Technical Memorandum

To:	SJBA Technical Advisory Group
From:	Wildermuth Environmental Inc. (WEI)
Date:	June 21, 2016; Updated August 30, 2016
Subject:	San Juan Basin 2016 Adaptive Pumping Management (APM) Plan

Introduction and Background

The San Juan Basin Authority (SJBA) holds a *Permit for Diversion and Use of Water* (Permit 21074), issued by the State Water Resources Control Board (State Board). Permit 21074 was issued in October 2000 and amended in October 2011. Under Permit 21074, the SJBA may extract up to 8,026 acre-feet per year (afy) from the San Juan Basin (Basin). Pumping of these rights is subject to various terms and conditions. The key terms and conditions that can limit the of pumping the rights allocated by Permit 21074 include:

Groundwater levels and storage. The SJBA must manage pumping and groundwater levels to ensure that the cumulative pumping by all producers does not decrease the volume of water in storage in the Basin to less than 50 percent of full capacity.

Groundwater quality. The SJBA must manage pumping and water levels to ensure that water quality degradation that would impair beneficial uses does not occur, specifically to ensure that seawater intrusion does not occur and result in increased chloride and total dissolved solids (TDS) concentrations.

Riparian vegetation. The SJBA must ensure that riparian vegetation along the San Juan Creek are not impacted by pumping.

Prior riparian rights. The SJBA must manage pumping and groundwater levels such that it does not interfere with prior riparian rights, to the extent that any such rights are determined to be valid.

To demonstrate compliance with the terms and conditions of Permit 21074, the SJBA implements a comprehensive data collection and management program that involves collecting groundwater, surface water, and vegetation data in the field, as well as compiling groundwater, surface water, and climate data that is collected by cooperating agencies. For a full discussion of all the terms and conditions included in Permit 21074 refer to the *2015 Annual Progress Report of Compliance* submitted to the State Board in June 2016[1].

Currently, the City is the only SJBA member agency pumping water under Permit 21074 and is doing so pursuant to the October 2002 *Project Implementation Agreement for the San Juan Basin Desalter Project*. Groundwater pumped pursuant to Permit 21074 is treated at the City's Groundwater Recovery Plant (GWRP). Since the first full year of operation in calendar year 2005, pumping from the City's GWRP wells has averaged about 3,510 afy, ranging from about 1,450 to 5,330 afy. The location of the GWRP wells pumping pursuant to 21074 is shown in Figure 1.

The South Coast Water District (SCWD) also holds a permit to divert and use water in the Basin. Permit 21138 was issued by the State Board in December 2002 and amended in July 2012. Under the original Permit 21138, the SCWD could extract up to 976 afy; under the amended permit, the SCWD may extract up to 1,300 afy, subject to various terms and conditions that are similar to Permit 21074. In 2007, the SCWD completed the construction of a well and desalter facility, the SCWD Groundwater Recovery Facility (GRF), to exercise its water right. A second well that will feed into the GRF was constructed in 2014 but is not yet operational. Since the first full year of operation in calendar year 2008, groundwater pumping by the SCWD has averaged about 850 afy, ranging from 0 afy to about 1,140 afy. The location of the GRF wells pumping pursuant to 21138 is shown in Figure 1.

What is Adaptive Pumping Management?

Adaptive pumping management (APM), was a concept defined in the 2014 San Juan Basin Groundwater and Facilities Management Plan (SJBGFMP). APM is an attempt to manage groundwater pumping to comply with the water rights permits held by the SJBA and SCWD and the private agreements that settled their protests on each other's applications to appropriate water. APM involves the management of groundwater pumping at wells subject to water rights permits to manage storage, prevent seawater intrusion and maintain groundwater levels that are protective of riparian vegetation.

APM was a concept that was included in every management alternative of the SJBGFMP and was recommended for immediate implementation by the SJBA. The following is the rationale for why an APM Plan is needed to set pumping limitations on an annual basis:

1. The groundwater storage capacity of the Basin is small, and is estimated to be about 41,400 acre-feet (af)[2].
2. Streambed recharge of storm-water runoff, which is the largest source of recharge to the Basin, is highly variable dependent on climate conditions. Based on surface water and

[1] WEI, 2016. *SJBA 2015 Annual Progress Report of Compliance*. Prepared for the San Juan Basin Authority. June 14, 2016.

[2] See *Spring 2016 analysis of storage in the San Juan groundwater basin*, prepared by WEI for the San Juan Basin Authority, dated May 13, 2016 and which is included as Attachment A to this technical memorandum.

groundwater modeling analyses performed by WEI for the *San Juan Basin Desalination Optimization Program*[3], under current land use conditions streambed recharge will range from a low of 1,100 acre-feet per year (afy) to a high of 22,000 afy, and average about 6,800 afy, assuming a repeat of the precipitation time history that occurred between 1947 and 2014.

3. Based on the groundwater modeling analysis performed by the Municipal Water District of Orange County (MWDOC) in 2012 in support of the South Orange County Ocean Desalination Program[4], seawater intrusion in the Basin was projected to occur within ten years of achieving the then-planned groundwater pumping goals of the City, the SCWD and other minor producers (referred to therein as planning Scenario 2h[5]).
4. In 2014, groundwater pumping in the San Juan Basin was significantly reduced because:
   a. groundwater level and water quality conditions indicative of seawater intrusion were observed in the SJBA's monitoring data[6], and
   b. groundwater level and pumping, and climate conditions resulted in severe stress to riparian habitat communities[7].

The groundwater management implication is that during dry periods groundwater pumping from the Basin will be lower than in wet periods. And, given such a small storage volume relative to planned groundwater pumping, storage and water levels can rapidly be depleted in dry periods if pumping is not adaptively managed to match climate and storage conditions.

Use of the SJBA Model to Develop an Adaptive Pumping Management Plan

Summary of Prior Modeling Work that Informs an Adaptive Management Plan

The original concept envisioned in the SJBGFMP for setting pumping limits as part of the APM Plan was to develop a storage-pumping relationship using the results of the MWDOC groundwater model for its planning Scenario 2h. In that scenario, groundwater pumping at wells was estimated as the minimum of an agencies pumping target or what the model would allow

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[3] G3 Soil Works, WEI, and Black and Veatch, 2016. *San Juan Basin Groundwater and Desalination Optimization Program Foundational Actions Fund (FAF) Program*, *Final Report.* Prepared for the San Juan Basin Authority, March 2016. The report is available at: http://www.sjbauthority.com/assets/downloads/San%20Juan%20Basin%20Groundwater%20and%20Desalination%20Optimization%20Program%20Final%20Report%203-28-16.pdf

[4] Geoscience Support Services, 2013. *South Orange County Ocean Desalination Project, Phase 3 Extended Pumping and Pilot Plant Testing, Volume 3 – San Juan Basin Regional Watershed and Groundwater Models*. Prepared for the Municipal Water District of Orange County.

[5] The total planned groundwater pumping for Scenario 2h was 11,216 afy: 8,781 afy by the City, 1,585 afy by SCWD, and 850 afy by private producers.

[6] For a detailed discussion on the water level and water quality data, see WEI, 2016. *SJBA 2015 Annual Progress Report of Compliance*. Prepared for the San Juan Basin Authority. June 14, 2016.

[7] For a detailed discussion on the water level and riparian habitat data, see WEI, 2016. *SJBA 2015 Annual Progress Report of Compliance*. Prepared for the San Juan Basin Authority. June 14, 2016.

based on groundwater level constraints set at each well. The water budget table developed from the modeling results enabled WEI to develop a relationship of groundwater storage to pumping. The Scenario 2h projection and simulation however did not include pumping limitations to prevent seawater intrusion or negative impacts to riparian vegetation.

The SJBA recently completed its *San Juan Basin Groundwater and Desalinization Optimization Program* (Program) investigation. As part of the investigation, future groundwater conditions for a baseline and a variety of Program alternatives were projected with an updated version of the MWDOC groundwater model of the Basin, referred to herein as the SJBA Model[8]. The baseline, or "no-project" alternative, was run to characterize the yield of the Basin in the absence of the Program and determine the increase in yield and other hydrologic impacts attributable to implementation of the Program alternatives. The baseline alternative was run for a 68-year planning period with a hydrology based on historical precipitation from 1947 through 2014, current land use conditions, and stated pumping targets of the City and SCWD. The pumping targets provided by the agencies were based on anticipated ultimate pumping demands. Additionally, the baseline alternative was designed to enforce pumping limitations on wells in order to comply with specific water rights permits conditions in Permit 21074 and 21138. Specifically, the model reduced pumping from the City GWRP and the SCWD GRF wells based on groundwater level thresholds that were established to maintain storage greater than 50 percent of capacity and a subsurface outflow to the ocean, the latter being required to ensure that seawater intrusion would not occur. Lastly, the baseline alternative was designed to proportionately reduce pumping from the City GWRP and SCWD GRF wells when pumping limitations were required. No pumping constraints were enforced at privately owned wells or at the City's non-GWRP wells[9]. The following table summarizes the pumping targets implemented in the baseline alternative and the average pumping achieved over the planning hydrology.

Pumping Targets and Average Pumping Achieved in the Baseline Alternative			
Producers	**Annual Pumping Target (afy)**	**Pumping Constraints Implemented to Comply with Permits?**	**Average Pumping Achieved (afy)**
South Coast Water District	1,300	Yes	966
City of San Juan Capistrano (GWRP Wells)	7,705	Yes	5,675
City of San Juan Capistrano (Non-GWRP Wells)	1,023	No	1,023
Private Pumpers	866	No	866
Total	**10,894**		**8,530**

[8] For a detailed description of the model update and its use in evaluating the baseline and the Program alternatives, read Section 3.3 of Appendix C of the *San Juan Basin Groundwater and Desalination Optimization Program Foundational Actions Fund (FAF) Program*, *Final Report*. Refer to link provided in Footnote 3.

[9] The non-GWRP wells are used by the City for potable and non-potable supply and are not regulated under Permit 21074, or any other water rights permit.

The baseline alternative results demonstrated that pumping could be adaptively managed based on groundwater levels and storage to prevent seawater intrusion. It also demonstrated that neither the SCWD nor the City would be able to achieve their pumping targets; not even in the wettest years of the 68-year hydrologic period. In other words, to manage storage and protect the basin from seawater intrusion, groundwater pumping limitations had to be enforced in every year of the planning hydrology. On average, the SJBA Model limited pumping to about 74 percent of the SCWD and City pumping targets. In achieving this objective, Basin storage in the model projection was managed over a range of about 25,000 afy (61 percent of full[10]) to about 40,600 af (98 percent of full) and averaged about 30,900 af (75 percent of full). It managed the storage to always be above the minimum target of 50 percent of full, indicating that the 50 percent of full metric is not protective of the basin. These results demonstrate the importance of developing an APM strategy to set annual pumping limits that proactively manage groundwater levels and storage in the Basin.

2016 Adaptive Pumping Management Alternative

In order to develop an APM strategy that can immediately be implemented, a new APM alternative was developed and run using the SJBA Model. This alternative is hereafter referred to as the 2016 APM alternative. Two modifications were made to the Program's baseline alternative to create the 2016 APM alternative:

1. Implemented revised pumping targets based on existing permits and agreements.
2. Implemented groundwater level thresholds to protect riparian vegetation in accordance with condition number 23 of Permit 21074.

Like the baseline alternative, the 2016 APM alternative also includes groundwater level thresholds to maintain storage above 50 percent of capacity and protect against seawater intrusion. The two updates implemented in the 2016 APM alternative are discussed in more detail below.

Groundwater Pumping Targets

The table on the following page summarizes the updated pumping targets implemented in the 2016 APM alternative. The SCWD's pumping target remained at its water rights permit limit of 1,300 afy. The City's pumping target for the GWRP wells was changed to reflect the implementation agreement with the SJBA, which allocates up to 5,800 afy of pumping under the SJBA's Permit 21704. The City's pumping target for the non-GWRP wells was changed to reflect the average pumping volume from these wells for the 2004 to 2014 period.

[10] The basin storage capacity is about 41,400 af when limited to the storage at or below the stream thalweg elevation. Groundwater above the elevation of the stream thalweg will only temporarily remain in storage before it becomes rising groundwater in the stream channel.

Pumping Targets for the 2016 APM Alternative		
Producers	**Annual Pumping Target (afy)**	**Pumping Constraint Implemented?**
South Coast Water District	1,300	Yes
City of San Juan Capistrano (GWRP Wells)	5,800	Yes
City of San Juan Capistrano (Non-GWRP Wells)	850	No
Private Pumpers	866	No
Total	**8,816**	

Groundwater Level Thresholds to Protect Riparian Vegetation

The baseline alternative evaluated for the Program did not establish groundwater level thresholds to protect riparian vegetation. Figure 2 shows the time history of groundwater levels at monitoring wells SJBA MW-4, SJBA MW-5 and SJBA MW-6, which are located in the riparian vegetation monitoring area shown in Figure 1. Figure 2 also shows daily precipitation and monthly groundwater pumping by the City and the San Juan Hills Golf Club within the riparian vegetation monitoring area for the period from 2004 to 2016. The SJBA's Biologist of Record, Glenn Lukos Associates (GLA), began to observe and record signs of severe riparian vegetation stress in 2014. The timing of the observed stress is coincident with the decline in water level elevations, record high groundwater pumping and a severe, continuous dry period that has persisted from 2012 through the present.

While there is insufficient data available to determine the relative impacts that pumping and drought had on the riparian vegetation habitat along San Juan Creek, the information in Figure 2 can be used to set groundwater level thresholds that are protective of riparian vegetation health. WEI consulted with GLA to establish a protective groundwater level threshold. The recommended threshold was to maintain groundwater levels above the deepest elevation observed prior to the start of the dry period that began in water year 2012 (e.g. October 2011) and prior to the observation of vegetation stress[11]. The deepest water levels observed prior to the start of the dry period were observed in September 2011 and correspond to a depth to water of 20 feet-below ground surface (ft-bgs), 19 ft-bgs and 22 ft-bgs at SJBA MW-4, SJBA MW-5 and SJBA MW-6, respectively. Hereafter these depths will be referred to as the protective thresholds for riparian vegetation.

To ascertain the effects of groundwater pumping on the depth to groundwater in the riparian vegetation monitoring area, two sensitivity model runs were evaluated:

> Sensitivity Run No. 1: No groundwater pumping pursuant to Permits 21074 and 21138 (i.e. no pumping from the eight City GWRP wells nor the two SCWD GRF wells).

[11] Personal communication with Kevin Livergood of Glenn Lukos Associates.

Sensitivity Run No. 2: The Program investigation's baseline alternative, which implemented an APM strategy but did not limit pumping explicitly to maintain groundwater levels that are protective of riparian vegetation.

Figure 3 shows the projected time history of depth to groundwater at SJBA MW-4, SJBA MW-5 and SJBA MW-6 compared to the protective thresholds for Sensitivity Run No. 1. Figure 4 shows the same information expressed as probability curves. When the depth to groundwater is less than or equal to the protective threshold, there is no projected impact to the riparian vegetation (the depth to water is expressed as greater than 100 percent of the threshold value on Figure 4). When the depth to groundwater is greater than the protective threshold, riparian vegetation is projected to be impacted (the depth to water is expressed as less than 100 percent of the protective threshold value on Figure 4). Depth to groundwater is not projected to fall below the protective thresholds at SJBA MW-4 and SJBA MW-5; and it is only projected to fall below the protective threshold three percent of the time at SJBA MW-6. Thus, in the absence of pumping pursuant to water rights permits, riparian vegetation will be protected more than 97 percent of the time.

Figure 5 shows the projected time history of depth to groundwater at SJBA MW-4, SJBA MW-5 and SJBA MW-6 compared to the protective thresholds for Sensitivity Run No. 2. Figure 6 shows the same information expressed as probability curves. The figures demonstrate that pumping pursuant to water rights increases the frequency that the depth to groundwater at the three monitoring wells is below the protective thresholds for riparian vegetation. In this model run, depth to groundwater is projected to fall below the protective threshold 30 percent, 40 percent and 50 percent of the time at SJBA MW-4, SJBA MW-5 and SJBA MW-6, respectively.

