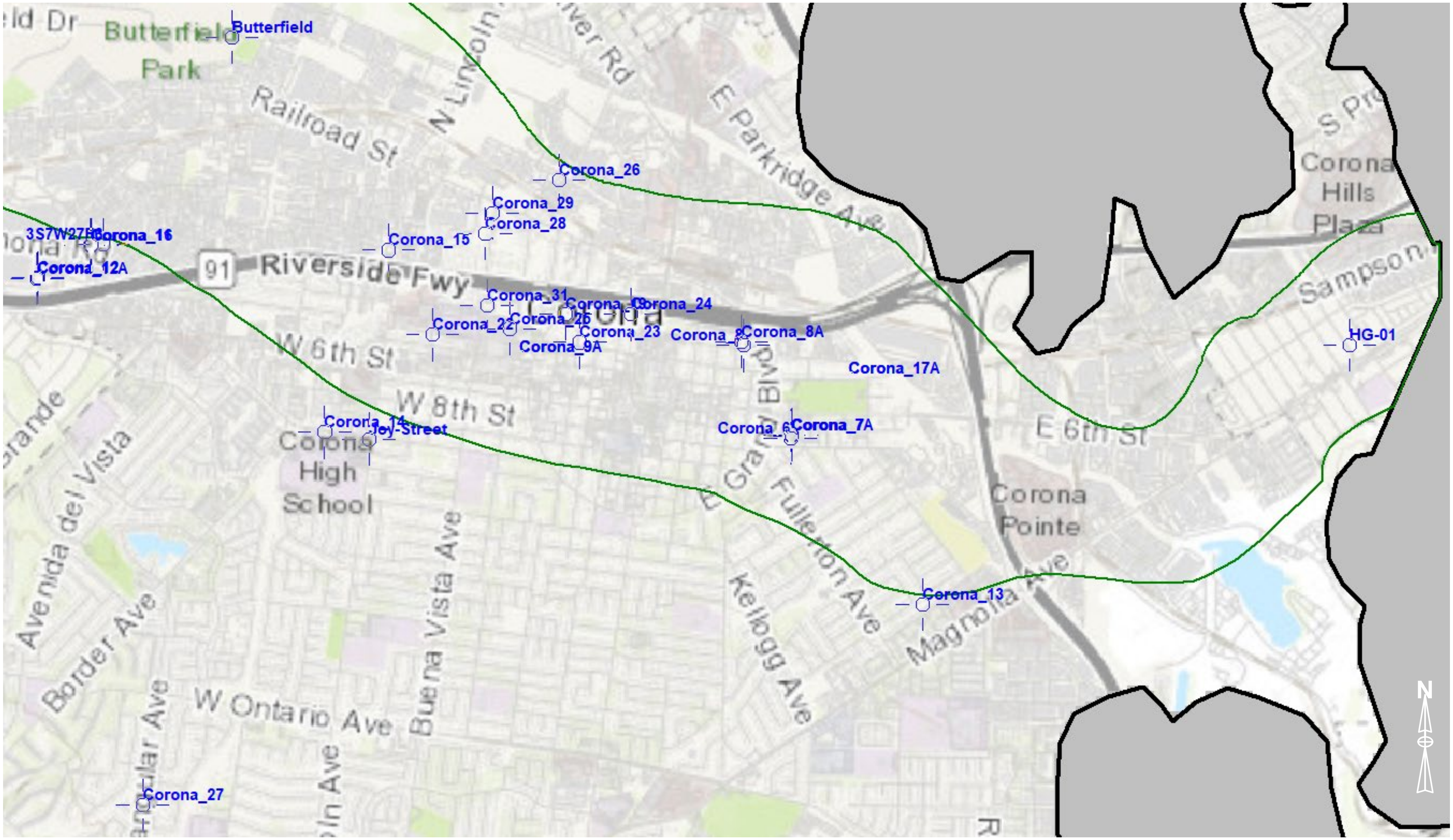
Figure 23
Distribution of Aquifer Property Zones for Layers 1, 2 and 3



December 2021

TODD GROUNDWATER

Figure 24
Initial Groundwater Elevations Applied in the MODFLOW Model



Legend

- Monitoring Well Location
- Temescal Subbasin
- Channel Aquifer Outline

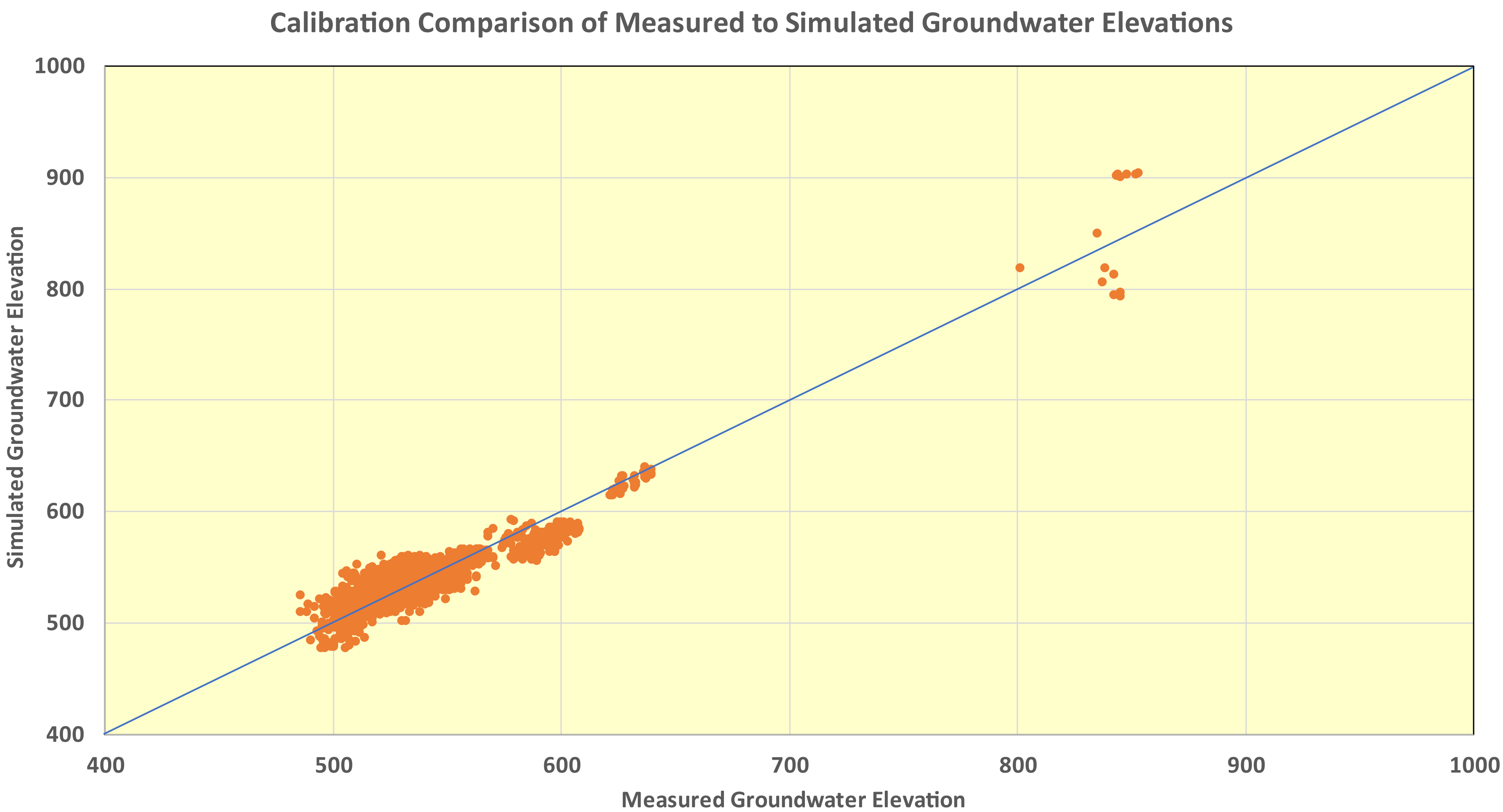
0 0.5 1

Scale: Miles

December 2021

TODD GROUNDWATER

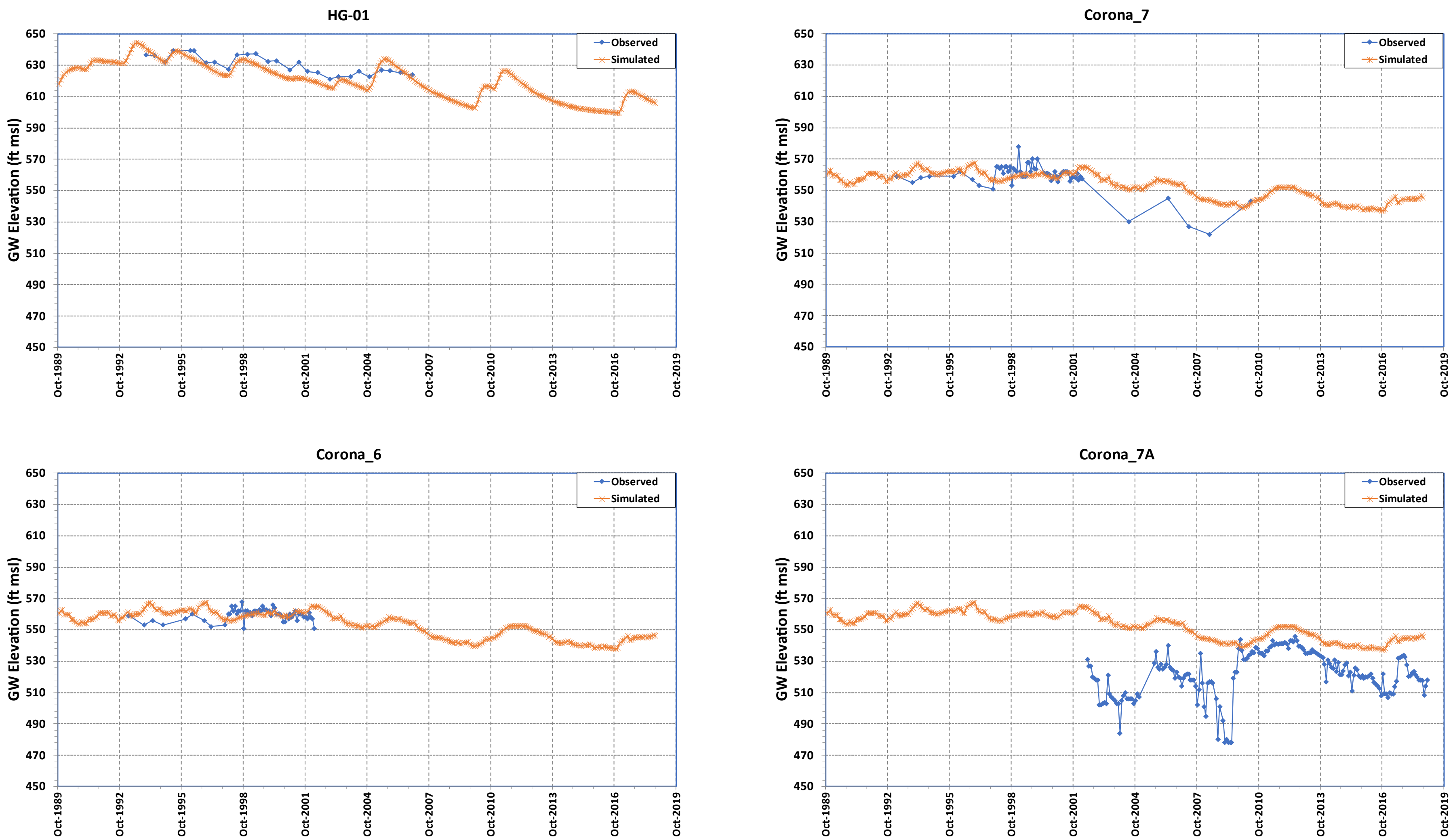
Figure 25
Location of Monitoring Wells Used for Calibration



