Edwards Aquifer Recovery Implementation Program (EARIP)
SAWS Aquifer Storage & Recovery (ASR) Activity

The SAWS Twin Oaks ASR (SAWS ASR) is an underground storage reservoir in the Carrizo sand aquifer in southern Bexar County. As a SAWS Water Management Project, it is designed to store permitted Edwards Aquifer water in years when demand is less than available supply. The stored water is then pumped back to the SAWS distribution system during drought periods and/or times of high demand. The SAWS 2009 Water Management Plan Update states that the water in the ASR will be utilized in Stage 3 and 4 of Critical Period Management to help meet SAWS ratepayer needs.

The estimated, but untested capacity of the SAWS ASR is 200,000 acre-feet. By agreement with the Evergreen Underground Water Conservation District SAWS may pump 100% of the Edwards water stored in the SAWS ASR. To accomplish that return even if the stored water does mix with Carrizo water to some degree, the SAWS ASR site has a 30 millions of gallons per day (MGD) water treatment plant. So far, however, during SAWS ASR use in tests and in the droughts of 2006 and 2008-2009 the returned water has retained its Edwards Aquifer characteristics.

Currently (early 2011), the use of the SAWS ASR is limited by its single pipeline. The pipeline on the east side of Bexar County connects Twin Oaks to the pump stations at Seale, Artesia (south of IH 35 near Ft. Sam Houston) and Randolph (south of IH 35 near the north east juncture of IH 35 and Loop 410 interchange).

The SAWS ASR facility has a capacity to inject or return 60 MGD (184 acre-feet per day) in a drought. The ASR as of February 1, 2011 has 90,000 acre-feet in storage.

Referring to the SAWS 2009 Water Management Plan Update and assuming the short and mid-term projects are successful, SAWS water supply is sufficient to meet projected demand. Even if there is a repeat of the drought of record the plan indicates surplus supplies until 2040 when 16,000 acre-feet would be needed. The analysis of SAWS' water supplies reflected in the 2009 Water Management Plan Update reveals that SAWS has considerable flexibility in the supply situation. That flexibility can be utilized to offset Edwards pumping demands during a focused drought period resulting in positive spring flow at Comal and San Marcos Springs (San Marcos is limited by the regional bypass or structural geology and both spring communities by localized activities) to meet the needs of the Endangered Species during a drought of record.

<u>Why is it Desirable to Fill the ASR through the Relaxed Rate Described in this Paper</u>

- Until SAWS completes the Western Integration Line, the limitation of the ASR is the one pipe outlet. The limitation is one of quantity and flow direction. Water can either be

injected in the ASR, or ASR and local Carrizo water must be flowing to San Antonio. The pipe must be in action.
- SAWS ratepayers paid for the ASR with expectation that it would return water during Stage 3 and 4. This water is excess stored Edwards water that was available during low demand periods.
- The ratepayer's expectations must be fulfilled before the ASR can be used to address regional needs to protect spring flow, unless they agree to a change of purpose.
- The "Good News" is that the SAWS ratepayer expectations to have access to local Carrizo and ASR water in Stage 3 and 4 can be addressed in addition to the Regional need to protect spring flow "if" the "relaxed fill" schedule continues.
- The "10-year Recharge Average" identified the drought of record and described a topping off schedule to provide adequate water in the ASR to meet drought of record requirements to have approximately 126,000 acre-feet to return during recovery operations.
- The conditions described in this paper also allow SAWS to utilize local Carrizo and ASR water during high demand times and to store SAWS excess Edward's supplies during low demand periods.
- In the typical year with normal rainfall, utilizing the relaxed refilling schedule, SAWS can pump its local Carrizo water to ratepayers in the summer while storing excess supplies in the normal low demand winter months.
- The relaxed fill schedule also is more conducive to dividing costs into yearly segments. It reduces the need for high initial costs and allows that cash reserves be built for the demands for topping off and returning the water to San Antonio.
- SAWS relies on the pumping of its local (Bexar County) Carrizo water to counteract the natural inclination of the injected water to flow down towards the Coast. The wells are positioned for that purpose.