In order to ensure compliance with Condition 23 of Permit 21074, the 2016 APM alternative will not include pumping at the City's Tirador, South Cooks and CVWD-5 wells. In other words, only the GWRP wells in the Alipaz well field (Dance Hall, SJBA-2, SJBA-4, CVWD-1, and Kinoshita) will be pumped in the 2016 APM alternative to meet the City's pumping target.

Summary of 2016 APM Alternative Features Compared to Prior Model Runs

The following table summarizes the features of the new 2016 APM alternative compared to the prior baseline model runs performed by MWDOC and the SJBA.

Comparison of Model Runs	Scenario 2h	Program Baseline	2016 APM
SCWD Pumping Target (afy)	1,585	1,300	1,300
City GWRP Pumping Target (afy)	7,758	7,705	5,800
City Non-GWRP Pumping (afy)	1,023	1,023	850
Private Pumping (afy)	850	866	866
Pumping Constraint to Maintain Water Level within Well Screen Interval	✓	✓	✓
Pumping Constraint to Maintain Storage above 50 percent		✓	✓
Pumping Constraint to Protect from Seawater Intrusion		✓	✓
Proportional Pumping Constraints		✓	✓
Pumping Constraint to Protect Riparian Vegetation Area			✓

Results

The following is a summary of the model results for the 2016 APM alternative.

Water Budget: Net Recharge and Storage

The annual water budget for the 2016 APM alternative is shown in Table 1 and is based on the hydrologic or water year (October 1 to September 30)[12]. Summary statistics of the annual net recharge, total groundwater pumping, storage and storage percent full are listed in the following table[13].

Key Water Budget Summary Statistics for the 2016 APM Alternative (af)				
Statistic	Net Recharge	Total Pumping	End of Year Storage Volume	Storage Percent Full
Minimum	2,800	6,100	34,000	82%
Maximum	12,700	7,400	45,800	111%
Average	6,600	6,700	39,500	96%

[12] For example, water year 2014 corresponds to the period from October 1, 2013 through September 30, 2014.

[13] Note that the minimum or maximum statistic does not necessarily occur in the same hydrologic year for each water budget term. For example, the minimum statistic for net recharge occurs in 2007, but the minimum statistic for pumping occurs in 2014.

Annual net recharge is equal to the annual groundwater pumping plus the annual change in storage. The minimum statistic for net recharge corresponds to one of the driest years in the planning hydrology, water year 2007. In this year, the net recharge is less than the total pumping indicating that the groundwater storage declined. Drafting water from storage would be typical in a dry year. The maximum statistic corresponds to one of the wettest years in the planning hydrology, water year 1978. In this year, the net recharge is greater than the total pumping indicating that the groundwater storage increased, which would be typical in a wet year.

The end-of-year storage was managed in the 2016 APM alternative over a very narrow range between 34,000 af and 45,800 af, or between 82 and 111 percent of full. Storage can be greater than 100 percent of full when groundwater is above the elevation of the stream thalweg (the deepest point of the channel). Groundwater above the thalweg elevation will only temporarily remain in storage before it becomes rising groundwater in the stream channel. The basin storage capacity is about 41,400 af when limited to the storage at or below the stream thalweg elevation.

Seawater Intrusion

Figure 7 shows the projected groundwater elevations at monitoring wells SCWD MW-4S and MWDOC MW-2M. These two wells are located downstream of the SCWD GRF wells (see Figure 1) and serve as sentinel monitoring locations for obtaining groundwater level and water quality data that is used to assess groundwater conditions, and more specifically seawater intrusion. When the groundwater elevation at SCWD MW-4S is higher than MWDCO MW-2M, the flow gradient is seaward. When groundwater elevation at SCWD MW-4S is lower than MWDCO MW-2M, the flow gradient is landward, indicating seawater intrusion. The groundwater elevation time histories illustrate that the groundwater flow gradient is seaward for the entire planning hydrology. Figure 7 also shows the volume of projected subsurface outflow from the Basin to the ocean. The average subsurface outflow to the ocean is about 100 afy and ranges from a minimum of -16 afy to a maximum of 400 afy. A negative value for subsurface outflow indicates seawater intrusion. Seawater intrusion is only projected to occur in seven out of 68 years. The projected seawater intrusion occurs in dry periods, is very small, and is completely mitigated by the subsurface outflow that occurs in most years and that is much larger in magnitude: the total subsurface outflow to the ocean over the entire planning hydrology is about 150 times greater than the subsurface inflow from the ocean. Figure 7 demonstrates that an APM strategy that precludes seawater intrusion should be protective of water quality in the Basin.

Groundwater Elevations in the Riparian Vegetation Monitoring Area

Figure 8 shows the projected time history of depth to groundwater at SJBA MW-4, SJBA MW-5 and SJBA MW-6 for the 2016 APM alternative compared to the protective thresholds for riparian vegetation. Figure 9 shows the same information expressed as probability curves. Depth to groundwater is not projected to fall below the protective thresholds at SJBA MW-4 and SJBA MW-5; and it is projected to fall below the protective threshold at SJBA MW-6 about nine percent of the time. The figures demonstrate that an APM strategy that precludes pumping at these three GWRP wells in the riparian vegetation habitat monitoring area should be protective of riparian vegetation.

Groundwater Pumping

Figure 10 shows the projected annual total pumping for the City GWRP and SCWD GRF wells for the planning period compared to each agency's respective pumping target; the annual pumping is also shown in Table 1. Pumping at the City GWRP wells in the Alipaz well field was managed between about 3,600 and 4,600 afy and averaged about 4,100. Pumping at the SCWD GRF wells was managed between about 800 and 1,100 afy and averaged about 900. Neither agency was able to pump at its target pumping level over the entire planning period.

Figure 11 shows the probability over the planning period of achieving levels of groundwater pumping from the City GWRP and SCWD GRF wells as a function of their respective pumping targets. The y-axis represents the projected pumping as percent of the pumping target and the x-axis represents the probability of pumping groundwater at some fraction (as a percent) of the target. For example, review of the chart shows that the City GWRP wells are projected to pump about 62 percent of the target about 99 percent of the time and 70 percent of the target 50 percent of the time. Note that the probability curves for the City GWRP and SCWD GRF wells are almost identical, indicating that the reduction in pumping to comply with the water rights permits has been proportionately applied.

Groundwater Storage and Pumping Relationship

Evaluation of the 2016 APM alternative simulation results demonstrated that adaptively adjusting pumping from year to year will ensure compliance with existing diversion permits and leads to a sustainable condition in the Basin (groundwater levels that protect against seawater intrusion and negative impacts to riparian vegetation). The results can be used to develop an understanding of the relationship between the volume of groundwater in storage and the sustainable pumping estimated by the model. Figure 12 is an XY scatter plot of the relationship between groundwater in storage in the spring (e.g. April 1) of each year of the planning hydrology and the modeled-adjusted pumping for the City GWRP and SCWD GRF wells for the subsequent 12 months. A best-fit linear equation of the storage-pumping relationship is shown for each agency. For example, when water in storage is 38,000, the sustainable pumping is estimated to be about 4,100 af for the City and 900 af for the SCWD. The figure illustrates that to comply with the permit conditions, neither the City nor SCWD can achieve their respective pumping targets, even when the Basin is full. More importantly, it also shows that the spring storage in the basin should never go below 33,000 acre-ft. When spring storage falls below 33,000 af, at least one water rights permit condition will be violated. Thus, the Basin storage should be maintained above 33,000 af in order for it to be operable in compliance with water rights permits.

Also shown on Figure 12 are the actual calculated storage volumes for the Basin for spring 2013, 2014, 2015 and 2016. These calculations are made by WEI each year using measured groundwater levels[14]. For spring 2013, 2014, and 2015, each agency's actual pumping for the subsequent 12 months (e.g. April 1 through March 30) is also plotted. The figure shows that since 2013 groundwater storage has been less than the minimum sustainable storage volume of 33,000

[14] WEI calculates water in storage for each spring (April 1) and fall (October 1). The spring 2016 storage memo detailing how the calculation is performed is included with this memo as Attachment A.

af and that pumping, in most cases, was in excess of the sustainable level, which is zero when storage is below 33,000.

Recommended Adaptive Pumping Management Plan

Implementation Steps

Figure 13 is the recommended sustainable storage-pumping curve that the SJBA should use to determine annual sustainable pumping based on the volume of water in storage in the spring of any given year to ensure compliance with water rights permits conditions. The sustainable pumping curve for each agency is based on the best-fit curve shown in Figure 12 and represents the sustainable pumping volume for the April 1 through March 30 period. The following are the recommended steps for implementing APM.

1. In April of each year, calculate the spring volume of water in storage.
    a. The calculation should be based on measured groundwater level elevations collected on April 1st, plus or minus 15 days, and the aquifer properties and model grid in the San Juan Model.
2. Use the sustainable storage-pumping curve in Figure 13 to estimate the sustainable pumping for the City GWRP and SCWD GRF wells based on the spring storage calculation[15].
    a. Pumping by the City should be limited to the five wells in the Alipaz well field.
3. Monitor and analyze groundwater levels and quality as follows to ensure that pumping does not cause seawater intrusion:
    a. Download continuously recording pressure transducers at a biweekly frequency from June through September, and a monthly frequency from October through May, at the following wells: MWDOC MW-2M, SCWD MW-4S/D, SJBA MW-01S and SCWD MW0-01S/D. The objective of this monitoring is to track changes in groundwater levels and groundwater flow gradients downstream of the SCWD GRF wells and to detect sudden increases in salinity, measured as electrical conductivity by the transducers.
    b. Collect groundwater quality samples at a monthly frequency from June through September, and a bimonthly frequency from October through May, at the following wells: MWDOC MW-2M, SCWD MW-4S/D, SJBA MW-01S and SCWD MW-01S/D. The objective of this monitoring is to develop a correlation between the electrical conductivity readings and lab-analyzed chloride concentrations.
    c. If the data show signs of seawater intrusion (landward groundwater flow gradients and increasing electrical conductivity or chloride trends), it will trigger a process

[15] Please refer to Attachment B to this report for a proposed alternative for allocating production to the CIty GWRP and SCWD GRF wells that is nearly identical to Figure 13, but accounts for agreements between the SCWD and the SJBA.

to reduce the pumping allocation. The SJBA TAG will review the available data and make a recommendation on a revised pumping allocation to the SJBA Board.

4. Monitor and analyze groundwater levels as follows to ensure that pumping does not cause groundwater levels to drop below the protective groundwater level thresholds for riparian vegetation along San Juan Creek:
   a. Download continuously recording pressure transducers at a monthly frequency from June through September, and a quarterly frequency from October through May (e.g. December and March), at the following wells: SJBA MW-04, SJBA MW-05, SJBA MW-06.
   b. If the data show that groundwater levels are below the protective thresholds, it will trigger a process to reduce the pumping allocation. The SJBA TAG will review the available data and make a recommendation on a revised pumping allocation to the SJBA Board.
5. Update and calibrate the modeling tools on a periodic basis to refine the APM plan (at least every five years).
   a. The APM plan should be updated every time the model is recalibrated by the SJBA, even if the model update is not for the purpose of the APM Plan.

Limitations and Recommendations for Improvement

The sustainable storage-pumping curve and the associated APM Plan is only as good as the modeling tools used to develop it and the monitoring program to evaluate it. The following limitations and recommendations should be considered.

Sustainable pumping may be overstated for the driest years and understated for the wettest years. The groundwater model used herein currently assumes a constant boundary inflow from Oso Creek, the Arroyo Trabuco, Horno Creek and San Juan Creek. In aggregate these boundary inflows total about 27 percent of the average inflow. This assumption could result in an overestimation of the annual net recharge during dry years and an underestimation for wet years. The boundary inflows need to be refined and incorporated into future investigations.

Historical precipitation patterns may not reflect future precipitation patterns as the climate warms. The 68-year planning hydrology used herein is based on actual precipitation values for the San Juan Creek watershed for the 1947 to 2014 period. Future precipitation patterns will likely be changed by a warming climate. The currently available global circulation models do not produce reliable estimates of precipitation. However, GCM-based precipitation projections will improve over time and the SJBA should consider using them in the future for updates to the APM Plan.

Disallowing pumping at the City wells in the riparian vegetation monitoring area may be overly conservative. The conservative approach to eliminate pumping at the City's Tirador, South Cooks, and CVWD-5A wells was included in the APM for two reasons. First, as stated above, the current assumptions for the subsurface boundary inflows overstate the recharge in dry years and artificially contribute to maintaining groundwater levels at protective thresholds. Second, the budget available to perform this analysis was not sufficient to perform the number of model sensitivity runs required to optimize sustainable pumping in riparian vegetation monitoring area. Ideally, the subsurface boundary inflows should be refined before incurring the expense of optimizing the APM plan to include pumping at the City's Tirador, South Cooks, and CVWD-5A wells.

Private groundwater pumping is not well understood. The annual private pumping assumed in the SJBA model runs is estimated. For a large majority of the wells, pumping was either estimated by Geoscience as part of the Phase 3 investigation of the South Orange County Ocean Desalination Project[16] or based on a water duty method performed by Hunt Thornton Resources as part of the SJBA's Program investigation[17]. The storage-pumping relationship for the SCWD GRF and City GWRP wells is impacted by the assumptions made for private pumping. Thus, the SJBA should implement a program to accurately characterize private groundwater pumping to ensure that the APM plan does over or under estimate the sustainable pumping for the SCWD GRF and City GWRP wells.

Monitoring to detect seawater intrusion. To improve the characterization of the hydrogeology, groundwater flow, and water quality responses to hydrologic stressors, a new multi-nested groundwater monitoring site should be constructed south of monitoring well SCWD-MW4S/D and north of MWDOC MW-2M. This will provide a new monitoring location closer to ocean for improved and more rapid detection of seawater intrusion.

All of the above mentioned recommendations will not only improve the SJBA's APM plan, but it will provide valuable information that can be utilized in implementing project alternatives evaluated in the *San Juan Basin Desalination and Optimization Program*.

2016 Sustainable Groundwater Pumping Allocation

WEI recently completed the spring 2016 analysis of groundwater storage. The technical memorandum documenting the work is included with this report as Attachment A. As of spring 2016, groundwater in storage is about 29,400 af. This is about 3,600 af less than the minimum sustainable storage threshold, as shown on Figure 12. As such, the sustainable groundwater pumping allocation should be zero based on the 2016 APM plan.

[16] Geoscience Support Services, 2013. *South Orange County Ocean Desalination Project, Phase 3 Extended Pumping and Pilot Plant Testing, Volume 3 – San Juan Basin Regional Watershed and Groundwater Models*. Prepared for the Municipal Water District of Orange County.

[17] Hunt Thornton Resource Strategies, LLC (2015). Technical Memorandum, Existing Wells, Owners, Locations and Use in the San Juan Basin, California. Prepared for the San Juan Basin Authority, August 20, 2015.