December 2021

TODD GROUNDWATER

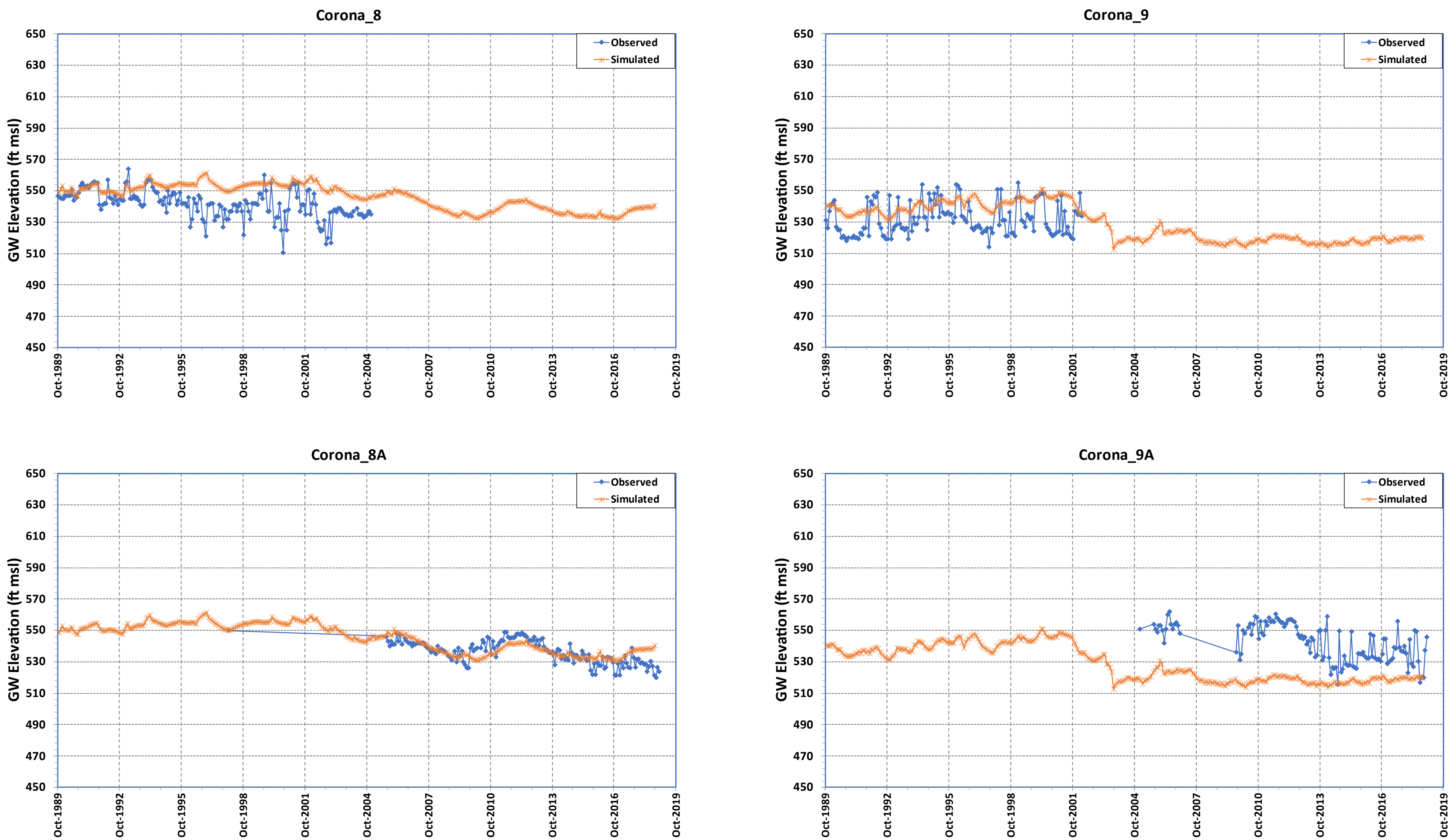
Figure 26
Scatter Plot Comparing Simulated to Measured Groundwater Levels



December 2021

TODD GROUNDWATER

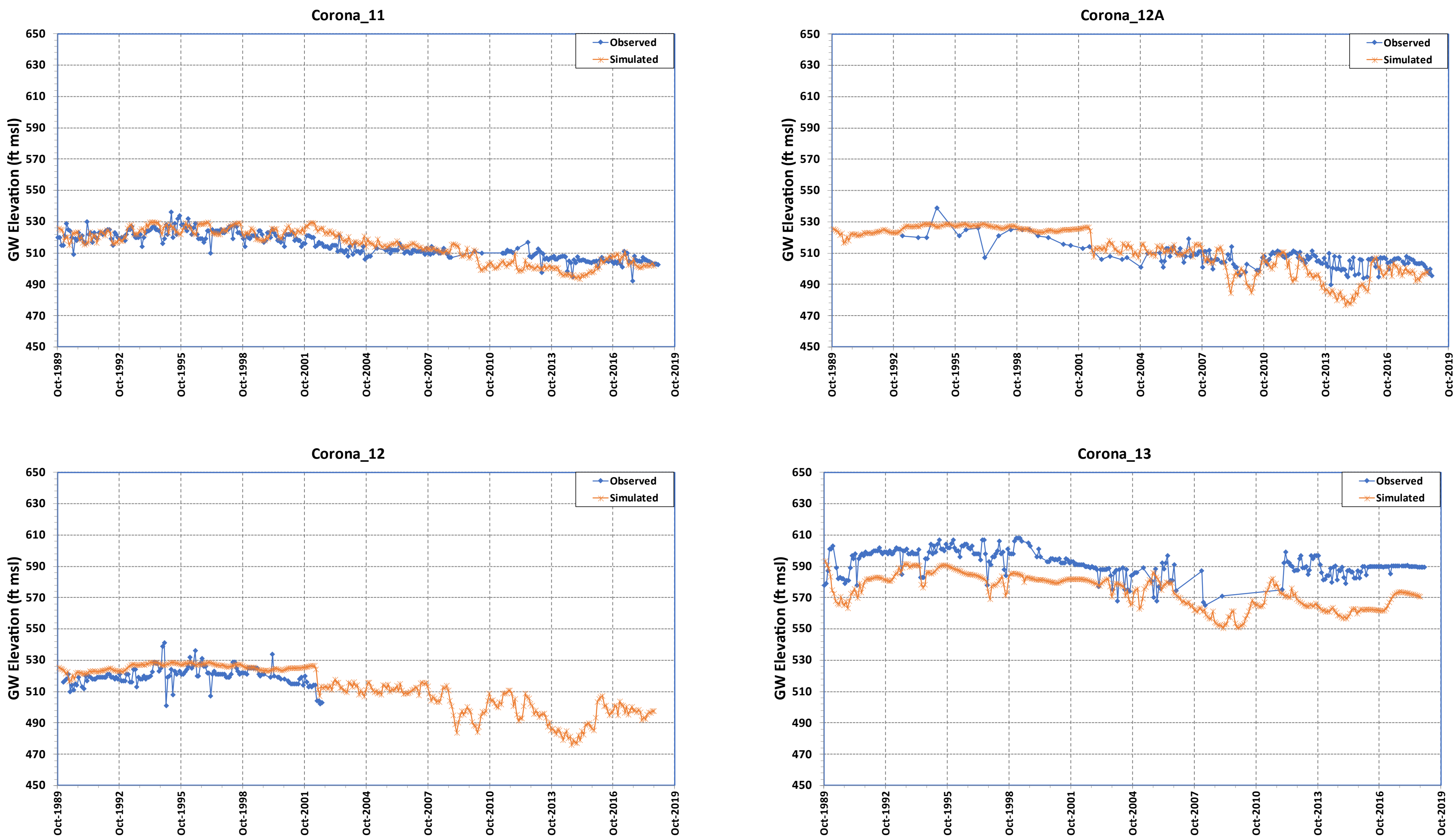
Figure 27
Calibration Hydrographs
Corona Wells 6, 7 and 7A
HG-01



December 2021

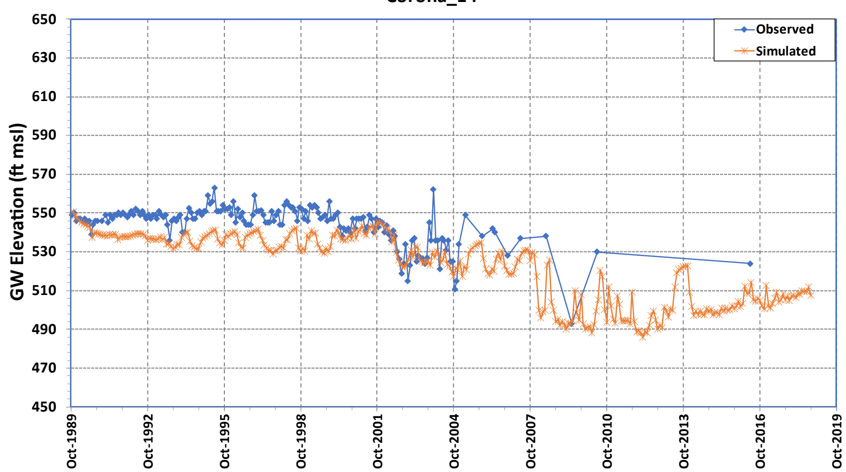
TODD GROUNDWATER

Figure 28
Calibration Hydrographs
Corona Wells 8, 8A, 9, 9A

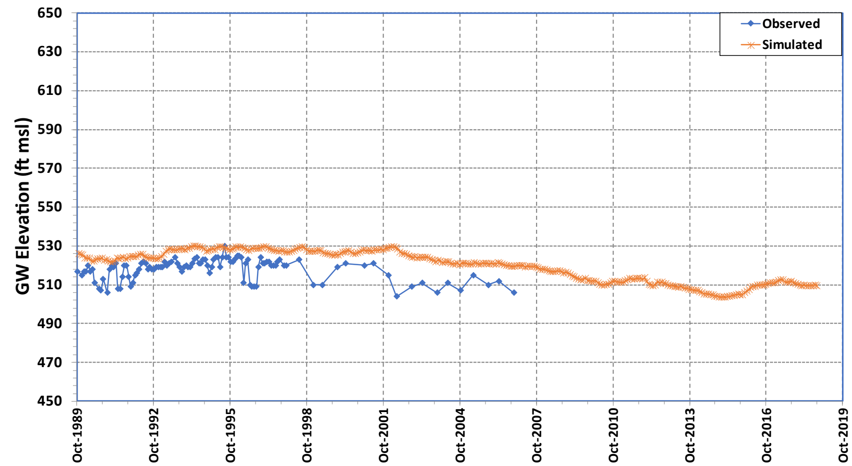


December 2021	Figure 29
TODD GROUNDWATER	Calibration Hydrographs Corona Wells 11, 12, 12A and 13