Attachments

Table 1 and Figures 1 through 13
Attachment A: Spring 2016 analysis of storage in the San Juan groundwater basin (dated May 13, 2016).
Attachment B: Response to Comments

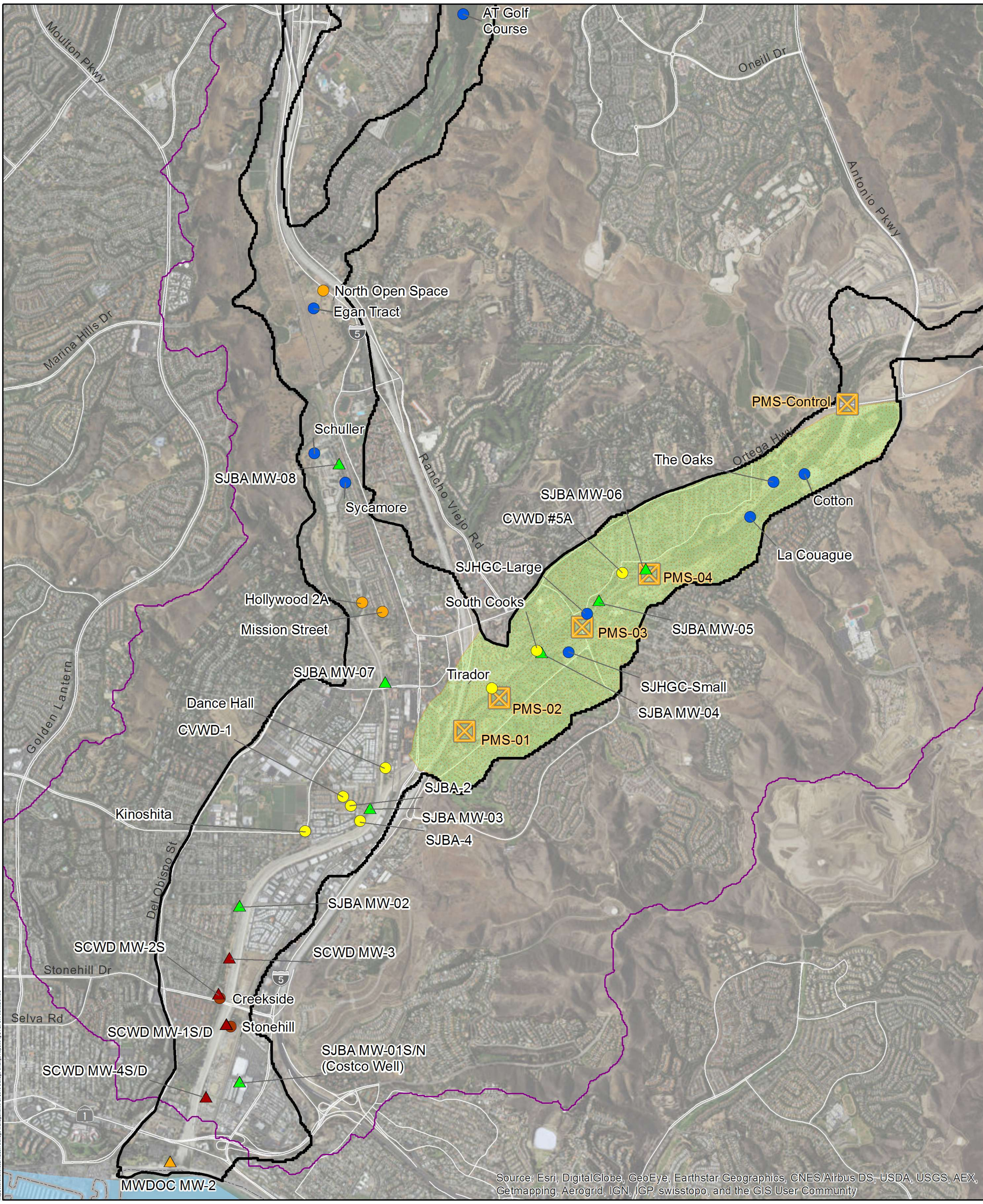
Table 1

2016 Adaptive Pumping Management Alternative

Projected Water Budget for San Juan Basin

(af)

Historical Hydrologic Year Used in Simulation	Recharge					Discharge								Change in Storage		Storage Percent Full	Storage Volume	Annual Net Recharge
	Subsurface Boundary Inflow from the San Juan, Horno, Trabuco and Oso Creeks	Deep Infiltration of Precipitation, Applied Water and Mountain Front Runoff	Streambed Infiltration	Subsurface Inflow from Ocean	Total Recharge	SCWD GRF Pumping	City GWRP Pumping	City Non-Potable Pumping	Private Groundwater Pumping	Subsurface Outflow to Ocean	Evapo-transpiration	Rising Groundwater	Total Discharge	Annual	Cumulative			
1948	2,711	126	2,220	0	5,056	973	4,074	850	866	67	777	469	8,075	-3,018	-3,018	93%	38,317	3,744
1949	2,703	160	3,942	0	6,805	849	3,885	850	866	5	663	687	7,805	-1,000	-4,018	90%	37,317	5,450
1950	2,703	238	4,525	7	7,473	838	3,909	850	866	0	643	713	7,819	-346	-4,364	89%	36,971	6,117
1951	2,703	253	3,473	11	6,440	816	3,834	850	866	0	578	358	7,303	-863	-5,227	87%	36,108	5,504
1952	2,711	774	10,514	0	13,998	943	4,184	850	866	193	958	2,335	10,330	3,669	-1,559	96%	39,776	10,512
1953	2,703	357	5,125	0	8,185	902	4,082	850	866	33	911	1,453	9,098	-912	-2,471	94%	38,864	5,787
1954	2,703	281	5,339	0	8,323	872	4,006	850	866	8	813	1,130	8,545	-222	-2,693	93%	38,642	6,372
1955	2,703	224	4,385	0	7,312	864	4,006	850	866	24	724	935	8,269	-957	-3,650	91%	37,685	5,629
1956	2,711	358	6,168	0	9,236	891	3,974	850	866	143	877	1,164	8,764	472	-3,178	92%	38,157	7,053
1957	2,703	269	4,798	0	7,770	856	3,950	850	866	11	796	850	8,179	-409	-3,587	91%	37,748	6,113
1958	2,703	742	13,771	0	17,216	978	4,378	850	866	215	1,159	4,620	13,066	4,150	563	101%	41,898	11,223
1959	2,703	385	3,154	0	6,242	917	4,033	850	866	53	985	1,192	8,896	-2,654	-2,091	95%	39,244	4,012
1960	2,711	172	4,695	0	7,578	865	3,992	850	866	29	825	1,008	8,436	-858	-2,949	93%	38,386	5,716
1961	2,703	138	1,967	5	4,814	817	3,734	850	866	0	622	359	7,248	-2,434	-5,383	87%	35,952	3,833
1962	2,703	467	8,578	0	11,748	885	3,990	850	866	134	879	1,321	8,924	2,824	-2,559	94%	38,776	9,414
1963	2,703	329	4,184	0	7,216	851	3,922	850	866	15	792	660	7,956	-739	-3,299	92%	38,036	5,750
1964	2,711	181	3,504	4	6,400	839	3,942	850	866	0	722	755	7,974	-1,574	-4,873	88%	36,462	4,924
1965	2,703	645	4,785	0	8,134	839	3,911	850	866	28	705	590	7,789	345	-4,528	89%	36,807	6,812
1966	2,703	487	8,616	0	11,806	946	4,092	850	866	181	1,010	2,237	10,181	1,625	-2,903	93%	38,432	8,379
1967	2,703	446	9,797	0	12,946	958	4,178	850	866	223	1,099	3,672	11,845	1,101	-1,802	96%	39,533	7,953
1968	2,711	234	4,290	0	7,234	889	4,045	850	866	38	930	1,264	8,882	-1,647	-3,449	92%	37,886	5,002
1969	2,703	1,015	13,492	0	17,210	1,012	4,264	850	866	316	1,151	5,379	13,839	3,371	-78	100%	41,257	10,363
1970	2,703	471	4,488	0	7,662	975	4,176	850	866	105	998	1,594	9,564	-1,902	-1,980	95%	39,355	4,965
1971	2,703	164	3,715	0	6,582	875	3,986	850	866	32	810	908	8,327	-1,745	-3,724	91%	37,611	4,832
1972	2,711	133	3,166	1	6,011	833	3,800	850	866	0	662	423	7,434	-1,423	-5,147	88%	36,188	4,926
1973	2,703	213	6,235	0	9,151	860	4,025	850	866	1	665	1,148	8,415	736	-4,411	89%	36,924	7,337
1974	2,703	244	4,926	0	7,873	860	3,951	850	866	20	675	682	7,904	-31	-4,443	89%	36,892	6,495
1975	2,703	260	6,155	0	9,118	868	4,040	850	866	68	743	1,039	8,473	645	-3,798	91%	37,537	7,269
1976	2,711	224	5,693	0	8,628	859	4,053	850	866	16	752	863	8,258	370	-3,428	92%	37,907	6,997
1977	2,703	196	5,090	0	7,990	857	4,104	850	866	9	733	1,004	8,423	-434	-3,862	91%	37,473	6,243
1978	2,703	932	16,281	0	19,916	1,027	4,420	850	866	275	1,219	5,700	14,357	5,559	1,697	104%	43,032	12,722
1979	2,703	758	12,693	0	16,153	1,059	4,444	850	866	248	1,374	7,001	15,841	312	2,009	105%	43,344	7,532
1980	2,711	1,174	15,636	0	19,520	1,091	4,448	850	866	388	1,474	9,474	18,591	929	2,939	107%	44,274	8,185
1981	2,703	495	3,421	0	6,619	961	4,170	850	866	69	1,107	1,685	9,708	-3,089	-150	100%	41,185	3,758
1982	2,703	337	8,706	0	11,747	922	4,257	850	866	121	1,166	2,817	10,999	748	598	101%	41,933	7,643
1983	2,703	826	15,144	0	18,673	1,024	4,544	850	866	184	1,436	6,841	15,746	2,928	3,525	109%	44,860	10,212
1984	2,711	399	6,125	0	9,234	1,003	4,302	850	866	150	1,273	3,492	11,937	-2,702	823	102%	42,158	4,319
1985	2,703	209	6,365	0	9,278	931	4,139	850	866	121	1,132	2,278	10,317	-1,039	-216	99%	41,119	5,747
1986	2,703	294	8,569	0	11,566	914	4,265	850	866	80	1,137	2,465	10,576	990	773	102%	42,108	7,884
1987	2,703	222	4,498	0	7,423	882	4,104	850	866	16	974	1,646	9,338	-1,915	-1,142	97%	40,193	4,786
1988	2,711	246	4,959	0	7,916	868	4,101	850	866	9	868	1,386	8,948	-1,032	-2,174	95%	39,161	5,653
1989	2,703	210	5,731	0	8,644	870	4,033	850	866	23	854	1,229	8,724	-80	-2,254	95%	39,081	6,539
1990	2,703	193	3,806	0	6,702	851	3,927	850	866	54	781	778	8,107	-1,405	-3,659	91%	37,676	5,089
1991	2,703	338	6,643	0	9,684	873	3,953	850	866	106	901	1,120	8,670	1,014	-2,645	94%	38,690	7,556
1992	2,711	726	10,195	0	13,631	947	4,188	850	866	199	1,110	3,584	11,744	1,888	-757	98%	40,578	8,739
1993	2,703	1,544	15,380	0	19,627	1,089	4,454	850	866	377	1,304	8,489	17,428	2,199	1,442	103%	42,777	9,458
1994	2,703	608	4,553	0	7,864	979	4,208	850	866	79	1,093	1,935	10,010	-2,146	-704	98%	40,631	4,757
1995	2,703	940	13,735	0	17,378	1,028	4,377	850	866	303	1,312	6,122	14,858	2,520	1,816	104%	43,151	9,641
1996	2,711	767	7,824	0	11,302	1,004	4,261	850	866	186	1,267	3,774	12,208	-907	909	102%	42,244	6,075
1997	2,703	784	11,748	0	15,236	1,030	4,298	850	866	268	1,359	5,883	14,553	682	1,592	104%	42,927	7,726
1998	2,703	1,505	22,205	0	26,414	1,110	4,594	850	866	385	1,616	14,106	23,527	2,886	4,478	111%	45,813	10,307
1999	2,703	541	4,016	0	7,260	1,022	4,323	850	866	104	1,228	2,765	11,158	-3,898	580	101%	41,915	3,163
2000	2,711	232	6,671	0	9,613	915	4,154	850	866	79	1,079	2,057	10,002	-388	191	100%	41,526	6,398
2001	2,703	274	7,217	0	10,194	910	4,150	850	866	102	1,123	2,330	10,332	-138	53	100%	41,388	6,638
2002	2,703	172	1,501	0	4,375	835	3,815	850	866	5	794	617	7,782	-3,407	-3,353	92%	37,982	2,959
2003	2,703	310	9,164	0	12,177	901	4,138	850	866	148	1,028	2,070	10,002	2,175	-1,178	97%	40,157	8,930
2004	2,711	345	7,314	0	10,370	898	4,069	850	866	120	1,054	1,689	9,546	824	-354	99%	40,981	7,507
2005	2,703	865	14,245	0	17,814	1,034	4,339	850	866	341	1,348	7,219	15,998	1,816	1,461	104%	42,796	8,905
2006	2,703	432	4,891	0	8,027	927	4,178	850	866	78	1,125	1,929	9,953	-1,926	-465	99%	40,870	4,895
2007	2,703	142	1,221	0	4,066	833	3,792	850	866	4	763	510	7,617	-3,551	-4,016	90%	37,319	2,790
2008	2,711	282	3,344	0	6,337	825	3,738	850	866	12	661	442	7,394	-1,057	-5,073	88%	36,262	5,222
2009	2,703	322	6,283	0	9,308	873	3,884	850	866	133	819	874	8,299	1,010	-4,063	90%	37,272	7,482
2010	2,703	80	9,372	0	12,155	919	4,019	850	866	195	1,014	2,714	10,578	1,577	-2,486	94%	38,849	8,232
2011	2,703	407	11,290	0	14,400	977	4,180	850	866	265	1,156	4,647	12,940	1,460	-1,026	98%	40,309	8,333
2012	2,711	316	4,496	0	7,523	898	4,104	850	866	36	989	1,488	9,230	-1,707	-2,733	93%	38,602	5,011
2013	2,703	196	2,675	2	5,577	836	3,876	850	866	0	753	717	7,898	-2,321	-5,054	88%	36,281	4,107
2014	2,703	46	1,791	16	4,556	796	3,597	850	866	0	553	180	6,842	-2,286	-7,340	82%	33,995	3,823
Average	2,705	428	7,022	1	10,156	917	4,095	850	866	108	969	2,461	10,265	-110	na	96%	39,486	6,619
% of Total	26%	4%	68%	0%	99%	9%	40%	8%	8%	1%	9%	24%	100%	na	na	na	na	na
Median	2,703	316	5,693	0	8,628	898	4,082	850	866	78	958	1,453	9,098	-346	na	94%	38,864	6,372
Minimum	2,703	46	1,221	0	4,066	796	3,597	850	866	0	553	180	6,842	-3,898	na	82%	33,995	2,790
Maximum	2,711	1,544	22,205	16	26,414	1,110	4,594	850	866	388	1,616	14,106	23,527	5,559	na	111%	45,813	12,722
Total	181,240	28,654	470,500	46	680,440	61,450	274,367	56,950	58,022	7,229	64,899	164,862	687,780	-7,340	na	na	2,645,578	443,450



Production Wells

- Pumping Pursuant to Permit 21074 (City)
- Pumping Pursuant to Permit 21138 (SCWD)
- Other City Well
- Private Well

Field Monitoring Sites

- SJBA Monitoring Well
- SCWD Monitoring Well
- MWDOC Monitoring Well
- Riparian Vegetation Monitoring Site

Boundaries

- Riparian Vegetation Monitoring Area (per Permit 21074)
- SJBA Model Boundary
- San Juan Creek Watershed

Produced by:

WEI
Wildermuth Environmental, Inc.

Author: CS
Date: 20160616
File: Figure1.mxd

0 1,000 2,000 Feet
0 0.25 0.5 Miles

San Juan Basin Authority

Location Map

Figure 1

Figure 2
Groundwater Elevation and Monthly Pumping in the Riparian Vegetation Monitoring Area
2005 to 2016

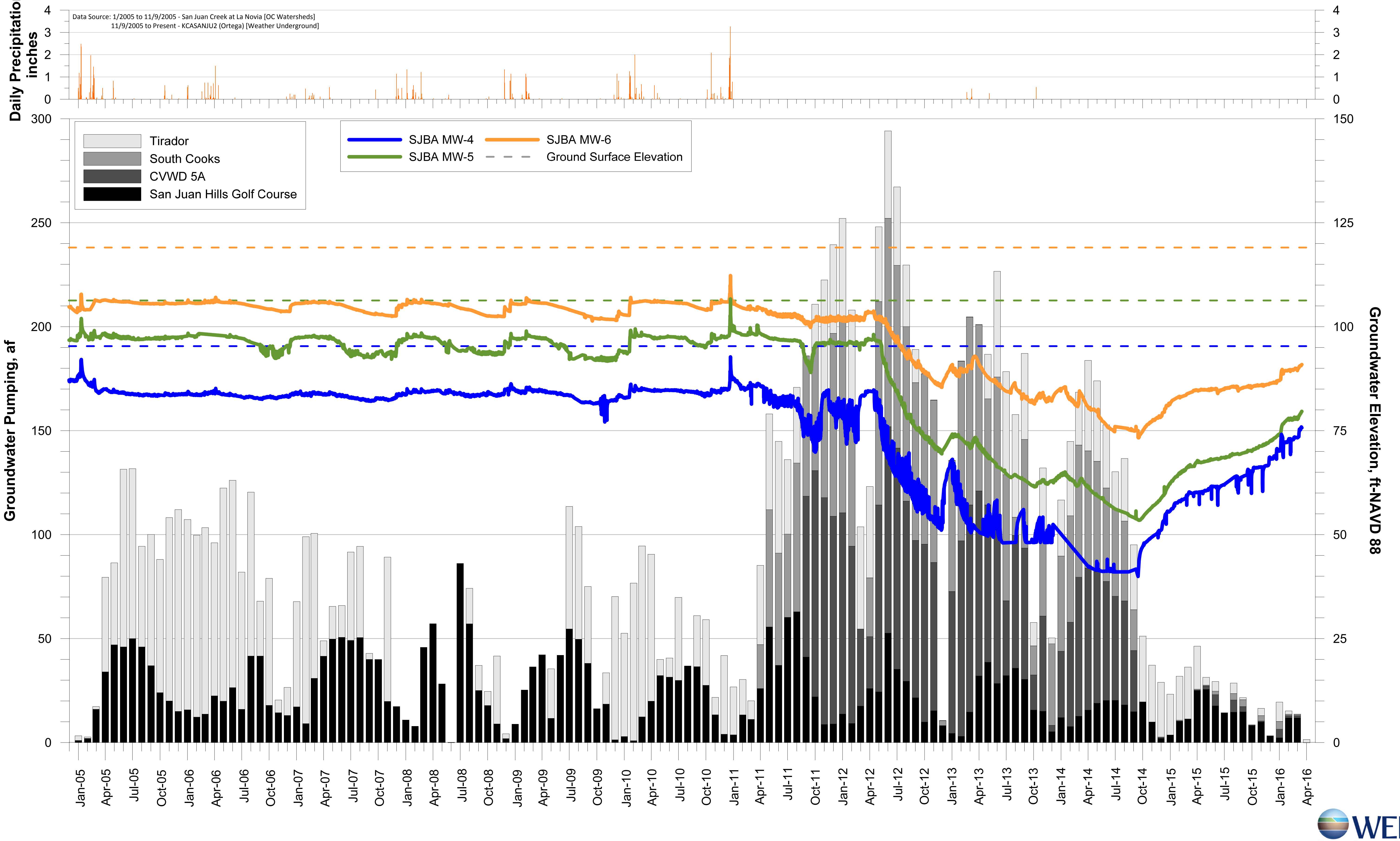


Figure 3
Depth to Water in the Riparian Vegetation Monitoring Area
SJBA MW-4, MW-5 and MW-6
No Pumping Pursuant to Water Rights Permits 21704 and 21138 - Sensitivity Run No. 1

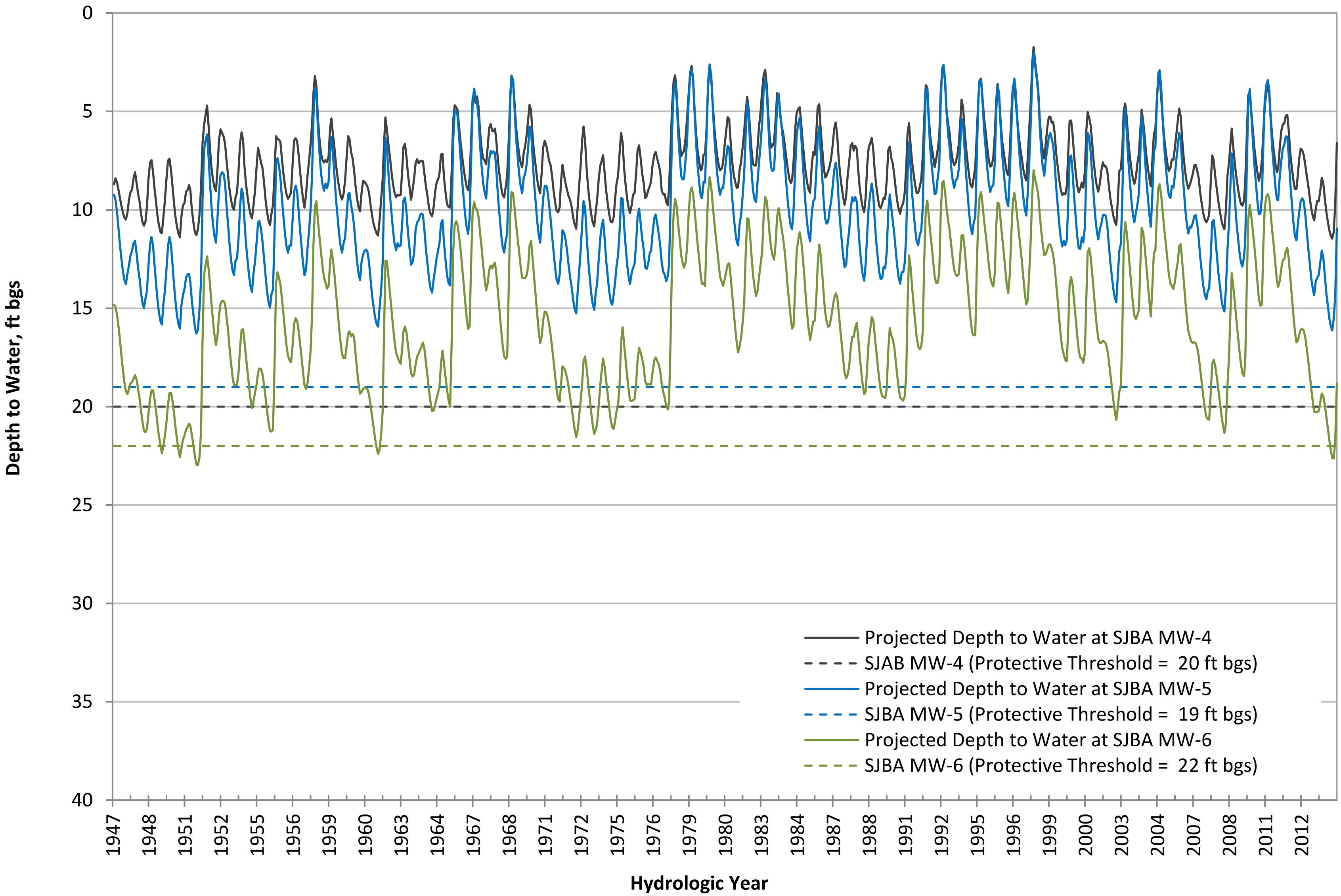


Fig 3-4 Target WLs_BA_Update_5800 Run7--Fig 3 DTW SJBA_MW_4
Printed: 6/21/2016

Figure 4
Exceedance Frequency Curve for
Percent of Protective Threshold in the Riparian Vegetation Monitoring Area
No Pumping Pursuant to Water Rights Permits 21704 and 21138 - Sensitivity Run No. 1

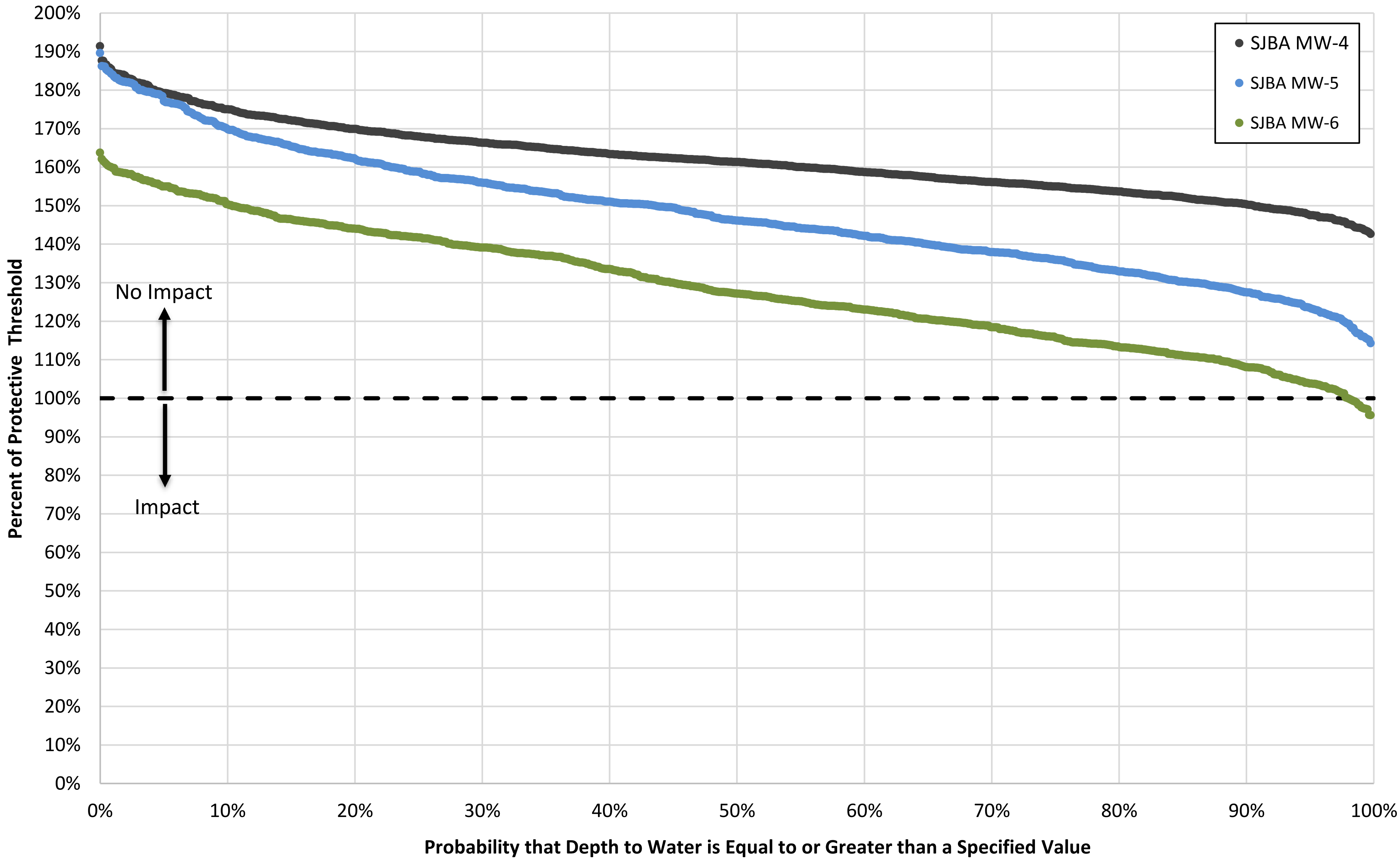


Fig 3-4 Target WLs_BA_Update_5800 Run7--Fig 4 Freq Prob
Printed: 6/21/2016

Figure 5
Depth to Water in the Riparian Vegetation Monitoring Area
SJBA MW-4, MW-5 and MW-6
Baseline Alternative - Sensitivity Run No. 2

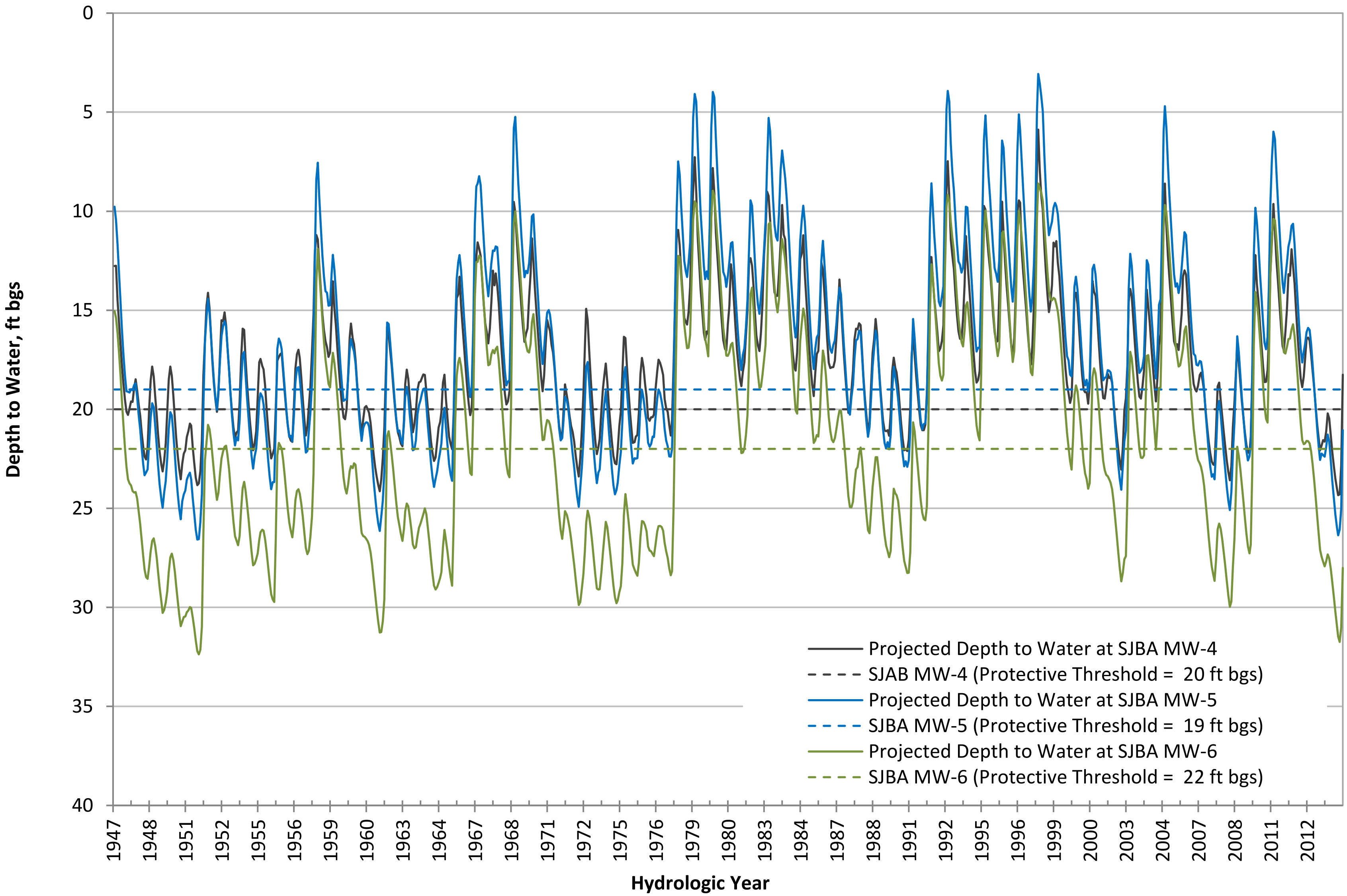


Fig 5-6 Target WLs_BA_Update_5800 Run6--Fig 5 DTW SJBA_MW_6
Printed: 6/21/2016

Figure 6
Exceedance Frequency Curve for
Percent of Protective Threshold in the Riparian Vegetation Monitoring Area
Baseline Alternative - Sensitivity Run No. 2