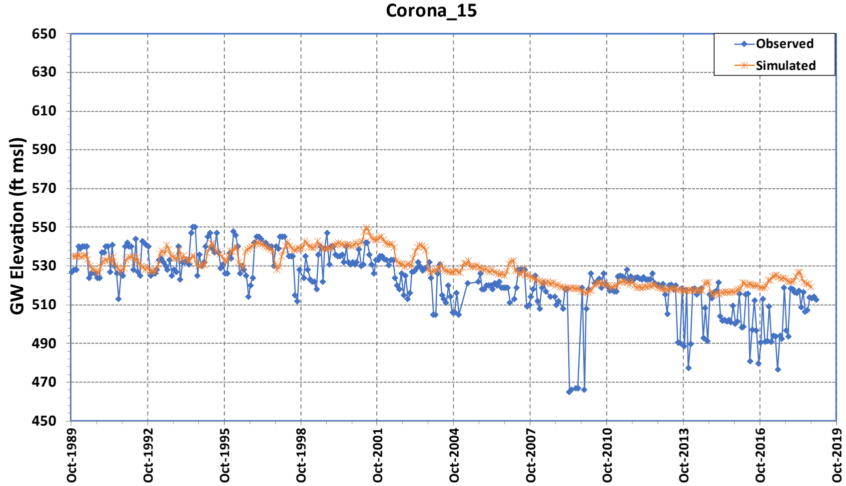
Corona_14



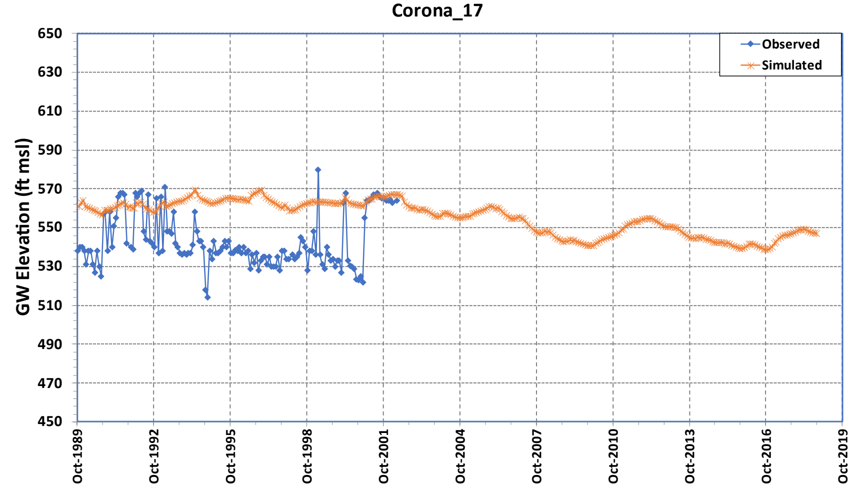
Corona_16



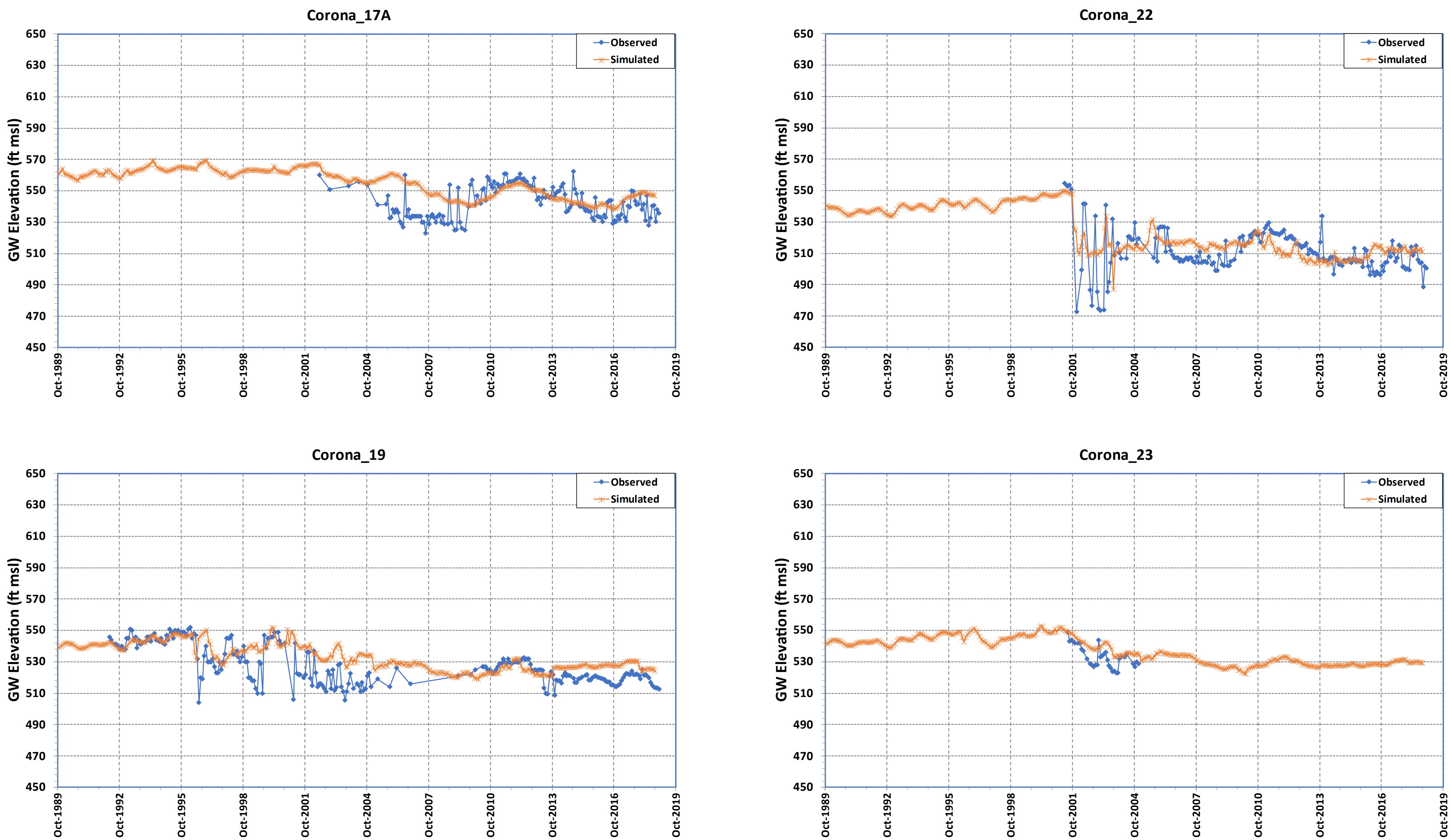
Corona_15



Corona_17



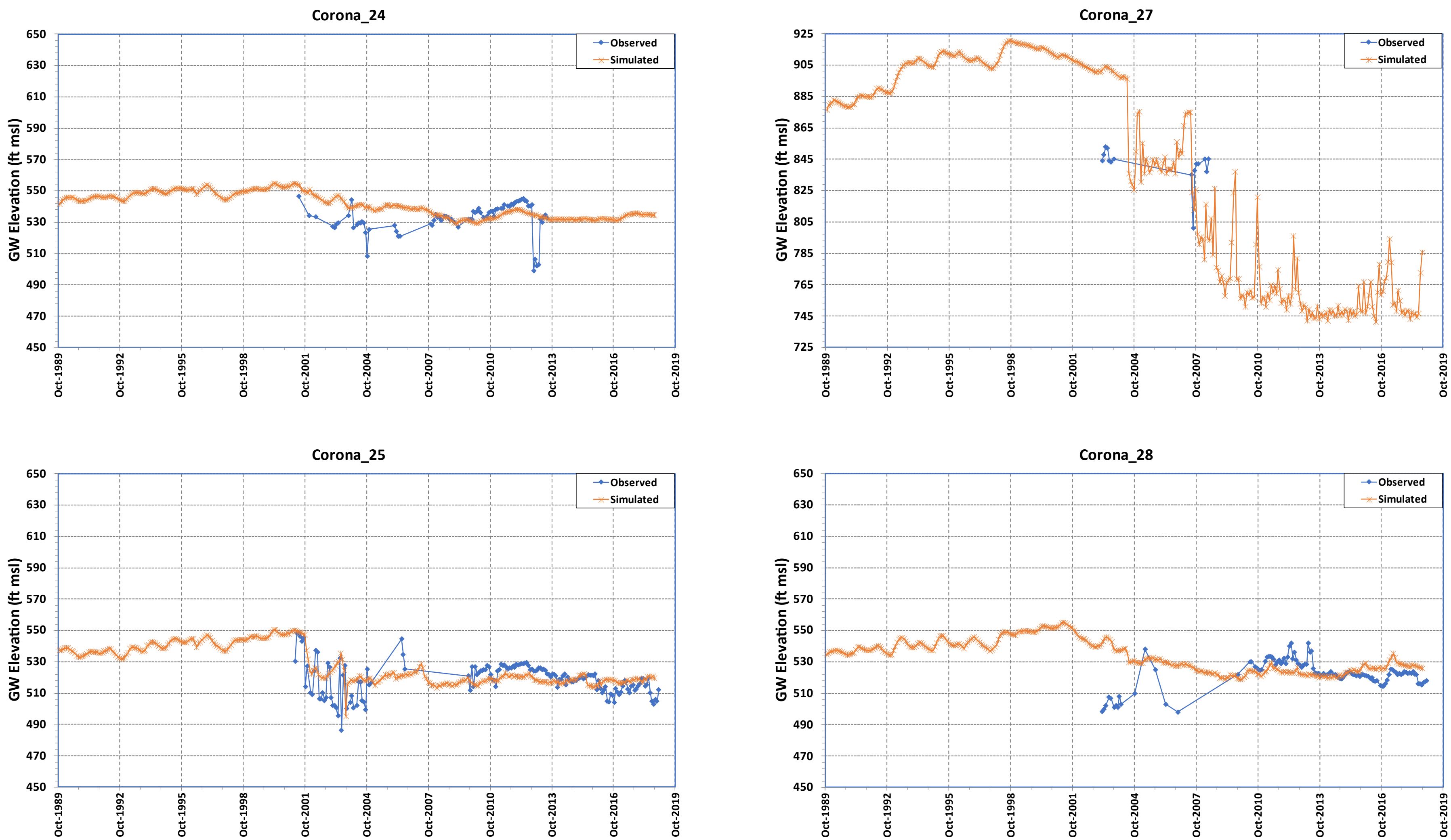
December 2021	**Figure 30**
TODD GROUNDWATER	**Calibration Hydrographs Corona Wells 14, 15, 16 and 17**



December 2021

TODD GROUNDWATER

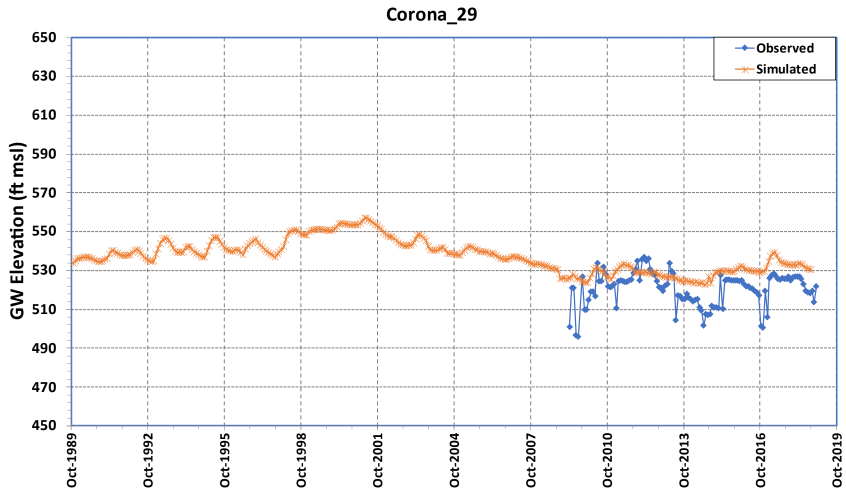
Figure 31
Calibration Hydrographs Corona Wells 17A, 19, 22 and 23