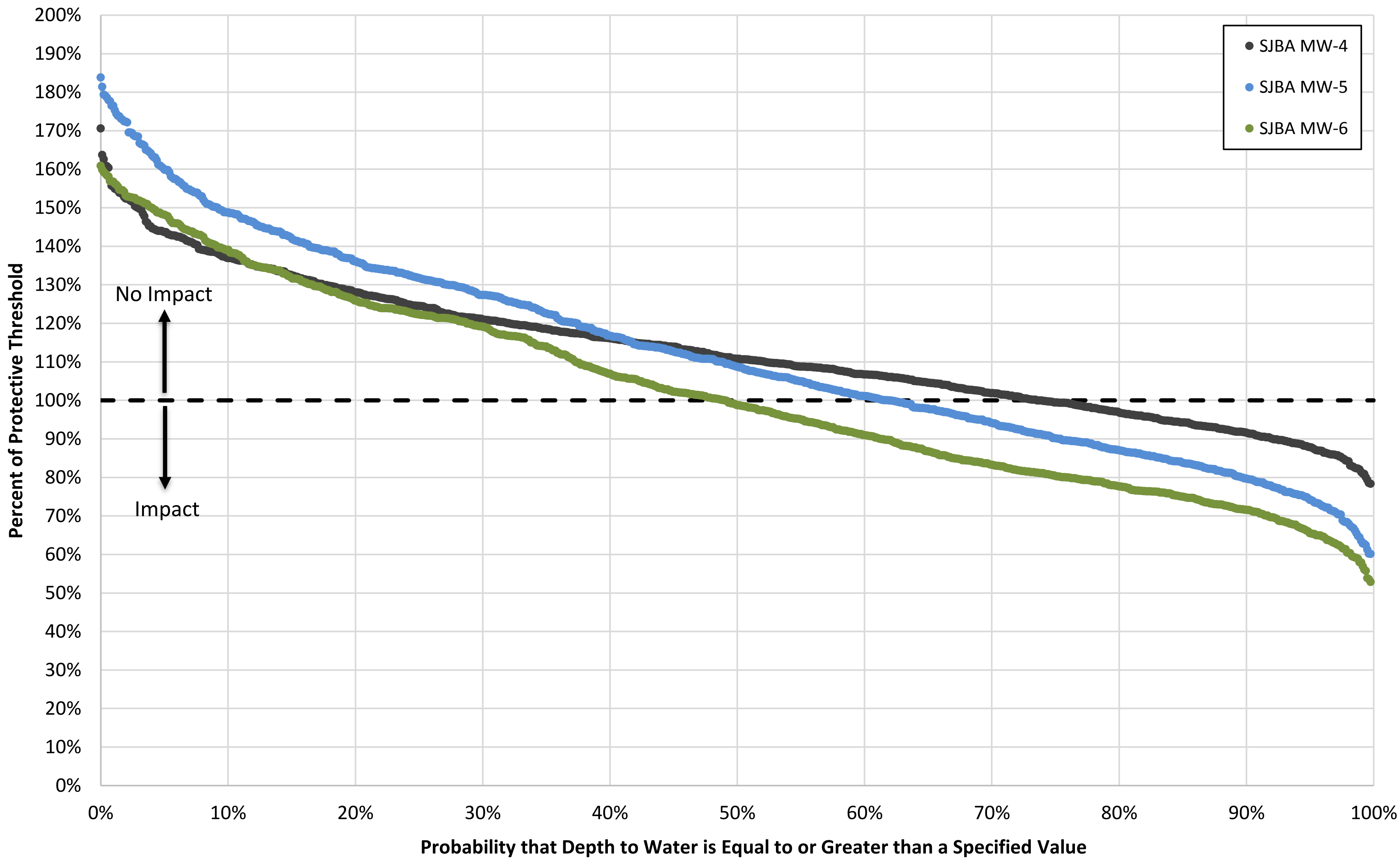


Figure 7
Groundwater Elevation at SCWD MW-4S and MWDOC MW-2M Wells and Subsurface Outflow to the Pacific Ocean
2016 Adaptive Pumping Management Alternative

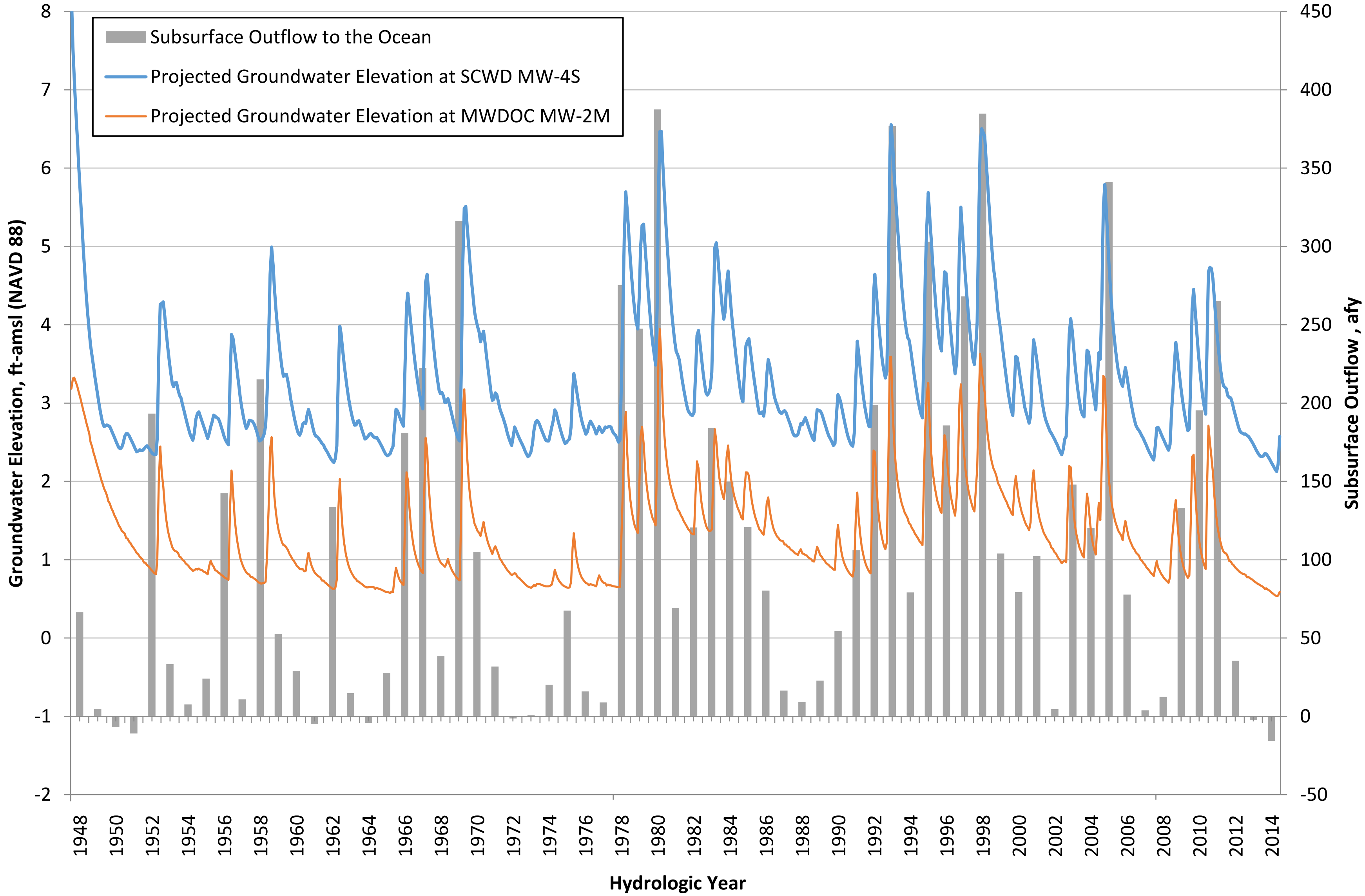


Fig 7_Seawater_Baseline_PG7250--Fig 7 SCWD_MW4S
Printed: 6/20/2016

Figure 8
Depth to Water in the Riparian Vegetation Monitoring Area
SJBA MW-4, MW-5 and MW-6
2016 Adaptive Pumping Management Alternative

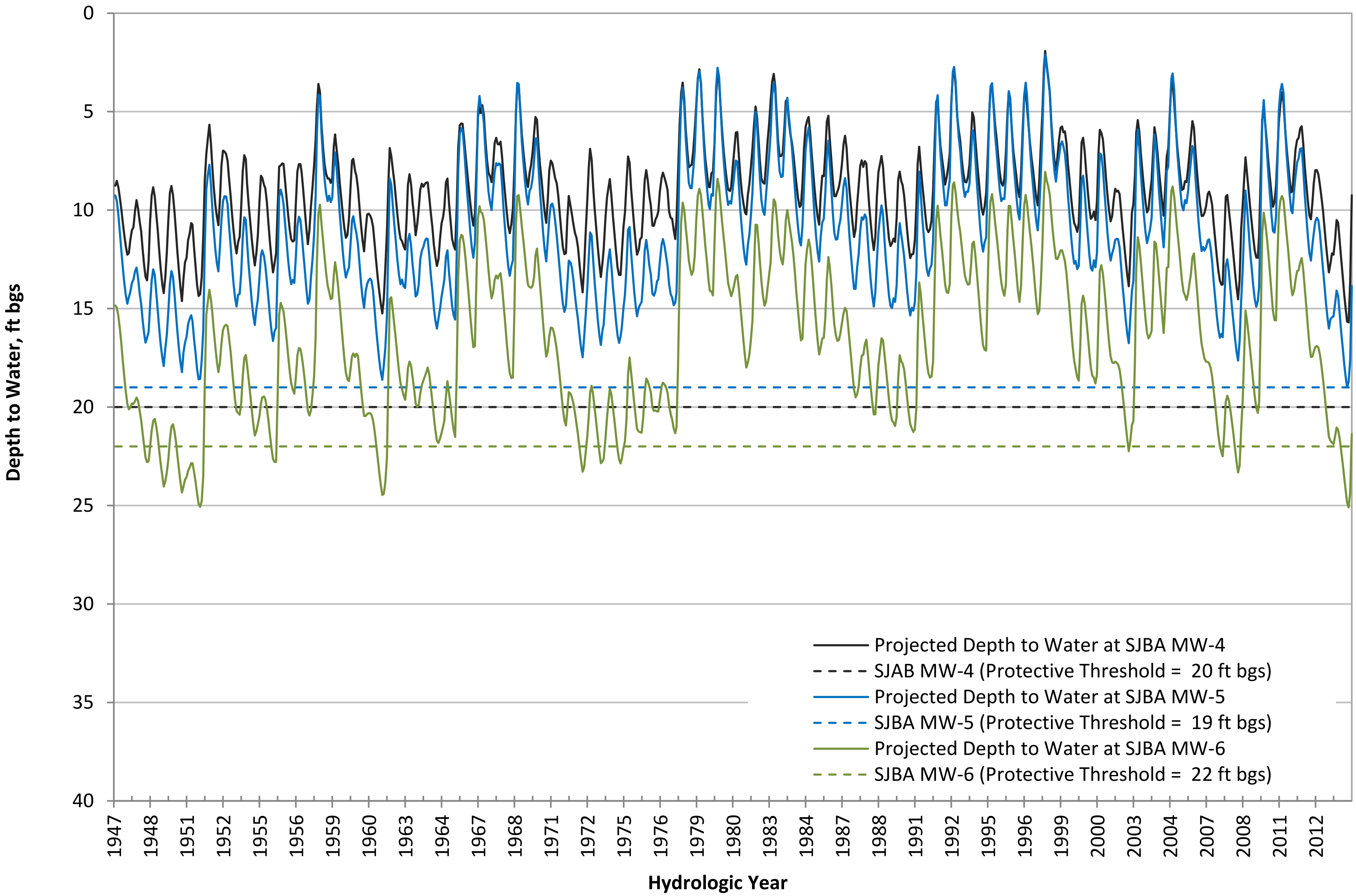


Fig 8-9 Target WLs_BA_Update_5800 Run9--Fig 8 DTW SJBA_MW_6
Printed: 6/21/2016

Figure 9
Exceedance Frequency Curve for
Percent of Protective Threshold in the Riparian Vegetation Monitoring Area
2016 Adaptive Pumping Management Alternative

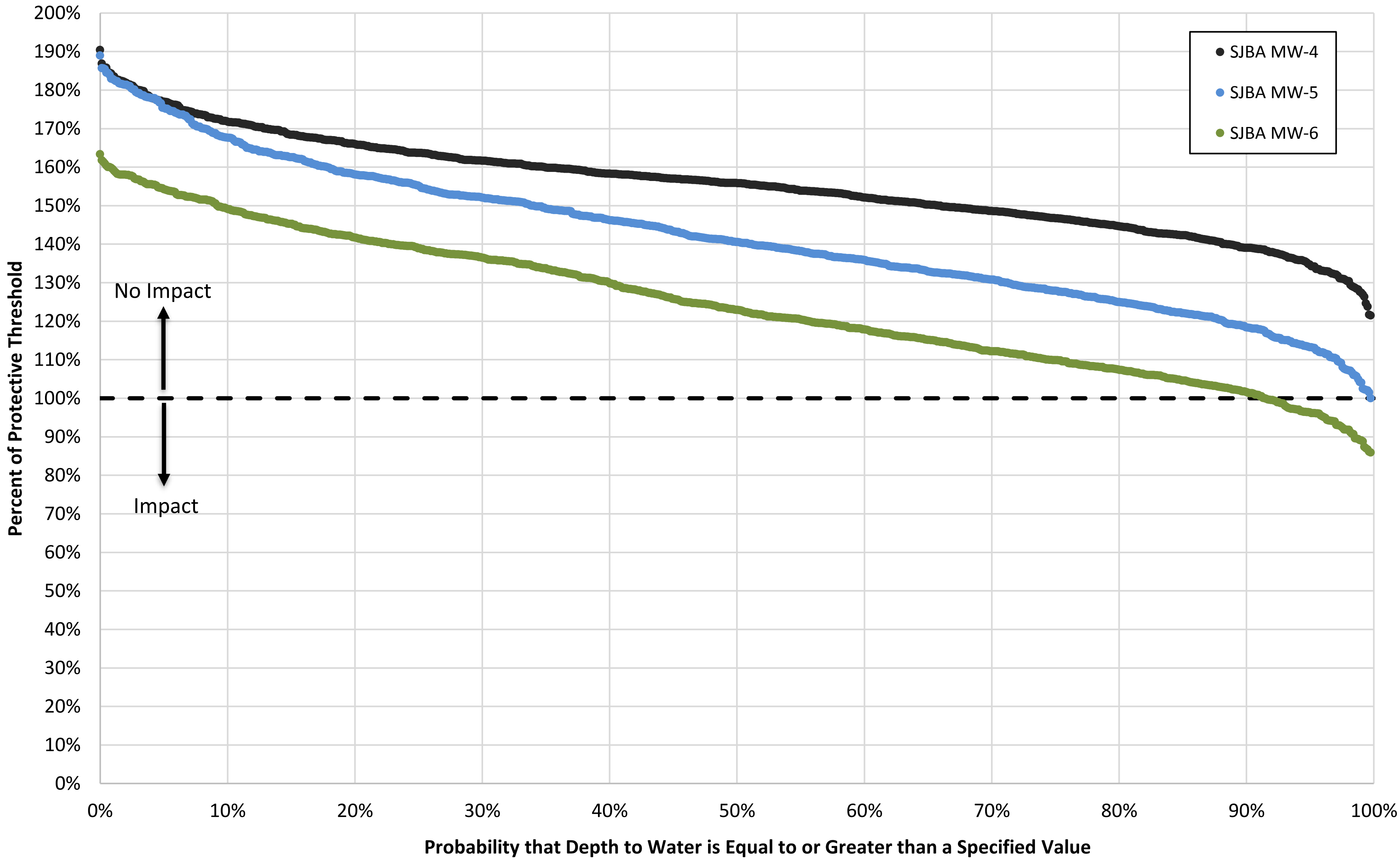


Figure 10
Projected Pumping by
City GWRF and SCWD GRF Wells for the Hydrologic Planning Period
2016 Adaptive Pumping Management Alternative

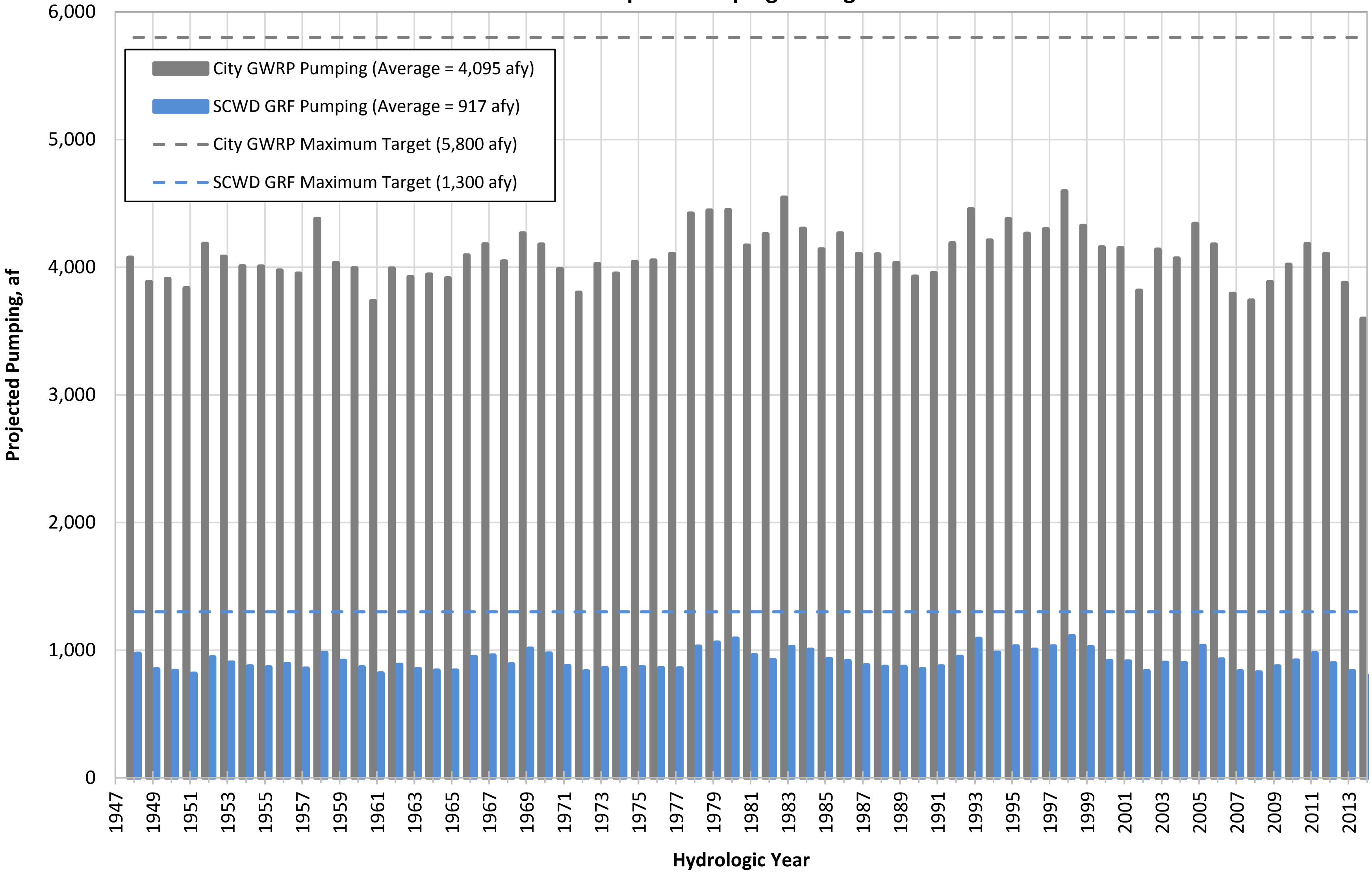


Fig 10-11-12-13 Freq_Prod_Storag_CS--Fig 10 Production
Printed: 6/21/2016

Figure 11
Exceedance Frequency Curve for
Percent of Pumping Target by Agency
2016 Adaptive Pumping Management Alternative

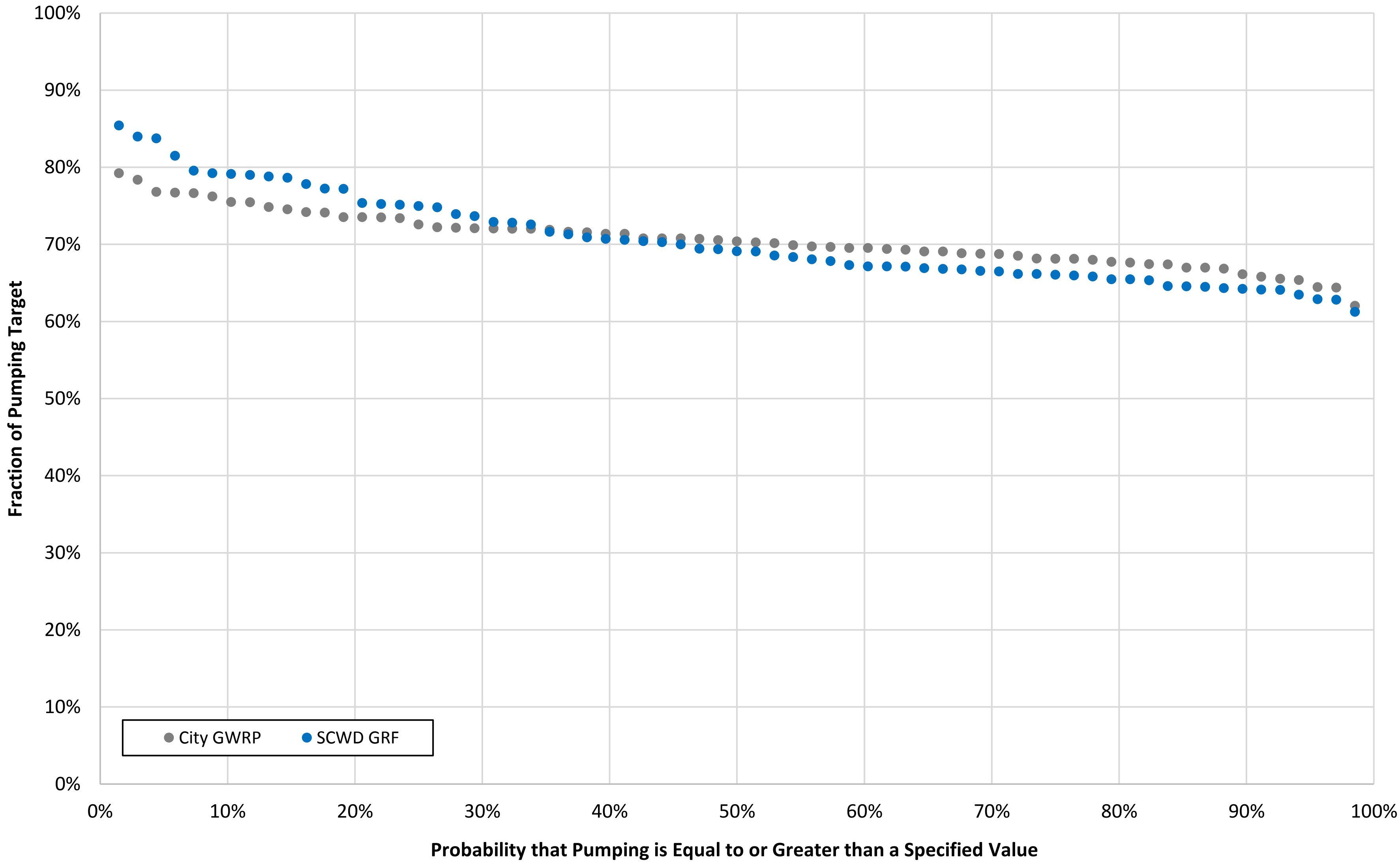


Figure 12
2016 Adaptive Pumping Management
Sustainable Pumping Based on Modeled Storage-Pumping Relationship

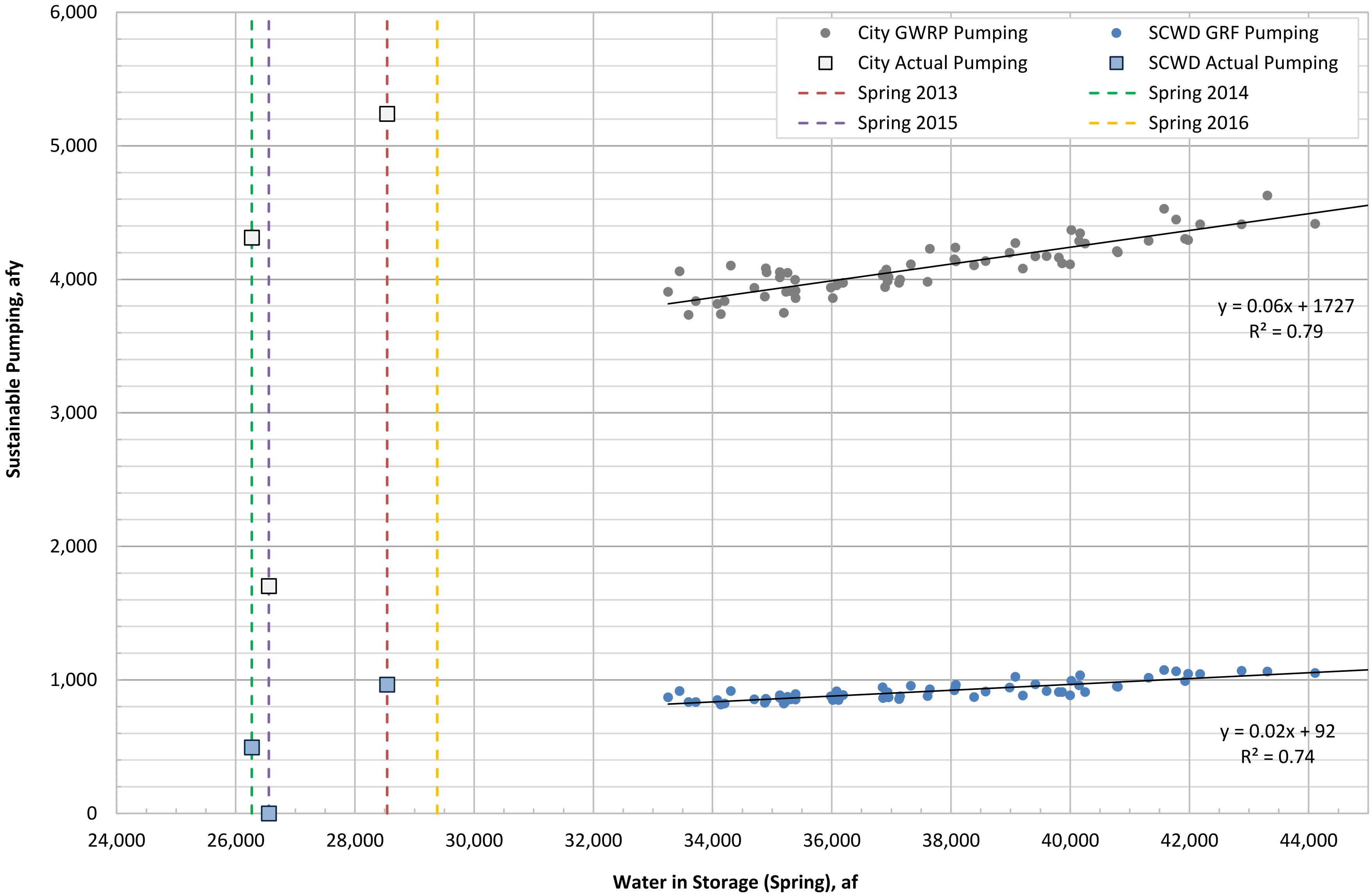


Fig 10-11-12-13 Freq_Prod_Storag_CS--Fig 12 Storage Fit Cht
Printed: 6/21/2016

Figure 13
2016 Adaptive Pumping Management
Sustainable Pumping Curve Based on Modeled Spring Storage-Pumping Relationship

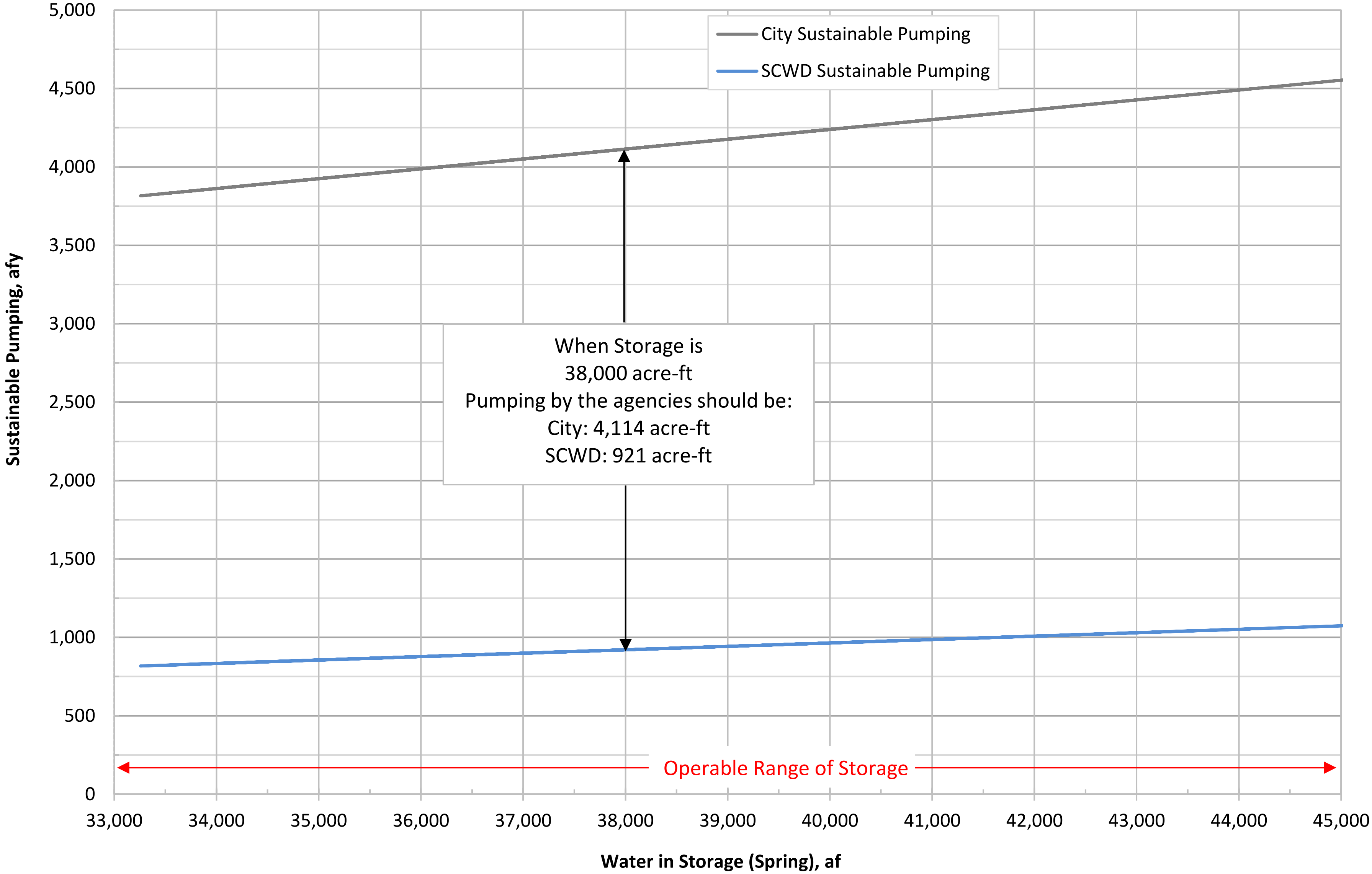


Fig 10-11-12-13 Freq_Prod_Storag_CS--Fig 13 Sustain Prod Cht
Printed: 6/23/2016

Attachment A

WILDERMUTH ENVIRONMENTAL, INC.