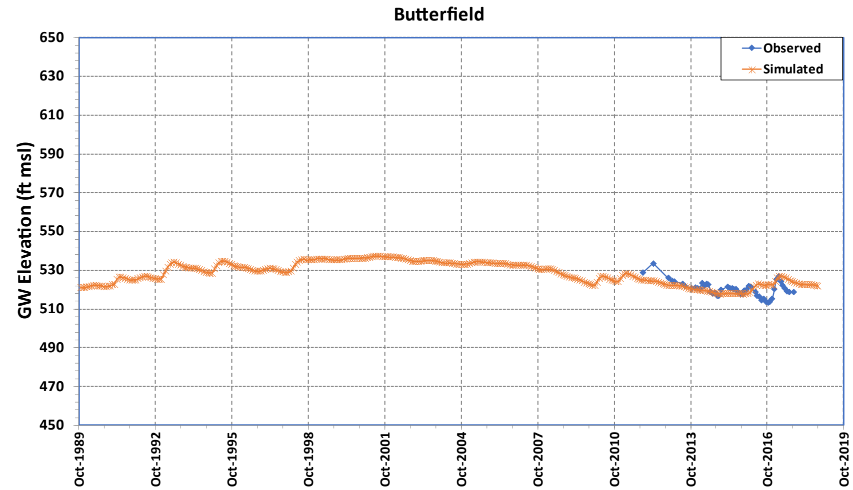


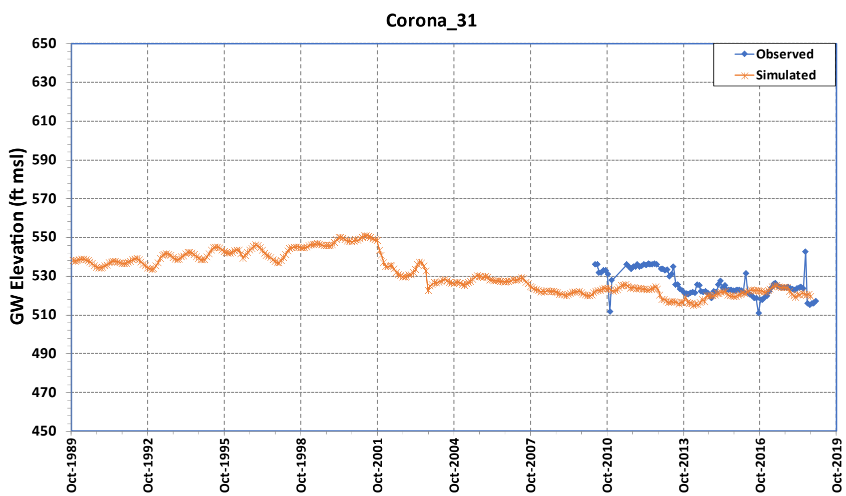
December 2021

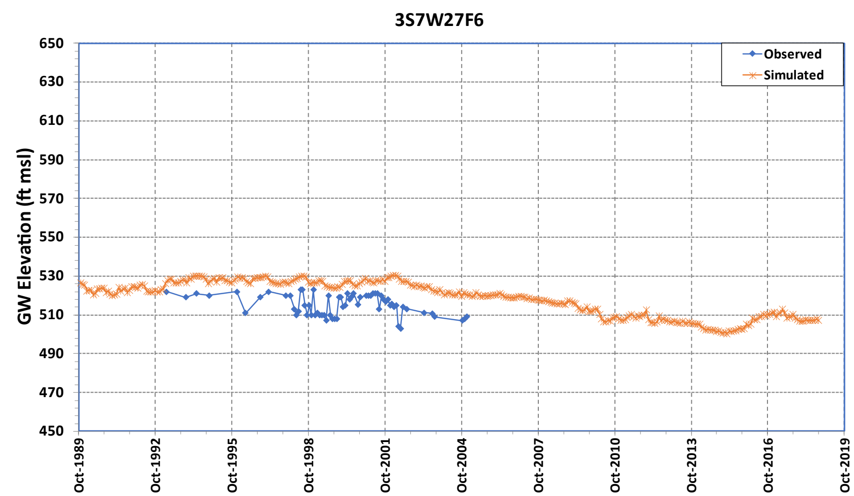
TODD GROUNDWATER

Figure 32
Calibration Hydrographs
Corona Wells 24, 25, 27 and 28

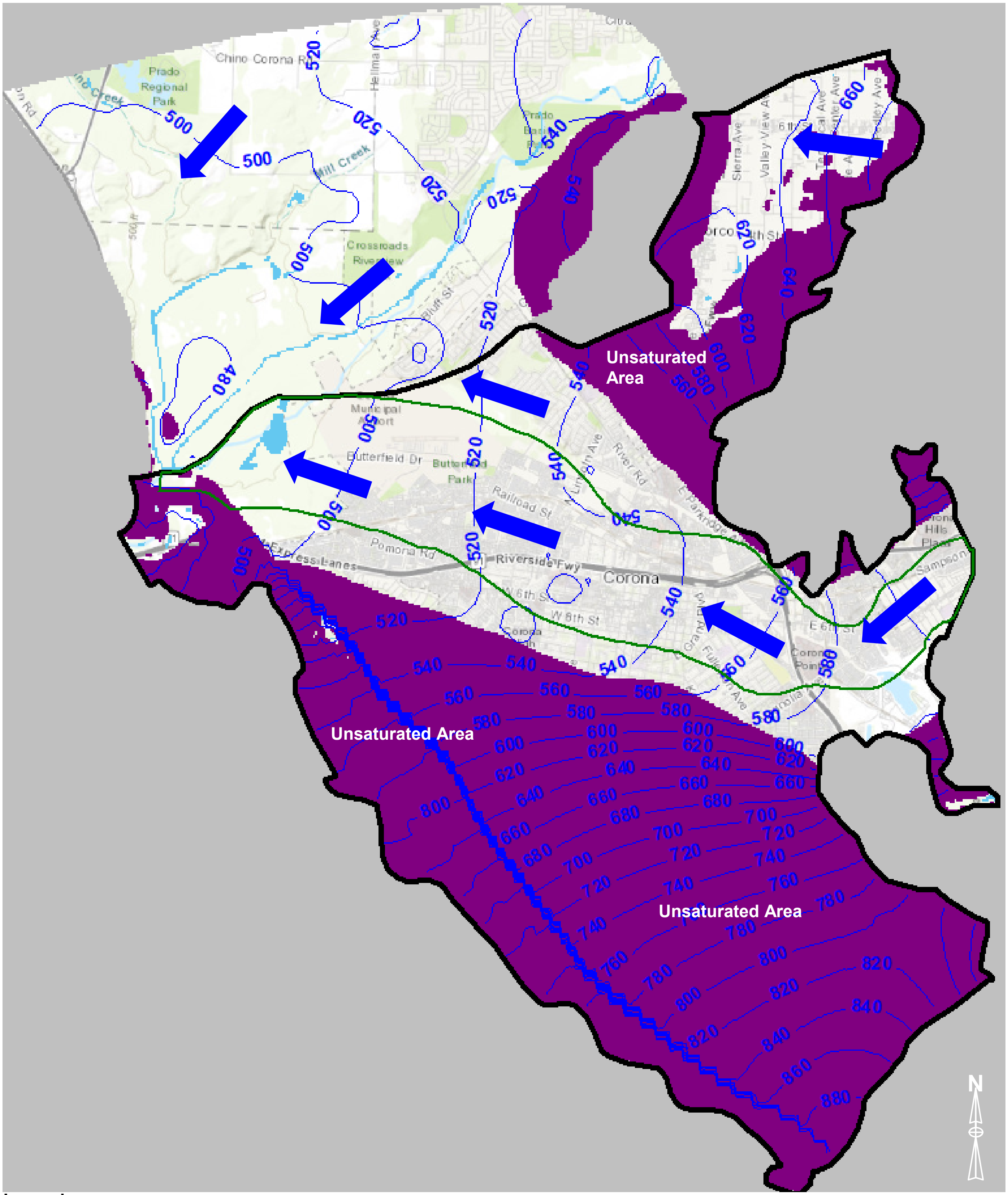








December 2021	**Figure 33**
TODD GROUNDWATER	**Calibration Hydrographs Corona Wells 29 and 31, Butterfield and 3S7W-27F6**



10000 feet

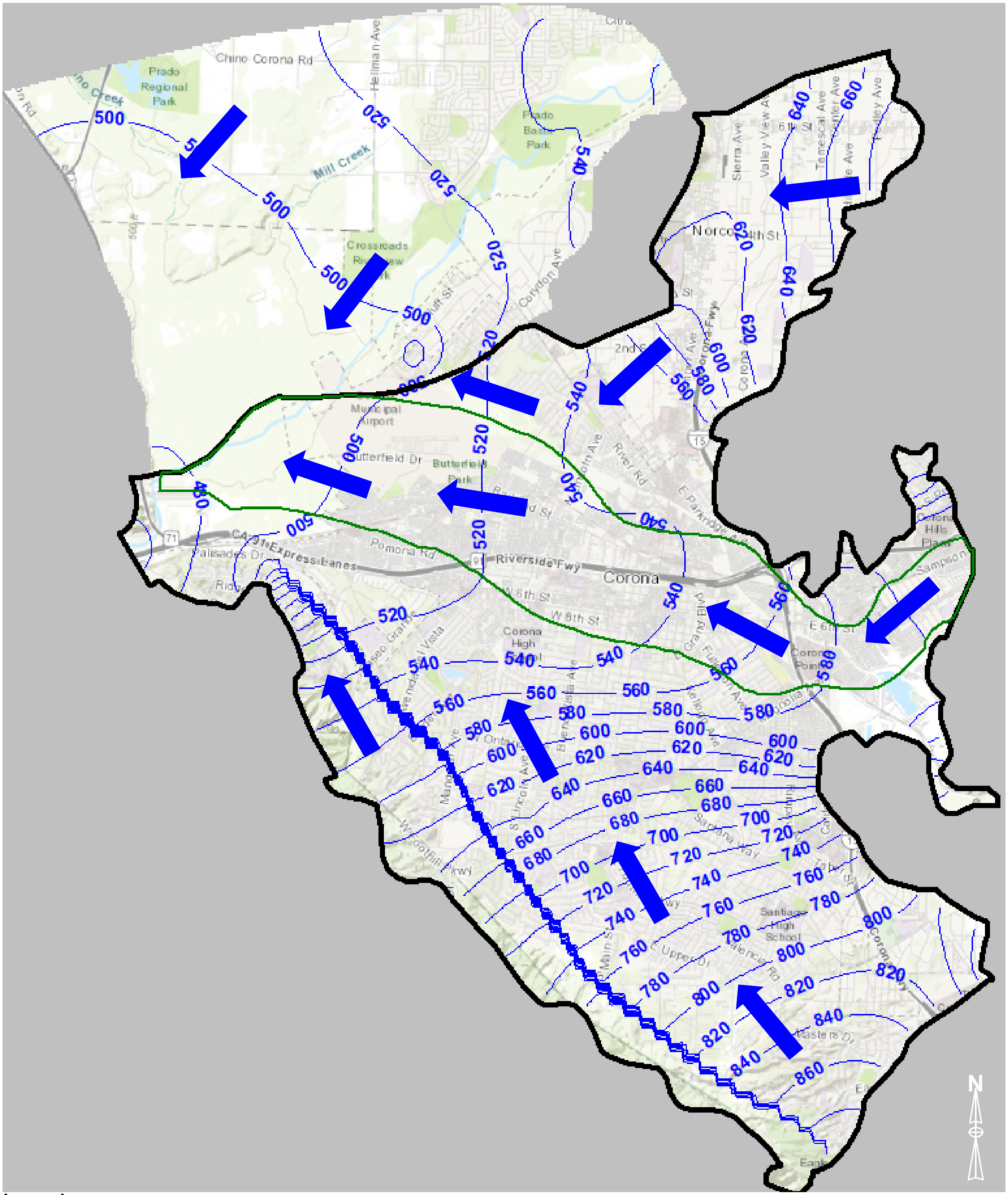
Legend

- Inferred Groundwater Flow Direction
- 900 Simulated Groundwater Elevation
- Temescal Subbasin
- Channel Aquifer Outline
- Unsaturated Areas