May 13, 2016

San Juan Basin Authority Technical Advisory Group
Attention: Andy Brunhart, Matt Collings, Dan Ferons, and Steve May
c/o Dan Ferons, General Manager
Santa Margarita Water District
26111 Antonio Parkway
Rancho Santa Margarita, CA 92688

Subject: ***Spring 2016 analysis of storage in the San Juan Groundwater Basin***

Dear Messrs. Brunhart, Collings, Ferons, and May:

Pursuant to our professional services agreement with the San Juan Basin Authority (SJBA), dated January 12, 2016, we are pleased to submit this letter report, documenting the results of our spring 2016 analysis of groundwater storage in the San Juan Groundwater Basin (Basin).

Background and Objectives

Since early 2003, the SJBA has implemented a groundwater, surface water, and vegetation field monitoring program to comply with the conditions outlined in the SJBA's Permit for Diversion and Use of Water, No. 21074 (Permit 21074). Permit 21074 was issued by the State Water Resources Control Board (SWRCB) Division of Water Rights in October 2000 and amended in October 2011. The SJBA's monitoring program developed in 2001, focused primarily on collecting the data needed to satisfy the monitoring requirements included in Permit 21074.

In 2011, the SJBA hired Wildermuth Environmental, Inc. (WEI) to prepare an updated San Juan Basin Groundwater and Facilities Management Plan (SJBGFMP) for the long-term, sustainable management of the Basin's water resources. The final task of the SJBGFMP was to recommend a monitoring program to collect the data needed to effectively manage the Basin (e.g. assess the impact to groundwater levels and groundwater quality as a result of implementing the SJBGFMP) and to comply with the amended Permit 21074 requirements.

To improve storage management, the SJBGFMP monitoring program calls for a regional comprehensive groundwater-level survey and analysis of the Basin in the spring and the fall of each year. This information is used to calculate the volume of groundwater in storage. The storage calculation for the spring time period can be used as the starting point for the SJBA to determine an appropriate volume of pumping for the following year. The volume can be adjusted based on the fall storage calculation, which reflects the Basin response to the dry season. The storage calculations during the spring and fall time periods are also used to evaluate compliance with Condition No. 14 of Permit 21074, which states:

> *Cumulative extractions by the permittee, senior right holders, and rights governed by private agreements with the permittee (see condition 7) shall not exceed recharge from return flows and precipitation. This condition is satisfied when groundwater storage is not less than one-half of the storage capacity in the alluvial groundwater basin.*

This letter report summarizes the methodology used to calculate groundwater storage and summarizes the analysis of groundwater levels and storage in the Basin for spring 2016.

Methodology

The information required to estimate the storage capacity and volume of water in storage include: the elevation of the effective base of the alluvial aquifer, groundwater-level elevation, and specific yield (a parameter that describes the quantity of water that a unit volume of aquifer, after being saturated, will yield by gravity). For the Basin, the total volume of groundwater in storage is also controlled by the elevation of the stream bottom within the study area, meaning that groundwater above the stream-bottom elevation would only temporarily remain in storage before flowing towards the stream and becoming surface water. Therefore, groundwater above the stream-bottom elevation is not included in the storage capacity computation.

A fine-grain, regional groundwater model of the Basin was developed by the Municipal Water District of Orange County (MWDOC) in support of a proposed ocean desalination project (GEOSCIENCE Support Services, Inc. [GSSI], 2013[1]). This groundwater model uses a 15x15 meter grid and each model grid cell has uniquely assigned aquifer properties that include specific yield and the elevation of the effective base of the alluvial aquifer. WEI used the MWDOC groundwater model boundary and the model grid and its associated aquifer properties to develop a GIS-based storage model for this analysis. Figure 1 is a map of the model boundary used for the storage analysis.

The following steps were performed to estimate the storage capacity and volume of water in storage: 1) develop a fine rectangular grid (i.e. GIS polygon layer) over the storage area, 2) set maximum groundwater-elevation constraints based on the stream-bottom elevation, 3) compute the storage capacity of the Basin, and 4) compute the amount of groundwater in storage for spring 2016. These steps are described in more detail below.

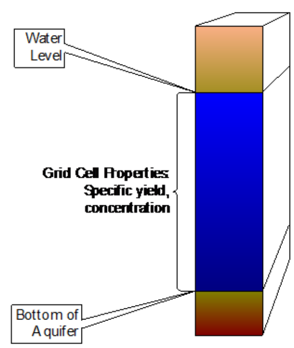
1. *Develop a fine rectangular grid and assign aquifer properties*. The grid cell size used in the calculation was the same size and extent as the MWDOC 15x15 meter grid (see Figure 1). The cell area, specific yield, and effective base of the alluvial aquifer values generated for the MWDOC model were applied within each cell.

[1] Geoscience Support Services, Inc. 2013. *Draft Report South Orange County Coastal Desalination Project Phase 3 Extended Pumping and Pilot Plant Testing Volume 3 – San Juan Basin Regional Watershed and Groundwater Models*. June 28, 2013.

2. *Set maximum groundwater-elevation constraints based on stream-bottom elevation.* To set constraints, a Digital Elevation Model (DEM) was created using two-foot interval ground-surface elevation contours generated from LIDAR[2] data provided by the City of San Juan Capistrano. The DEM was generated using a topo-to-raster interpolation scheme in the Spatial Analyst extension in ArcGIS. Using the DEM, stream-bottom elevations were assigned to San Juan Creek, Arroyo Trabuco, and Oso Creek in two-foot increments along the stream, and were used to control the volume of storage in the grid cells along the axis perpendicular to the stream at each two-foot interval.

3. *Compute the storage capacity of the Basin.* The storage capacity of a grid cell is computed as:

$$SC_i = A_i * (WL_{max} - B_i) * SY_i$$



Where:

SC_i	=	storage capacity in the i^{th} grid cell (acre-feet [af])
A_i	=	grid cell area of the i^{th} grid cell (acres)
WL_{max}	=	streambed elevation constraint in i^{th} grid cell (feet above mean sea level [ft-amsl])
B_i	=	elevation of the effective base of the alluvial aquifer in the i^{th} grid cell (ft-amsl)
SY_i	=	specific yield in the i^{th} grid cell

[2] LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. http://oceanservice.noaa.gov/facts/lidar.html.

The storage capacity of the Basin is the sum of the storage capacity of each grid cell in the storage model and is about 41,375 af.

4. *Compute the volume of groundwater in storage.* All wells with a groundwater-elevation measurement were mapped, and each well location was assigned a groundwater-elevation value representative of the spring 2016 period. The target date for selecting a spring groundwater-elevation was April 1st, plus or minus 30 days. Based on the representative groundwater elevations, equal-elevation contours were hand-drawn, digitized, and brought into GIS. Groundwater-elevations were assigned to each grid cell with an automated gridding program that interpolates between contours and groundwater-elevation measurement control points.

   As with storage capacity, the volume of groundwater in storage is controlled by the stream-bottom elevation. The groundwater elevation in a grid cell is constrained to be the minimum of: the groundwater elevation estimated from the contour map or the nearby stream-bottom elevation. The end of time period groundwater volume in a grid cell is computed as:

$$V_{i,t} = A_i * \left(WL_{i,t} - B_i\right) * SY_i$$

Where:

$V_{i,t}$	= volume of groundwater in i^{th} grid cell (af) at time t
$A_{i,}$	= grid cell area of the i^{th} grid cell (acres)
$WL_{i,t}$	= the lesser value of: the average groundwater elevation (ft-amsl) in the i^{th} grid cell at time t or the streambed elevation constraint in i^{th} grid cell
B_i	= elevation of the effective base of the alluvial aquifer in the i^{th} grid cell (ft-amsl)
SY_i	= specific yield in the i^{th} grid cell

Results

For spring 2016, Figure 2 shows: the storage model boundary (grey outline), wells with data available for spring 2016 (brown-filled circles), the spring 2016 groundwater elevations used to develop contours (brown labels alongside wells), the spring 2016 elevation contours (black lines), and the grid cells that were determined to be dry after the contours were developed (pink shaded areas).

The following table shows the time-history of the estimated groundwater in storage for the period of fall 2012 through spring 2016.

Point in Time of Estimation	Groundwater in Storage[3] (af)	Percentage of Total Capacity
Fall 2012	28,297	68%
Spring 2013	28,540	69%
Fall 2013	25,855	62%
Spring 2014	26,269	63%
Fall 2014	24,864	60%
Spring 2015	26,555	64%
Fall 2015	27,623	67%
Spring 2016	**29,380**	**71%**

The volume of water in storage for spring 2016 has increased by about 1,760 af relative to fall 2015. The increase relative to spring 2015 is about 2,830 af. This increase in storage is primarily due to:

1. the increase in precipitation for the May 2015 to April 2016 period (about 7.9 inches), compared to the total for the May 2014 to April 2015 period (about 5.4 inches)[4];
2. the reduction in groundwater production by the City of San Juan Capistrano for the May 2015 to April 2016 period (about 2,070 af), compared to the total for the May 2014 to April 2015 period (about 4,320 af); and
3. the reduction in groundwater production by the South Coast Water District for the May 2015 to April 2016 period (0 af), compared to the total for the May 2014 to April 2015 period (about 400 af)—the District's Groundwater Recovery Facility has remained offline since September 2014.

Limitations of the Analysis and Recommendations for Improvement

The estimated storage, estimated storage change and interpretation of the storage estimates need to be viewed with the understanding that there are areas in the basin where groundwater

[3] WEI's consensus best professional judgment of the error in an analysis for calculating total storage using model-generated specific yield values, hand contoured groundwater elevations based on measured data, and GIS to interpolate between contours is plus or minus ten percent of the calculated result.
[4] As measured at station Ortega KCASANJU2: http://www.wunderground.com/personal-weather-station/dashboard?ID=KCASANJU2#history

levels cannot be reliably estimated due to a lack of monitoring wells. The primary concern is the existence of spatial data gaps in some areas of the Basin. The areas of concern are:

1. the area to the west of the City of San Juan Capistrano's Alipaz well field;
2. the area to the north of the Alipaz well field, just south of where the Arroyo Trabuco and San Juan Creek arms of the Basin converge; and
3. the northern extent of the San Juan Creek arm of the Basin.

There are no wells, and thus no groundwater-level data, to support (or negate) the current interpretation of the groundwater elevation contours in these areas. WEI recommends that the SJBA include budget to construct three to four monitoring wells in the upcoming fiscal year to fill these data gaps and improve future estimates of groundwater elevation, contouring of the groundwater elevation estimates and storage calculation efforts[5].

Summary and Conclusions

Based on the available data and the assumptions of this analysis, the Basin is about 71 percent full as of spring 2016. Thus, Condition No. 14 of Permit 21074 is satisfied, and no restrictions on pumping are required to comply with this permit condition. However, other conditions in Permit 21074, such as Condition 23 (riparian vegetation health) and Condition 17 (water quality degradation), may limit how much and where this water could be extracted. Additional considerations beyond the permit constraints should also be evaluated by the SJBA TAG and Board in determining an appropriate production volume for the remainder of calendar year 2016, including, but not limited to, anticipated private groundwater production, agency production goals, and policy objectives (e.g. how much water should be reserved in storage for times of "drought"). WEI is developing an Adaptive Production Management Plan that will assist the Board in determining appropriate production volumes based on storage, water quality, and vegetation health. The plan is expected to be completed for the Board's review by July 2016.

Please call us if you have any questions or concerns regarding the analysis contained herein.

Very truly yours,

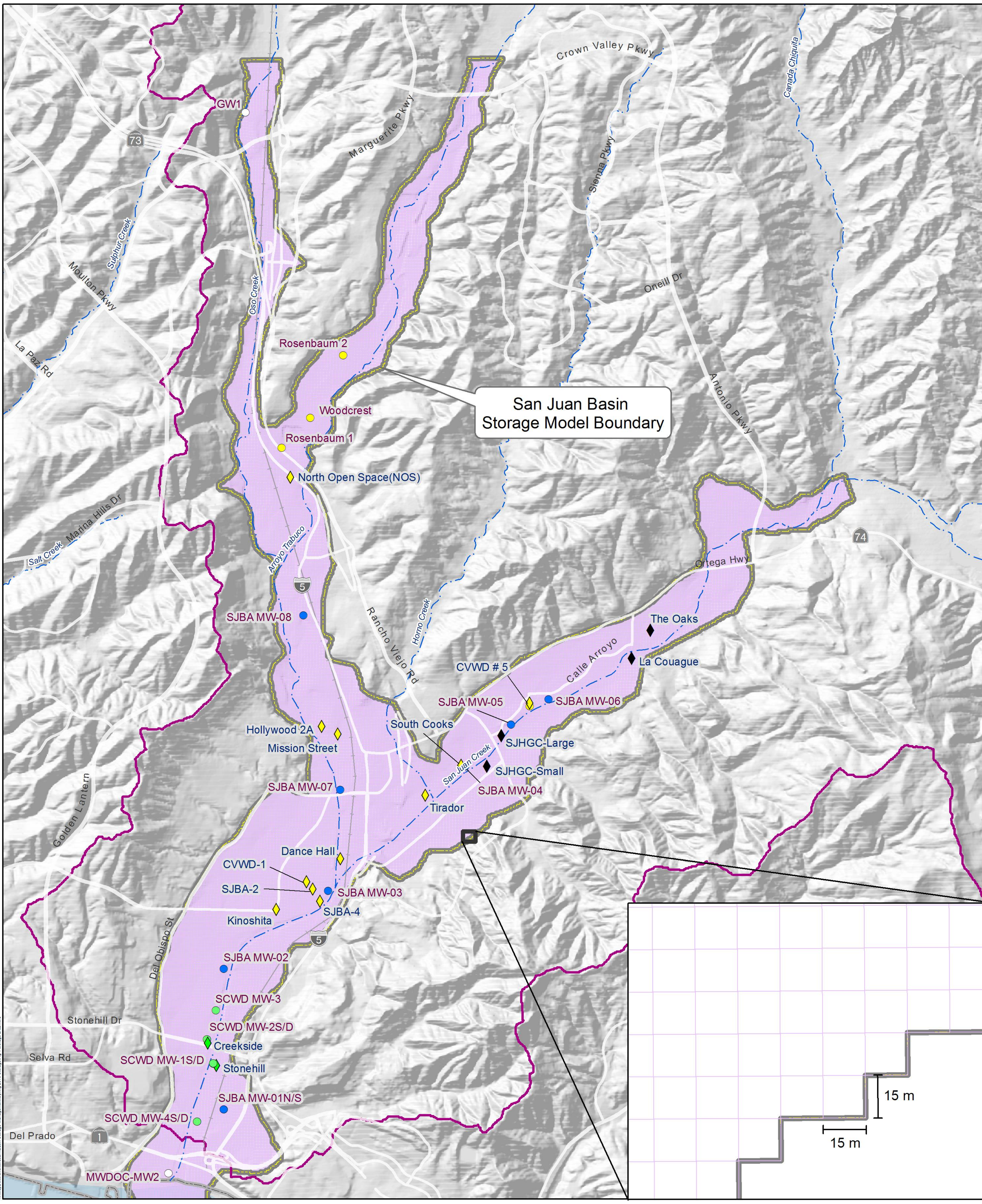
Wildermuth Environmental, Inc.

Mark J. Wildermuth, PE
President, Principal Engineer

Samantha S. Adams
Principal Scientist

Enclosure: Figures 1 and 2

[5] Note that at least one more monitoring well, in addition to those recommended herein, is needed near the coast to improve monitoring for seawater intrusion.



Main Features

Monitoring Well Network

Kinoshita	City of San Juan Production Well
Stonehill	South Coast Water District Production Well
SJHGC - Small	Private User Production Well
SJBA MW-01N	San Juan Basin Authority Monitoring Well
SCWD MW 1S/1D	South Coast Water District Monitoring Well
Woodcrest	City of San Juan Inactive Production Monitoring Well
GW1	Other Monitoring Wells

San Juan Basin Storage Model Boundary

San Juan Creek Watershed Boundary

Streams and Creeks

Produced by:

WEI
Wildermuth Environmental, Inc.