December 2021

TODD GROUNDWATER

Figure 34
Groundwater Elevations at End of Simulation in Layer 1
September 2018



Legend

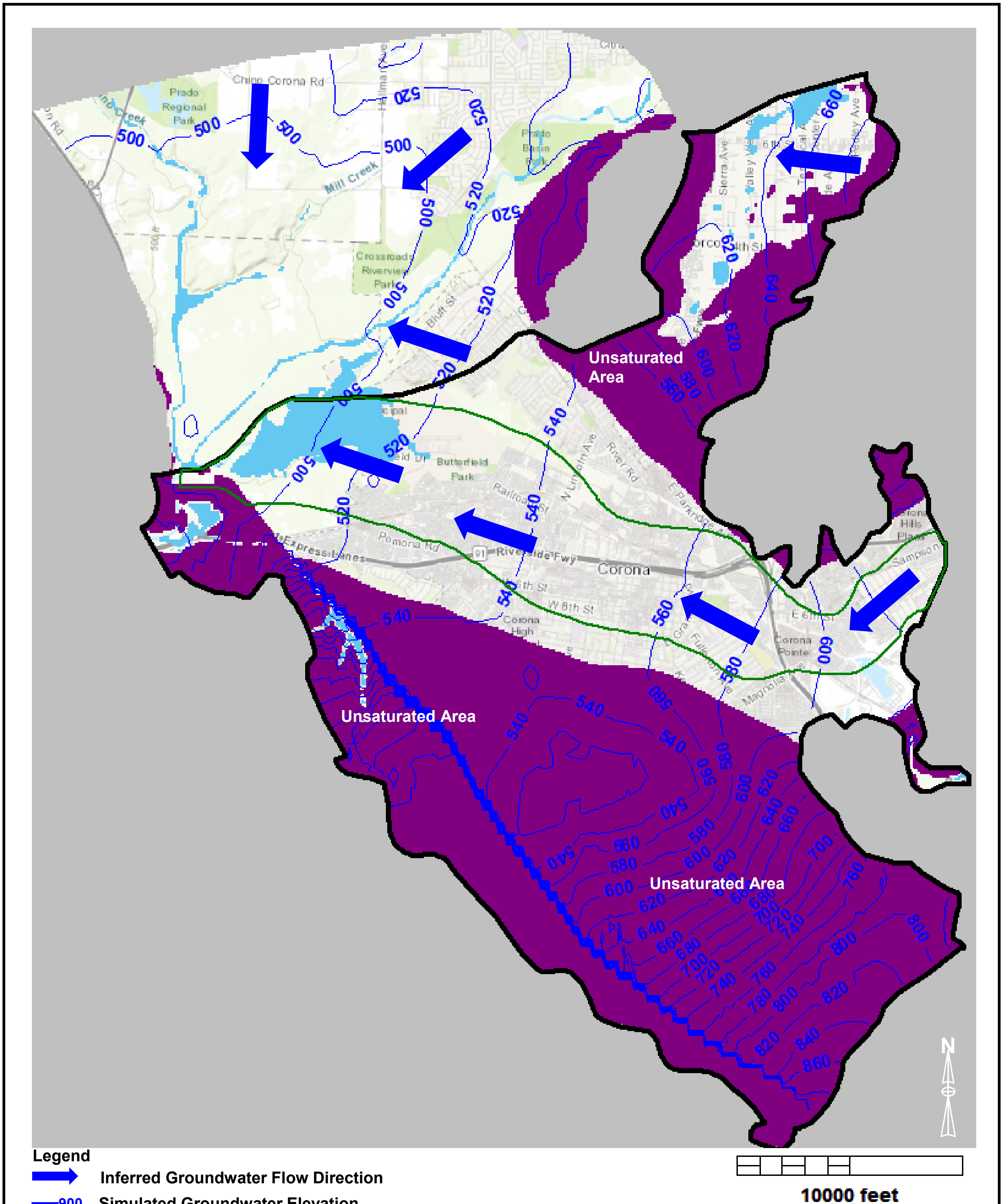
- Inferred Groundwater Flow Direction
- 900 Simulated Groundwater Elevation
- Temescal Subbasin
- Channel Aquifer Outline

10000 feet

December 2021

TODD GROUNDWATER

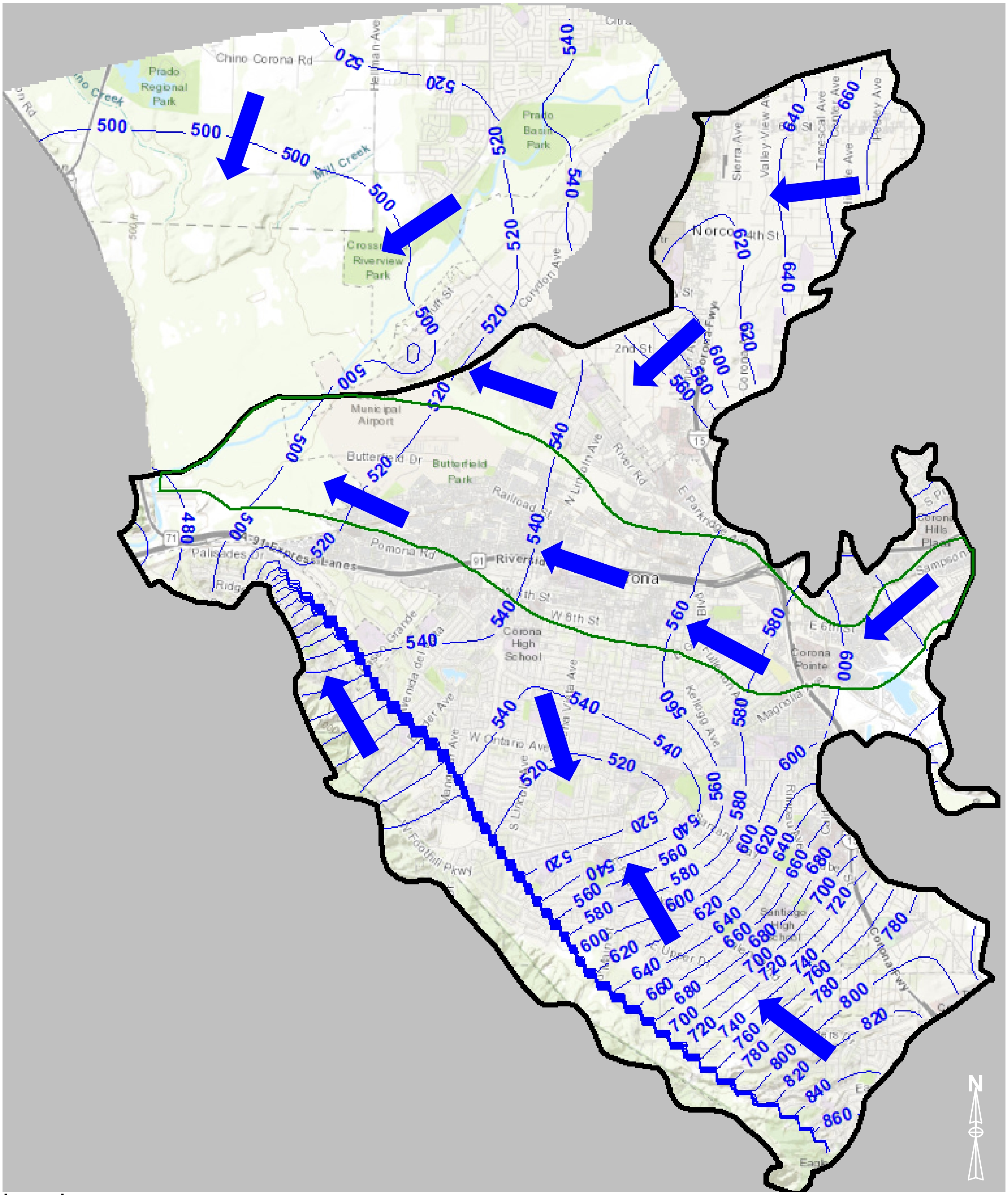
Figure 35
Groundwater Elevations at End of Simulation in Layer 3
September 2018



December 2021

TODD GROUNDWATER

Figure 36
Groundwater Elevations near Highest Levels in Layer 1
January 1997



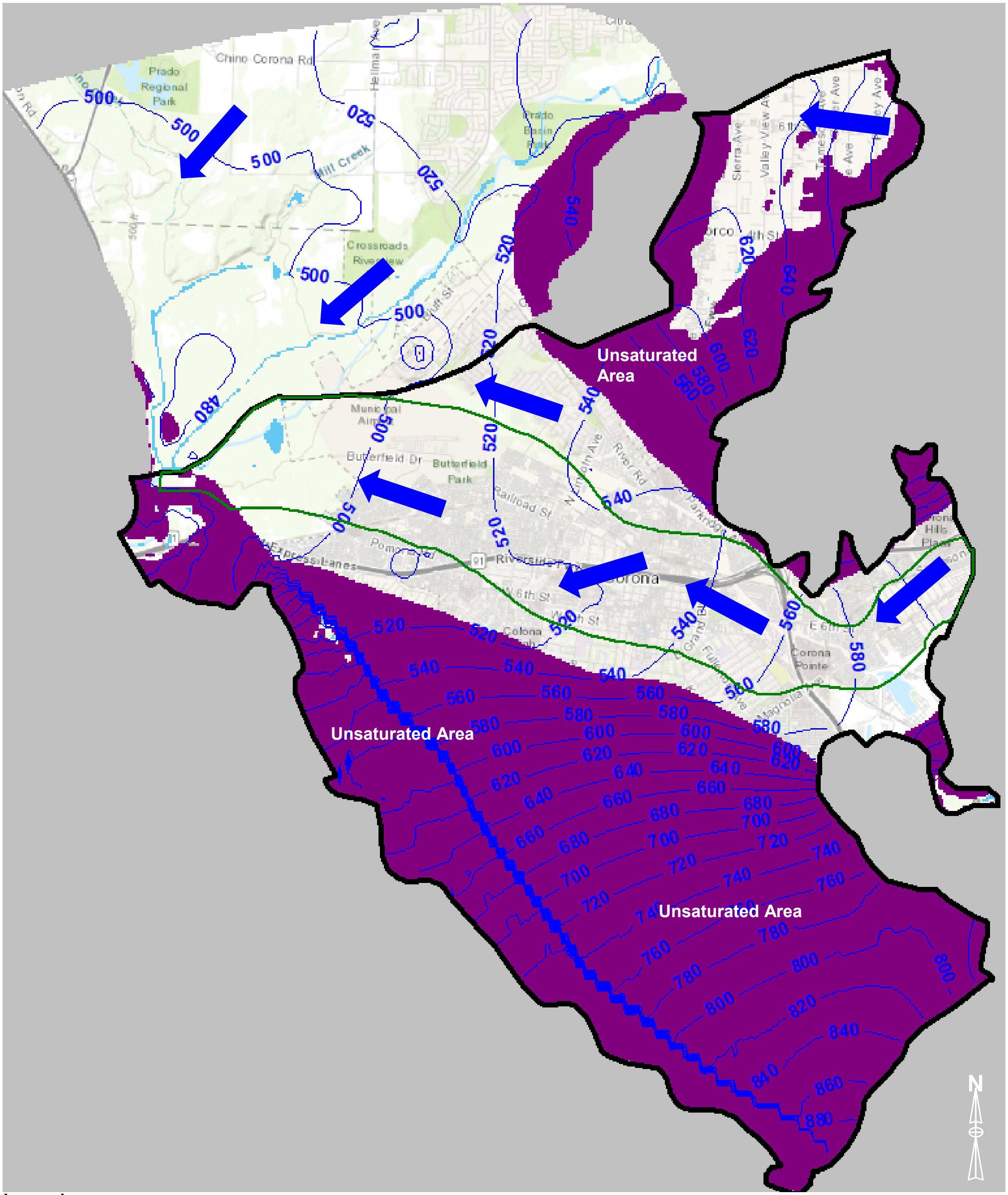
Legend

- Inferred Groundwater Flow Direction
- 900 Simulated Groundwater Elevation
- Temescal Subbasin
- Channel Aquifer Outline

December 2021

TODD GROUNDWATER

Figure 37
Groundwater Elevations near Highest Levels in Layer 3
January 1997



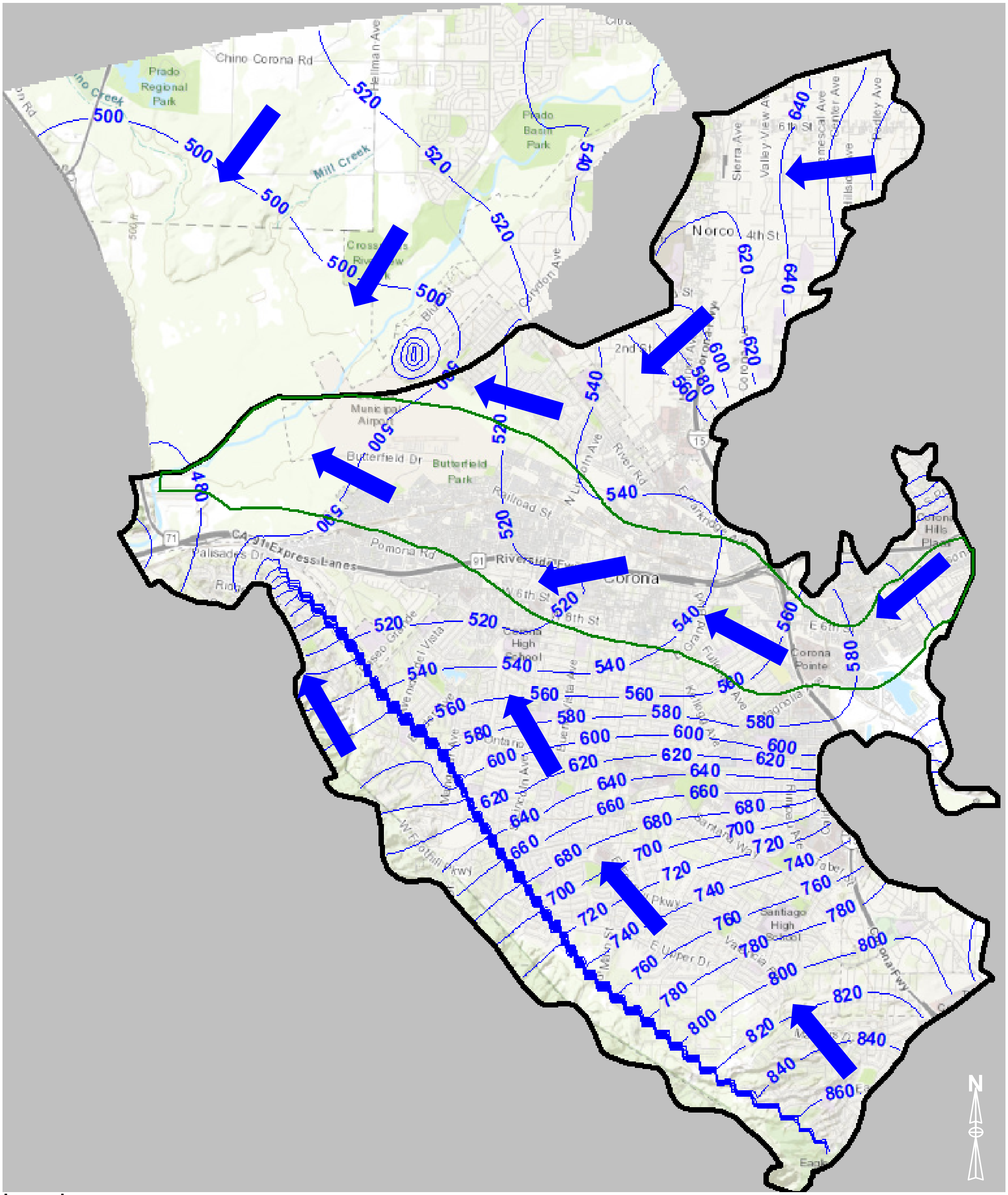
Legend
- Inferred Groundwater Flow Direction
- 900 Simulated Groundwater Elevation
- Temescal Subbasin
- Channel Aquifer Outline
- Unsaturated Areas

10000 feet

December 2021

TODD GROUNDWATER

Figure 38
Groundwater Elevations near Lowest Levels in Layer 1
August 2014



Legend

- Inferred Groundwater Flow Direction
- 900 Simulated Groundwater Elevation
- Temescal Subbasin
- Channel Aquifer Outline

December 2021

TODD GROUNDWATER

Figure 39
Groundwater Elevations near Lowest Levels in Layer 3
August 2014

APPENDIX K

Detailed Annual Surface and Groundwater Budgets

Temescal Basin Surface Water Budget, Model Calibration Period (1990 to 2018)

Water Year	Temescal Basin (acre-feet per year)						
	Temescal Wash Inflow	Corona WRF-1 Discharge	Tributary and Local Runoff	Stream Percolation to Groundwater	Seepage from Groundwater to Streams	Surface Outflow to Prado Basin	Tributary Runoff below Prado Dam
1990	0	0	26,559	5,247	4,261	25,573	11
1991	10,677	0	13,683	6,480	5,157	23,036	184
1992	989	0	7,589	5,783	5,526	8,321	96
1993	87,158	0	105,205	19,906	6,517	178,974	888
1994	0	0	10,361	7,101	6,682	9,942	23
1995	21,113	0	23,733	11,635	7,247	40,459	515
1996	0	0	5,152	5,225	6,989	6,916	19
1997	0	0	3,779	3,854	7,301	7,226	47
1998	43,113	1,591	41,309	16,326	5,964	75,651	818
1999	0	7,483	7,666	8,330	5,694	12,512	19
2000	0	7,702	4,121	6,155	5,549	11,217	44
2001	2,584	7,091	10,013	9,052	5,718	16,356	120
2002	0	5,756	3,953	6,041	5,490	9,158	18
2003	8,860	5,479	16,787	10,509	5,470	26,087	290
2004	0	4,022	5,825	7,427	5,312	7,732	69
2005	114,670	5,104	101,133	21,715	5,743	204,935	796
2006	895	5,641	30,082	10,472	5,428	31,576	38
2007	0	4,791	15,140	6,947	4,589	17,573	4
2008	0	3,783	11,847	5,713	4,562	14,479	52
2009	0	2,775	10,066	5,237	4,276	11,880	6
2010	28,490	1,975	33,112	13,187	4,561	54,951	401
2011	45,771	3,632	47,065	14,942	5,327	86,853	248
2012	0	3,139	6,884	7,894	5,058	7,188	27
2013	3	2,298	5,003	6,152	4,722	5,874	33
2014	0	1,819	3,504	5,031	4,259	4,551	34
2015	0	1,719	4,129	5,457	4,118	4,510	56
2016	0	6,529	3,526	5,556	4,247	8,746	26
2017	20,353	2,386	25,587	12,611	4,296	40,012	382
2018	0	2,621	4,912	6,294	4,222	5,462	71

Temescal Basin Detailed Annual Water Budget, Model Calibration Period (1990 to 2018)

	Water Year and Type[1]																												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	D	AN	AN	W	BN	W	D	D	W	D	D	N	D	AN	W	W	BN	D	D	BN	AN	W	BN	D	D	BN	D	W	D
Inflows (AFY)																													
Percolation from streams	837	7,936	2,734	18,240	1,332	12,096	947	1,103	15,357	5,316	5,447	6,924	4,696	11,344	5,792	21,433	6,269	5,389	5,036	3,302	15,822	16,100	4,338	3,508	2,969	3,385	7,683	15,585	3,581
Bedrock inflow	998	998	994	1,000	998	1,166	1,257	1,165	1,077	1,068	924	874	951	884	766	992	1,137	1,101	1,044	976	901	931	987	990	998	884	681	751	831
Dispersed recharge: non-irrigated land	834	5,076	3,293	16,079	2,128	8,996	1,654	1,843	13,739	647	1,176	3,131	740	6,099	2,275	13,727	1,372	204	1,371	427	6,711	6,909	2,000	1,901	2,224	3,673	2,246	7,012	1,607
Dispersed recharge: irrigated land	2,310	2,297	2,158	2,056	2,069	2,112	2,180	2,077	1,783	2,274	2,296	2,044	2,068	1,900	2,000	1,610	2,034	2,119	1,992	1,844	1,702	1,586	1,749	1,684	1,705	1,454	1,435	1,526	1,603
Pipe leaks	2,153	2,047	1,997	1,951	1,996	1,989	1,826	2,124	2,350	2,696	3,070	3,000	2,941	2,946	3,025	2,588	2,970	3,302	3,166	2,912	2,629	2,407	2,540	2,504	2,496	2,233	2,101	2,244	2,092
Reclaimed water percolation	5,385	6,063	6,714	7,440	8,094	8,772	9,413	10,919	10,806	6,575	7,763	8,452	8,667	8,629	10,032	10,245	9,449	8,462	7,570	6,679	6,679	5,342	5,928	6,851	6,818	7,666	3,839	6,029	5,529
Inflow from Chino Basin	143	123	120	122	115	115	119	123	114	113	122	123	124	122	123	119	121	129	132	131	129	130	132	132	122	119	120	121	126
Total Inflow	12,660	24,538	18,011	46,888	16,732	35,246	17,394	19,354	45,226	18,688	20,797	24,548	20,186	31,923	24,013	50,713	23,352	20,707	20,312	16,270	34,574	33,404	17,674	17,571	17,332	19,414	18,105	33,268	15,369
Outflows (AFY)																													
Wells - M&I and domestic	-9,713	-7,937	-10,103	-11,998	-10,533	-11,119	-8,757	-9,663	-12,538	-11,141	-9,562	-9,554	-15,831	-16,733	-18,289	-19,481	-19,940	-19,322	-19,917	-17,309	-17,283	-16,243	-17,074	-18,357	-16,163	-14,904	-12,029	-12,948	-14,541
Wells - agricultural	-7,588	-8,392	-7,130	-6,801	-6,686	-6,968	-8,199	-5,795	-2,780	-4,230	-2,617	-1,565	-2,979	-1,668	-1,277	-990	-987	-786	-1,284	-1,589	-1,408	-1,227	-1,634	-1,275	-1,527	-1,482	-1,010	-1,289	-1,148
Groundwater discharge to streams	-1,674	-2,707	-3,661	-5,728	-5,849	-6,530	-6,353	-6,793	-5,469	-2,959	-3,445	-4,491	-3,619	-3,357	-3,279	-4,626	-3,302	-2,381	-2,043	-1,530	-1,430	-1,604	-1,200	-948	-656	-523	-464	-889	-879
Riparian evapotranspiration	-3,213	-3,696	-3,912	-5,182	-4,670	-5,136	-4,947	-5,038	-5,450	-5,160	-4,942	-4,587	-4,808	-5,069	-4,966	-5,589	-4,658	-4,501	-3,860	-3,501	-4,087	-4,175	-3,903	-3,522	-3,399	-3,205	-3,498	-4,196	-3,541
Outflow to Chino Basin	-2,413	-2,461	-2,448	-2,544	-2,520	-2,851	-2,563	-2,956	-3,182	-3,631	-3,555	-3,429	-3,357	-2,971	-2,865	-2,764	-2,720	-2,579	-2,416	-2,187	-2,042	-2,140	-2,112	-2,043	-2,281	-2,224	-2,217	-2,444	-2,209
Total Outflow	-24,600	-25,194	-27,254	-32,253	-30,258	-32,604	-30,819	-30,245	-29,419	-27,121	-24,121	-23,626	-30,594	-29,797	-30,677	-33,451	-31,606	-29,570	-29,521	-26,115	-26,251	-25,389	-25,924	-26,144	-24,027	-22,338	-19,218	-21,765	-22,319
Storage Change (AFY)																													
Total Inflows minus Total Outflows	-11,940	-656	-9,243	14,636	-13,526	2,642	-13,425	-10,891	15,808	-8,433	-3,324	922	-10,408	2,126	-6,664	17,262	-8,254	-8,863	-9,209	-9,845	8,323	8,015	-8,250	-8,574	-6,695	-2,924	-1,113	11,503	-6,949

Notes:

[1]: Water year types are described in Section 5 - Water Budget, and shown on Figure 5-1. Water year types are summarized above as follows D = Dry, Below Normal = BN, N = Normal, AN = Above Normal, W = Wet.

Temescal Basin Detailed Annual Water Budget, Baseline Period

	Water Year																
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Inflows																	
Percolation from streams	22,447	3,505	14,478	3,425	3,469	17,214	3,317	2,697	4,073	7,434	12,046	6,298	22,915	5,447	4,041	5,550	5,665
Bedrock inflow	1,397	1,397	1,397	1,397	1,397	1,363	1,322	1,148	1,049	1,081	982	853	1,060	1,187	1,125	1,038	936
Dispersed recharge: non-irrigated land	14637	1775	5210	1199	1403	8473	986	1155	2004	735	3468	1329	8196	1232	197	973	184
Dispersed recharge: irrigated land	1,650	3,087	4,697	2,833	2,990	5,298	2,216	2,662	3,199	2,006	4,358	2,799	5,650	2,167	1,945	2,320	1,940
Pipe leaks	1,013	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179
Reclaimed water percolation	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122
Inflow from Chino Basin	116	119	116	125	130	117	121	130	127	122	120	121	111	119	133	131	132
Total Inflow	47,382	18,185	34,199	17,281	17,690	40,765	16,263	16,093	18,754	19,680	29,275	19,700	46,234	18,452	15,742	18,314	17,158
Outflows																	
Wells - M&I and domestic	-16,455	-15,599	-15,599	-15,595	-15,595	-15,601	-15,597	-15,597	-15,599	-15,598	-15,599	-15,597	-15,600	-15,600	-15,596	-15,600	-15,597
Wells - agricultural	0	-22	-21	-25	-26	-20	-24	-23	-21	-23	-22	-23	-20	-21	-24	-21	-23
Groundwater discharge to streams	-2,134	-1,470	-1,878	-1,566	-1,338	-2,531	-1,806	-1,525	-1,686	-1,492	-1,825	-1,806	-3,310	-2,305	-1,932	-1,957	-1,822
Riparian evapotranspiration	-4,661	-4,311	-4,827	-4,702	-4,681	-5,111	-4,861	-4,458	-4,009	-4,602	-5,018	-5,031	-5,494	-4,859	-4,616	-4,279	-4,442
Outflow to Chino Basin	-2,739	-2,540	-2,533	-2,347	-2,279	-2,520	-2,469	-2,284	-2,172	-2,361	-2,425	-2,463	-3,035	-2,988	-2,386	-2,312	-2,345
Total Outflow	-25,989	-23,942	-24,859	-24,236	-23,918	-25,782	-24,756	-23,888	-23,488	-24,075	-24,889	-24,921	-27,459	-25,773	-24,554	-24,168	-24,230
Storage change																	
Inflows - outflows	21,393	-5,757	9,341	-6,955	-6,228	14,983	-8,493	-7,795	-4,733	-4,395	4,386	-5,221	18,775	-7,320	-8,812	-5,854	-7,072