Author: LBB

Date: 20151113

0 1,000 2,000 Feet

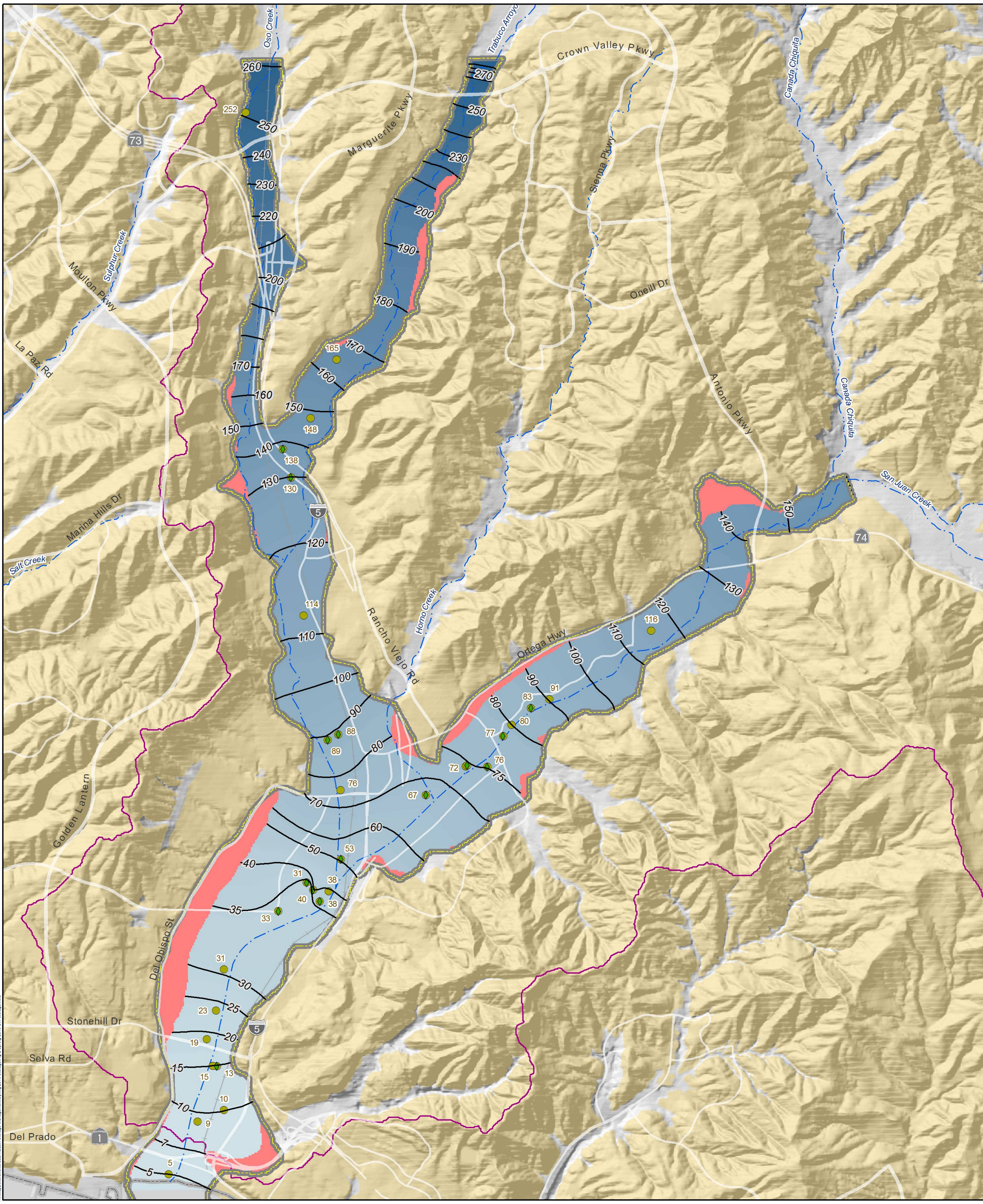
0 0.25 0.5 Miles

San Juan Basin Authority

Spring 2016 Groundwater Storage Analysis

San Juan Basin Storage Model Boundary

Figure 1



-10- Spring 2016 Groundwater Elevation Contour (ft amsl)

Spring 2016 Groundwater Elevation, ft amsl

300 ft amsl

0 ft amsl

Spring 2016 Dry Model Grid Cells

Wells with Groundwater Elevation Data Available in Spring 2016

Production Well

San Juan Basin Storage Model Boundary

San Juan Creek Watershed Boundary

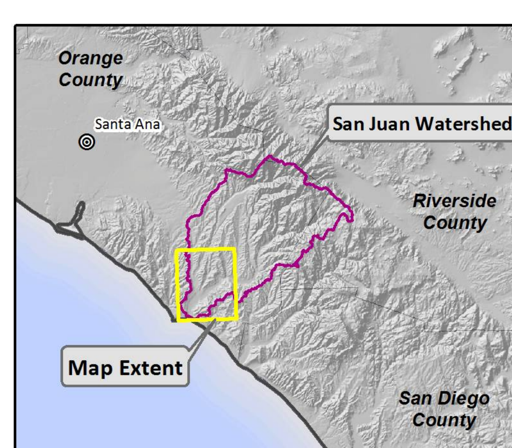
Streams and Creeks

Geologic Features

Younger Alluvial Deposits

Older Alluvial Deposits, Landslides, and Tertiary Sedimentary Bedrock

Source of Geologic Features: CGS Special Report 217.



Final Spring 2016 Groundwater Elevation and Areas with Water in Storage

Produced by:

WEI
Wildermuth Environmental, Inc.

Author: LBB

Date: 20160511

0 1,000 2,000 Feet

0 0.25 0.5 Miles

San Juan Basin Authority

Spring 2016 Groundwater Storage Analysis

Figure 2

Attachment B

South Coast Water District – Comments Provided by Andy Brunhart

1. **Figure 13 appears a little off. Specifically, the allocation formula used for the ratio of SCWD and SJBA (used by CSJC per Agreement) needs to be adjusted to 20%/80% respectively. The ratio should be consistent with the Agreement between the SJBA and Capistrano Beach Water District (now SCWD) of March 1, 1998, which identifies Allocations of Water based on Available Safe Yield of: 20% to Capistrano Beach Water District (now SCWD) and 80% to the Authority (SJBA – again, of which SJBA has an Agreement with CSJC).**

WEI Response: You are correct that Figure 13 does not allocate pumping to the City (SJBA) and SCWD per the 80/20 formula in the referenced agreement. The formula used to create Figure 13 is based on the relationship of storage and sustainable pumping in the 2016 APM alternative, which allocates pumping at wells in order to comply with the permit conditions. The model limits pumping by both agencies when pumping limits are required. Specifically, the run was designed to reduce pumping in a proportionate manner, but did not achieve an exact 80/20 split. In applying the pumping limitations, the allocation of the sustainable pumping pursuant to water rights permits to the City and the SCWD ends up at about 82% and 18%, respectively. Over the entire simulation period the difference between the SCWD's 20 percent allocation and the model allocation ranges from 52 to 110 afy, and averages 88 afy.

It is our understanding that the TAG and Board may use the information and recommendations in our technical memo to develop a draft resolution (or other agreement) with guidelines and terms for an APM plan. The attached graphic demonstrates what an adjustment to allocate the sustainable pumping per the 80/20 relationship would look like. As you can see (and as stated above) the difference is small. In our professional opinion, the Board could elect to adjust the allocation to match the 80/20 agreement and achieve the same result, so long as the other recommendations are followed (e.g. no pumping at City wells in the riparian habitat monitoring area, implement specified monitoring protocols, and plan to update the APM curve on a periodic basis).

South Coast Water District – Comments Provided by Steve Dishon

2. **Page 3, number 3 – It would be prudent to note what the extraction amount in AF is that is referred to as "planned groundwater pumping" for the Geoscience study. This is an important fact for this plan.**

WEI Response: The projected pumping amount assumed by MWDOC in 2012 has been added as a footnote.

3. **Page 3, number 4, letter b. – Does the Glenn Lukos report describe the riparian habitat being "severely stressed". It is important to use the same descriptions as the report of the expert opinion.**

WEI Response: Yes, Glen Lukos uses the word "severe" when referring to the stress of the riparian vegetation. See for example Page 10 of *Summary of Findings: Qualitative Assessment of Supplemental Control Sites in the San Juan Creek Watershed*, dated September 29, 2014.

4. **Page 3, paragraph 4 – The phrase “given such a small storage volume relative to planned groundwater pumping” is not necessary and should be removed from the sentence.**

WEI Response: Hydrologically speaking, this is a necessary condition for the rapid depletion of water levels in dry periods.

5. **Page 4, comment – The privately owned and non-GWRP wells should be under the same restraints and subject to the APM. Isn’t this what the State Water Resources Control Board is moving towards so that they can monitor and manage all water pumping and distribution?**

WEI Response: The existing permits and agreements do not regulate production at the City’s non-GWRP wells nor at private wells. The Protest Settlement Agreement Between San Juan Basin Authority and Capistrano Beach Water District dated March 1, 1998 acknowledges that this is the case; see Recital F (note there are two paragraphs labeled as “F”: pages 2 and 3).

6. **Page 5, paragraph 3 – This paragraph states that the threshold is 50%, whereas the first paragraph on the page states that the plan uses 61%. This is confusing.**

WEI Response: We will revisit the text and update it clarity. The text in the first paragraph refers to the storage range actually achieved during the baseline model run. The threshold level was set so that the Basin was not allowed to drop below 50 percent of full, but to comply with the seawater intrusion thresholds, the model “managed” pumping such that storage never dropped below 61 percent of full. The implication of this result is that is that the 50% threshold allowed by the permit is not protective of the Basin.

7. **Page 8, comment – Figure 7 is referring to “projected” groundwater elevation but refers to years that are in the past. How does this work?**

WEI Response: Great question. The model was used to project the hydrologic response of the basin assuming current land use and water supply plans (cultural conditions) and a repeat of the hydrologic period of 1947 to 2014. Because we can’t reliably predict future precipitation for any given year, the historical precipitation record was used. So, to interpret Figure 7, you would look to hydrologic year 1978 to see what the expected groundwater level and subsurface outflow conditions would be for 1978 (a very wet year) and the hydrologic conditions and management activities leading up to and during that year.

8. **Page 8, comment paragraph 3 and 4 – Both of these paragraphs end with sentences that state “will be protective”, being that all of this hypothesis and model calculations this should be changed to “should be protective”.**

WEI Response: The text will be updated to “should be”.

9. **Page 9, paragraph 1 – The basin planned pumping should be 80% SJBA/20% SCWD of the total recommended pumping as defined by current agreements.**

WEI Response: Please refer to WEI’s response to Comment 1.

10. **Figure 13 – Does not reflect the current agreement of 80% SJBA/20% SCWD.**

WEI Response: Please refer to WEI’s response to Comment 1.

11. **Recommended Plan – When do you foresee initializing this plan? How are the SJBA wells still pumping?**

WEI Response: The schedule will be developed by the SJBA TAG and determined by the Board.

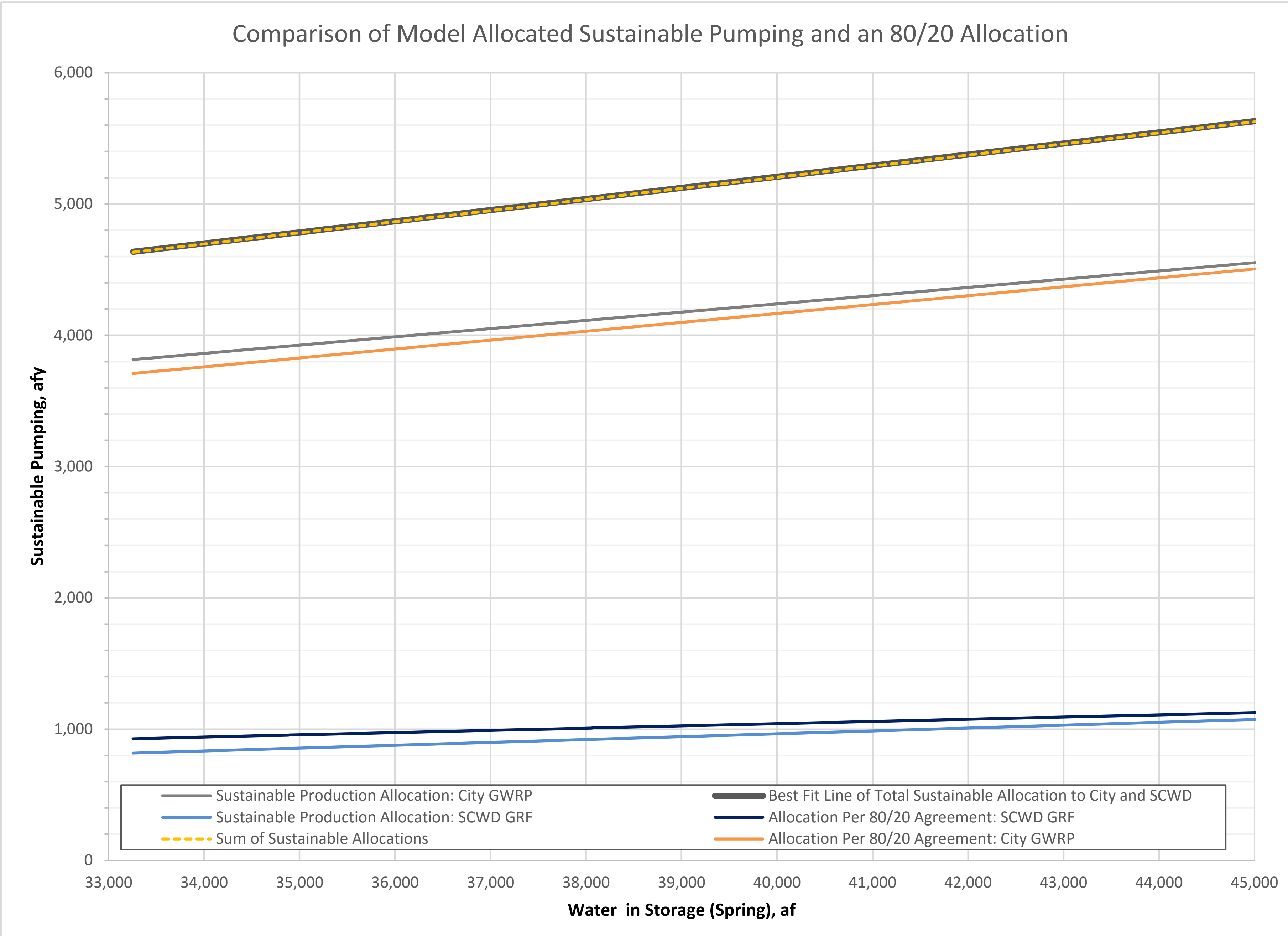
12. **Recommended Plan – I see a procedure/process for turning everything off in response to data, but what is the plan to turn back on after an event like this? Shouldn't this be spelled out as part of this plan?**

WEI Response: Thank you, you are correct this should be addressed. We propose the following revision to Page 10, sub-bullet 3.c:

> If the data show signs of seawater intrusion (landward groundwater flow gradients and increasing electrical conductivity or chloride trends), it will trigger a process to reduce the pumping allocation. The SJBA TAG will review the available data and make a recommendation on a revised pumping allocation to the SJBA Board.

Similarly, a process will be needed for responding to potential impacts in the riparian habitat area. We propose the following revision to Page 11, sub-bullet 4.b:

> If the data show that groundwater levels are dropping below the protective thresholds, it will trigger a process to reduce the pumping allocation. The SJBA TAG will review the available data and make a recommendation on a revised pumping allocation to the SJBA Board.



Comparison of Model Allocated Sustainable Pumping and an 80/20 Allocation
Sustainable Pumping, afy
6,000
5,000
4,000
3,000
2,000
1,000
0
33,000
34,000
35,000
36,000
37,000
38,000
39,000
40,000
41,000
42,000
43,000
44,000
45,000
Water in Storage (Spring), af
Sustainable Production Allocation: City GWRP
Sustainable Production Allocation: SCWD GRF
Sum of Sustainable Allocations
Best Fit Line of Total Sustainable Allocation to City and SCWD
Allocation Per 80/20 Agreement: SCWD GRF
Allocation Per 80/20 Agreement: City GWRP