	Water Year																
	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
Inflows																	
Percolation from streams	15,593	15,062	3,178	2,420	4,053	3,677	2,640	14,435	20,618	5,754	13,229	3,273	3,481	16,846	3,331	3,418	5,450
Bedrock inflow	855	900	973	980	997	881	666	746	1,052	1,303	1,466	1,607	1,486	1,358	1,322	1,148	1,050
Dispersed recharge: non-irrigated land	3757	3833	1261	1200	1069	1913	1009	4163	8998	1776	5210	1199	1403	8470	986	1155	2004
Dispersed recharge: irrigated land	4,075	4,046	2,444	2,320	2,786	3,244	2,601	3,958	5,651	3,087	4,697	2,833	3,004	5,284	2,216	2,662	3,200
Pipe leaks	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179
Reclaimed water percolation	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122
Inflow from Chino Basin	125	122	134	138	136	136	137	128	119	114	121	129	134	119	123	133	130
Total Inflow	32,706	32,264	16,291	15,360	17,342	18,153	15,354	31,731	44,740	20,336	33,024	17,343	17,808	40,377	16,280	16,817	20,135
Outflows																	
Wells - M&I and domestic	-15,599	-15,601	-15,597	-15,598	-15,594	-15,596	-15,595	-15,597	-15,600	-15,599	-15,599	-15,595	-15,594	-15,601	-15,597	-15,597	-15,599
Wells - agricultural	-22	-20	-23	-23	-27	-24	-26	-24	-21	-22	-21	-25	-26	-19	-24	-23	-21
Groundwater discharge to streams	-1,989	-3,289	-1,603	-1,346	-1,094	-1,072	-953	-1,231	-2,881	-1,752	-2,308	-1,695	-1,412	-2,653	-1,842	-1,528	-1,761
Riparian evapotranspiration	-4,922	-4,756	-4,634	-4,235	-4,380	-4,234	-4,170	-4,509	-5,128	-4,864	-5,099	-4,842	-4,820	-5,145	-4,903	-4,496	-4,137
Outflow to Chino Basin	-2,344	-2,931	-2,409	-2,146	-2,121	-2,074	-2,043	-2,086	-2,789	-2,764	-2,671	-2,374	-2,279	-2,500	-2,456	-2,259	-2,178
Total Outflow	-24,876	-26,596	-24,267	-23,347	-23,216	-23,001	-22,786	-23,446	-26,419	-25,001	-25,698	-24,531	-24,132	-25,918	-24,822	-23,904	-23,696
Storage change																	
Inflows - outflows	7,829	5,668	-7,976	-7,987	-5,874	-4,848	-7,432	8,285	18,322	-4,665	7,326	-7,188	-6,324	14,459	-8,543	-7,087	-3,562

	Water Year															
	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068
Inflows																
Percolation from streams	3,194	9,393	3,340	23,342	3,839	3,128	3,277	3,095	15,196	15,665	3,244	3,317	3,293	3,410	3,224	15,460
Bedrock inflow	1,081	982	853	1,061	1,187	1,125	1,038	936	854	900	973	980	996	881	666	747
Dispersed recharge: non-irrigated land	735	3468	1329	8198	1231	197	973	184	3756	3833	1261	1200	1069	1913	1009	4164
Dispersed recharge: irrigated land	2,005	4,358	2,799	5,659	2,158	1,945	2,320	1,955	4,060	4,046	2,444	2,344	2,763	3,244	2,601	3,959
Pipe leaks	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	1,912
Reclaimed water percolation	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122
Inflow from Chino Basin	133	128	130	115	126	135	138	139	128	124	134	137	138	138	137	128
Total Inflow	15,450	26,630	16,751	46,677	16,843	14,831	16,048	14,610	32,295	32,869	16,357	16,280	16,560	17,887	15,938	32,492
Outflows																
Wells - M&I and domestic	-15,598	-15,599	-15,597	-15,600	-15,600	-15,596	-15,600	-15,597	-15,599	-15,601	-15,597	-15,597	-15,594	-15,596	-15,595	-15,597
Wells - agricultural	-23	-22	-23	-20	-21	-24	-21	-23	-22	-20	-23	-23	-26	-24	-26	-24
Groundwater discharge to streams	-1,433	-1,402	-1,273	-2,895	-1,772	-1,462	-1,508	-1,270	-1,393	-3,283	-1,331	-1,161	-969	-949	-846	-1,197
Riparian evapotranspiration	-4,122	-4,335	-4,193	-5,084	-4,330	-4,109	-3,717	-3,701	-4,371	-4,438	-4,356	-4,119	-4,188	-4,060	-4,057	-4,496
Outflow to Chino Basin	-2,156	-2,114	-2,121	-2,836	-2,752	-2,158	-2,067	-2,026	-2,116	-2,762	-2,273	-2,080	-2,049	-2,002	-1,984	-2,072
Total Outflow	-23,331	-23,472	-23,208	-26,436	-24,475	-23,349	-22,913	-22,616	-23,501	-26,103	-23,580	-22,981	-22,826	-22,631	-22,508	-23,385
Storage change																
Inflows - outflows	-7,881	3,159	-6,457	20,241	-7,632	-8,518	-6,865	-8,006	8,794	6,766	-7,223	-6,700	-6,265	-4,744	-6,569	9,108

Temescal Basin Detailed Annual Water Budget, Growth And Climate Change 50-year Period

	Water Year																								
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Inflows																									
Percolation from streams	22,267	5,370	15,234	4,797	4,991	17,003	4,451	4,119	6,464	7,506	13,489	7,242	22,515	6,319	4,322	6,379	5,799	17,021	14,870	4,247	3,354	4,975	5,285	3,866	14,583
Bedrock inflow	1,606	1,606	1,606	1,606	1,606	1,580	1,526	1,371	1,300	1,327	1,225	1,121	1,316	1,414	1,331	1,246	1,132	1,050	1,113	1,198	1,219	1,257	1,160	965	1,034
Dispersed recharge: non-irrigated land	9254	2049	4682	1575	1825	7404	1280	1455	2619	714	3224	1794	7224	1393	309	1113	309	4191	3749	1234	1469	1243	2026	1264	3421
Dispersed recharge: irrigated land	5,701	3,087	4,697	2,833	2,990	5,298	2,216	2,662	3,199	2,006	4,358	2,799	5,650	2,167	1,945	2,320	1,940	4,075	4,046	2,444	2,320	2,786	3,244	2,601	3,958
Pipe leaks	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179
Reclaimed water percolation	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122
Inflow from Chino Basin	114	119	117	125	129	117	122	128	125	121	119	120	112	119	131	129	130	123	119	133	137	134	134	134	126
Total Inflow	47,243	20,532	34,636	19,239	19,842	39,703	17,897	18,037	22,010	19,975	30,716	21,377	45,117	19,712	16,339	19,489	17,610	34,761	32,198	17,558	16,800	18,696	20,149	17,130	31,424
Outflows																									
Wells - M&I and domestic	-16,433	-15,599	-15,599	-15,595	-15,595	-15,601	-15,597	-15,597	-15,599	-15,598	-15,599	-15,597	-15,600	-15,600	-15,596	-15,600	-15,597	-15,599	-15,601	-15,597	-15,598	-15,594	-15,596	-15,595	-15,597
Wells - agricultural	-21	-22	-21	-25	-26	-20	-24	-23	-21	-23	-22	-23	-20	-21	-24	-21	-23	-22	-20	-23	-23	-27	-24	-26	-24
Groundwater discharge to streams	-1,494	-1,292	-1,715	-1,419	-1,213	-2,194	-1,686	-1,436	-1,658	-1,441	-1,716	-1,677	-2,572	-2,154	-1,778	-1,830	-1,664	-1,935	-2,017	-1,445	-1,190	-950	-945	-850	-927
Riparian evapotranspiration	-5,001	-4,770	-5,208	-5,154	-5,212	-5,490	-5,414	-4,956	-4,517	-5,131	-5,470	-5,530	-5,821	-5,269	-4,993	-4,679	-4,808	-5,367	-5,213	-5,133	-4,670	-4,820	-4,709	-4,692	-4,869
Outflow to Chino Basin	-2,308	-2,289	-2,363	-2,376	-2,349	-2,395	-2,453	-2,360	-2,265	-2,449	-2,478	-2,514	-2,498	-2,515	-2,430	-2,366	-2,393	-2,396	-2,393	-2,322	-2,200	-2,181	-2,138	-2,122	-2,154
Total Outflow	-25,258	-23,972	-24,907	-24,569	-24,393	-25,700	-25,174	-24,371	-24,061	-24,642	-25,285	-25,342	-26,512	-25,558	-24,822	-24,496	-24,485	-25,318	-25,244	-24,521	-23,680	-23,572	-23,412	-23,284	-23,570
Storage change																									
Inflows - outflows	21,985	-3,440	9,729	-5,330	-4,551	14,003	-7,277	-6,335	-2,051	-4,667	5,431	-3,965	18,605	-5,846	-8,483	-5,007	-6,875	9,443	6,954	-6,963	-6,880	-4,875	-3,263	-6,154	7,854

	Water Year																								
	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068
Inflows																									
Percolation from streams	20,605	7,307	14,165	4,642	5,011	16,796	4,450	4,834	7,915	3,848	11,820	4,804	22,597	4,949	3,453	4,203	3,312	16,842	15,008	4,302	4,270	4,225	5,024	4,450	15,546
Bedrock inflow	1,295	1,525	1,665	1,768	1,670	1,576	1,526	1,370	1,301	1,326	1,225	1,121	1,317	1,413	1,331	1,246	1,132	1,049	1,113	1,198	1,219	1,258	1,160	965	1,035
Dispersed recharge: non-irrigated land	8987	2044	4682	1575	1815	7390	1282	1455	2632	701	3225	1794	7221	1390	309	1113	295	4203	3749	1234	1488	1265	2026	1264	3423
Dispersed recharge: irrigated land	5,651	3,087	4,697	2,833	3,004	5,284	2,216	2,662	3,200	2,005	4,358	2,799	5,659	2,158	1,945	2,320	1,955	4,060	4,046	2,444	2,344	2,763	3,244	2,601	3,959
Pipe leaks	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	2,179	1,912
Reclaimed water percolation	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122	6,122
Inflow from Chino Basin	117	113	120	127	131	118	123	129	126	131	124	128	115	125	134	135	137	124	120	132	136	135	134	133	126
Total Inflow	44,957	22,377	33,628	19,247	19,933	39,464	17,897	18,752	23,475	16,313	29,053	18,947	45,210	18,337	15,473	17,318	15,132	34,579	32,336	17,612	17,757	17,947	19,889	17,714	32,123
Outflows																									
Wells - M&I and domestic	-15,600	-15,599	-15,599	-15,595	-15,594	-15,601	-15,597	-15,597	-15,599	-15,598	-15,599	-15,597	-15,600	-15,600	-15,596	-15,600	-15,597	-15,599	-15,601	-15,597	-15,597	-15,594	-15,596	-15,595	-15,597
Wells - agricultural	-21	-22	-21	-25	-26	-19	-24	-23	-21	-23	-22	-23	-20	-21	-24	-21	-23	-22	-20	-23	-23	-26	-24	-26	-24
Groundwater discharge to streams	-1,918	-1,578	-2,125	-1,539	-1,287	-2,250	-1,702	-1,430	-1,762	-1,387	-1,368	-1,257	-2,029	-1,706	-1,374	-1,436	-1,191	-1,393	-1,626	-1,217	-1,052	-860	-853	-765	-873
Riparian evapotranspiration	-5,508	-5,344	-5,484	-5,273	-5,326	-5,517	-5,439	-4,980	-4,676	-4,676	-4,955	-4,820	-5,462	-4,805	-4,530	-4,133	-4,055	-4,876	-4,944	-4,887	-4,591	-4,649	-4,548	-4,595	-4,867
Outflow to Chino Basin	-2,255	-2,416	-2,410	-2,361	-2,343	-2,363	-2,430	-2,332	-2,284	-2,256	-2,254	-2,236	-2,334	-2,312	-2,237	-2,143	-2,099	-2,210	-2,285	-2,226	-2,155	-2,124	-2,078	-2,074	-2,147
Total Outflow	-25,301	-24,958	-25,640	-24,793	-24,577	-25,751	-25,191	-24,362	-24,342	-23,939	-24,197	-23,933	-25,445	-24,443	-23,762	-23,333	-22,966	-24,100	-24,475	-23,950	-23,418	-23,253	-23,099	-23,054	-23,507
Storage change																									
Inflows - outflows	19,655	-2,581	7,989	-5,546	-4,644	13,713	-7,294	-5,609	-867	-7,627	4,856	-4,986	19,765	-6,106	-8,289	-6,015	-7,834	10,480	7,861	-6,339	-5,661	-5,307	-3,210	-5,341	8,616

APPENDIX L

Temescal Groundwater Sustainability Plan Data Management System Description

TODD GROUNDWATER

October 18, 2021

MEMORANDUM

To: Melissa Estrada-Maravilla, City of Corona

From: Maureen Reilly, PE and Chad Taylor, PG, CHG

Re: Temescal Basin Groundwater Sustainability Plan Data Management System

1. INTRODUCTION

The Groundwater Sustainable Agency (GSA)was formed by the City of Corona (Corona), City of Norco (Norco, and Home Gardens County Water District (HGCWD)) to fulfill the role and legal obligations of a GSA for the Temescal Subbasin (Basin) in accordance with the Sustainable Groundwater Management Act (SGMA). Foremost among the responsibilities is to develop, adopt, and implement a Groundwater Sustainability Plan (GSP) for the Basin.

As part of GSP development, the Temescal Basin GSA (TBGSA) retained Todd Groundwater to prepare the GSP and compile all relevant data for the Basin. This compilation is to focus on those data and information that may be required or useful for the preparation of the GSP and for the evaluation and identification of possible gaps in the available data. The purpose of this memorandum is to document the Data Management System (DMS) developed as part of the GSP.

The TBGSA has been collecting and compiling groundwater data annually including water levels, water quality, and water use. These data have been used in the GSP and will be used in future Annual Groundwater Reports. As part of the GSP, the DMS has been designed to be practicable, usable, intuitive, and cost effective. The data compiled for the GSP have been compiled in a set of databases and other related files. This includes an Access database, a GIS geodatabase, and Excel workbooks. The DMS has been prepared to include related tables in the databases other files that can be efficiently updated, reviewed for quality, and queried to produce new data reports and tables. A summary of the data within and the structure of the DMS is presented below.

2. DMS TYPES AND SOURCES

Data collected and compiled for the GSP have been stored in a variety of formats based on the type of data collected. Spatial information such as ArcGIS files, aerial imagery, and or other map sources, is stored in a Geodatabase. Tabular data are stored in subject-specific relational databases. Additional datasets are stored in files best suited for analysis. To be specific, climate data are stored in an Excel workbook to allow for cumulative departure calculations, scanned well documents are stored as images to preserve the detail on the hardcopy forms, and online datasets updated by other agencies are included by reference. Discussed below are the data formats and the type of data available within that format.

3. GEODATABASE

Spatial data are stored in geodatabase that allows spatial files to be easily accessed and transferred with all appropriate spatial information. Within the Temescal Geodatabase, consistent and feature dataset structures have been constructed to group associated data sets and maintain coordinate system assignments.

3.1 Jurisdiction Boundaries

The boundaries for the Basin and neighboring basins are available as spatial coverages in the geodatabase. State, local, and federal boundaries within and surrounding the Basin were compiled from state and federal sources. These boundaries include all water districts and other local agencies near the Basin as well as federally owned land. These boundaries are included in the project geodatabase.

3.2 Surface Water Body Location and Watershed Mapping

Mapping data for surface water features have been provided from publicly available sources. These mapped data include locations of aqueducts, reservoirs, rivers, streams, drainages, lakes, and ponds. These data are presented in the project geodatabase in feature classes. DWR defined watershed coverages are also stored in the geodatabase as a feature class.

3.3 Mapping of Natural Communities Commonly Associated with Groundwater

GSP Regulations require identification of Groundwater Dependent Ecosystems (GDEs), which are defined as ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. A statewide database and mapping tool, developed by DWR, provides geographic information on Natural Communities Commonly Associated with Groundwater (NCAAG). While these do not necessarily represent GDEs, the dataset is a starting point in identifying GDEs. The mapping data for watersheds surrounding the Basin are included in the project geodatabase

3.4 Ground Surface Elevation Data

Ground surface elevation data are available from the USGS in the form of National Elevation Dataset (NED) GIS grid files (rasters) and raster and vector topographic map datasets. Both datasets have been compiled for the area surrounding and including the Basin. The 10-meter resolution NED data have been combined into a single raster.

3.5 Aerial Photographs

Aerial photographs of the area surrounding the Basin have been downloaded from the USGS National Aerial Imagery Program (NAIP) for 2004, 2005, 2006, 2009, 2010, 2012, 2014, and 2016. These aerial photographs are all rectified GIS raster datasets and included in the project geodatabase. Additional aerial photographs from Google Earth were also reviewed, but these are stored online and accessible through Google Earth.

3.6 Soil Maps

Soil information for the Basin and surrounding areas have been downloaded from the Natural Resources Conservation Service (NRCS). Soil data are mapped and maintained by NRCS in a standardized format that is compatible with tools that NRCS makes freely available to the public. The soils data for the area surrounding the basin have been maintained in the standard NRCS formats to facilitate future use. These raw data are available for preparation of a various soil data presentations and analyses. The hydrologic soil group data from these datasets have been also mapped using the NRCS *Soil Data Development Toolbox.* These data are in the project geodatabase.

3.7 Land Use Maps

Land use map data have been collected from DWR, the California Department of Conservation Farmland Mapping and Monitoring Program (FMMP), and Riverside County. The available land use maps are indicated below:

- DWR: 2014 and 2106 statewide land use mapping specifically developed for SGMA and GSPs.
- FMMP: 1984, 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, 2014, and 2016
- Riverside County: 1993 and 2000

3.8 Geologic Mapping of Surficial Geology and Faults

Surficial geology in the area of the Temescal Basin has been mapped by the United States Geological Survey (USGS) in the 2004 *Preliminary Digital Geologic Map of the Santa Ana 30' x 60' Quadrangle* and the 2006 *Geologic Map of the San Bernardino and Santa Ana 30' x 60' Quadrangles*. This mapped geology has been digitized into GIS formats available from the USGS, and these complete datasets are included in the project geodatabase.

3.9 Subsidence - NASA JPL InSAR Dataset

Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with DWR. Changes in vertical displacement can be viewed through the DWR SGMA mapping tool. Data have been downloaded from the SGMA data viewer and stored in the project geodatabase.

3.10 Water Infrastructure

3.10.1 Imported Water
Available imported water delivery pipelines and tie-in locations available from Corona, Norco, and HGCWD are included in the project geodatabase and relate to imported water delivery data in the project database.

3.10.2 Recycled Water and Wastewater
Corona waste discharge and recycled water distribution and use locations are included in the GIS datasets in the project geodatabase. Corona discharges wastewater to ponds adjacent to their wastewater treatment facility and they provide recycled water within the Basin. Recycled water use and wastewater discharge data are included in the project database.

3.11 Climate Data

The CIMIS stations, NOAA stations, and other climate locations are available in the geodatabase as a point coverage.

3.12 Surface Water Gage Locations

The locations of USGS surface water gages are also stored in the Geodatabase. Three streamflow gage stations near the Temescal Basin that are maintained by the USGS were identified. These stations are located on Temescal Creek at about Main Street in Corona (USGS 11072100), Temescal Creek at Corona Lake (USGS 11071900), and San Jacinto River near Elsinore (USGS 11070500). Up to date surface water measurements are available from the USGS NWIS data repository.

3.13 Well Records

Well location and other records are included in the GIS datasets in the project geodatabases. This includes location and other information as available for known and locatable wells in the Basin.

4. ACCESS DATABASES

Tabular data are linked in relational databases by subject. The DMS include one access database with stand-alone tables that pull together data from all sources for groundwater elevation, groundwater quality, and groundwater pumping. In addition, a table containing all know wells in the Basin links to the subject specific tables. The well table includes locational information as State Plane coordinates.

The types of data stored in the Access database are described below.

4.1 Well Information Table

Well locations and available information were collected from multiple sources, including previous investigations, USGS National Water Information System (NWIS), DWR California Groundwater Elevation Monitoring (CASGEM) program, and others. This data collection effort included available well locations, well construction information, and aquifer parameter information. Data from all the available sources for the Basin and surrounding area were collected and reviewed and then the data were combined into a single unified dataset. The unified dataset retains detailed information from the source files. Well data from individual sources often use agency-specific identification numbers or names. This variation in identification number by source is problematic for organizing, relating, and querying data. A *UniqueID* field was added to the unified well dataset and assigned integer identification numbers for each well to serve as the primary field for joins, relating, and querying data. The unified well dataset includes wells with and without location data. In compiling these data, attempts were made to remove duplicate wells while compiling these data. The unified well information dataset is included in the project database. A separate table with additional information about active Corona wells is included as *Well Corona Information*.

4.2 Groundwater Elevation Table

As with well locations, groundwater elevation records were collected from multiple sources, including previous investigations, the TBGSA agencies, USGS NWIS, DWR CASGEM, and others. Data from these sources were collected, reviewed, and compiled into a single unified groundwater elevation dataset. The dataset includes all information from each source and uses the *UniqueID* field for linking, joining, or relating tables with information from wells. Groundwater elevation data were not calculated for wells without reference elevation data; records for these wells include only depth to water measurements. In addition, there are temporal gaps in some of the data records between the completion of previous investigations and the start of data collection for publicly available records.

Groundwater elevation data has been structured according to the requirements of the CASGEM program in accordance with DWR's grant funding agreement with the TBGSA.

The Groundwater Elevation Database includes relevant information about the wells and elevation data. The database is structured into tables with information on well location, well construction, and monitoring data.

4.3 Groundwater Quality Table

The groundwater quality tables combine water quality data from a variety of sources for a comprehensive repository of regional water quality data. The relational tables include locations for all wells with water quality data, a table of water quality data, a table with information on the water system that was sampled, and a table of constituents monitored with agency codes, reporting levels, and applicable water quality goals. Queries are included to extract data on the key constituents of concern. Data from the TBGSA agencies, regional monitoring (Regional Water Quality Control Board and the Division of Drinking Water), and special studies are included. The wells are linked to the Well Information table by the *UniqueID* field, and the source recorded in the dataset attribute field. Groundwater Pumping Table

Groundwater production in the Basin was compiled from all available sources and includes annual groundwater pumping for all wells is tracked by the Santa Ana River Watermaster, along with production in the rest of the watershed. Western Municipal Water District (WMWD) currently coordinates groundwater use data collection. Complete records of historical groundwater use were requested from and provided by WMWD. The groundwater production data for all wells were reviewed and organized for inclusion in the project database. Monthly pumping totals from the City of Corona wells are included separately. All production records are related to well locations by the *UniqueID* field.

4.4 Imported Water

Imported water delivery data were collected from the TBGSA agencies and are included in the project database.

4.5 Recycled Water and Wastewater

Wastewater information and reclaimed water production from the TBGSA agencies was compiled and included in the database.

5. OTHER FORMATS

5.1 Climate Data (precipitation, evaporation, temperature) - Excel

Climate data are compiled and stored as an Excel file. The workbook also calculates the cumulative departure of precipitation and local water year type by quintiles. This record set includes all available local climate and weather data.

6. DATA MANAGEMENT STORAGE

The DMS will continue to be updated with more recent data for annual reports and the GSP 5-year update. It is expected that new datasets will be added as projects and management actions are undertaken. For example, shallow monitoring wells in the Prado wetlands area may be added to the project database.

The datasets that were created for the groundwater model of the Basin and the simulations of future conditions are documented separately, including model outputs, surface water budgets, and groundwater budgets. While these data are valuable to understanding the basin, they represent simulated conditions and are stored separately from the observed data documented here.