SAWS' ASR as a Bottom Up Activity in the EARIP Habitat Conservation Plan (HCP)

It is believed that the SAWS ASR can fulfill its role in the 2009 Water Management Plan Update and also provide considerable spring flow. This can be achieved when ASR is used with the other management strategies of the "Bottom Up" package; Voluntary Irrigation Suspension Program Option (VISPO), the Regional Conservation Program and the Stage 5 Emergency Pumping Reduction as the final activity triggered in the sequence (ASR would implement after VISPO and Conservation and before Stage 5).

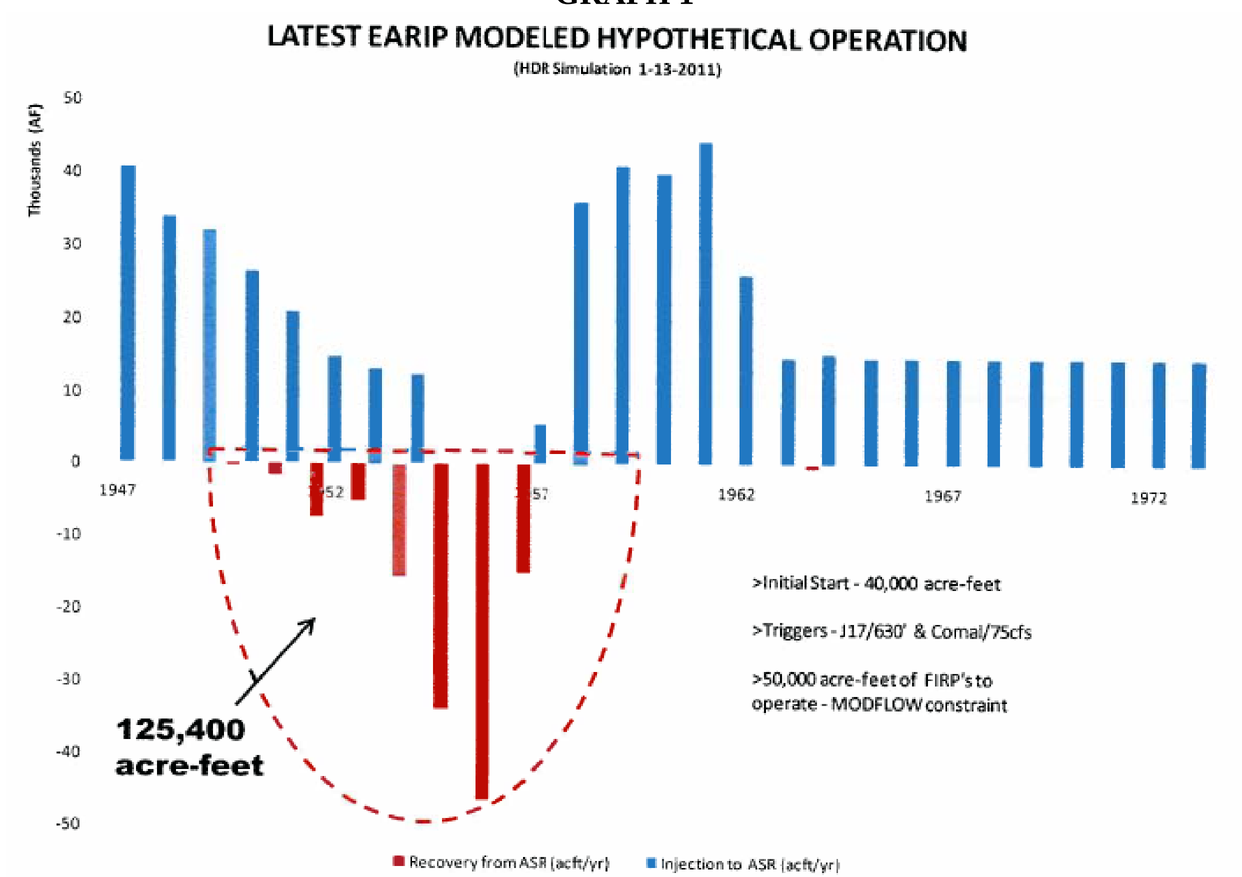
The current proposal calls for the SAWS ASR to begin supplementing up to 60 MGD of SAWS Edwards pumping when monitoring well J-17 indicates that the aquifer level is 630 feet msl and Comal Spring flow reaches 75 cubic feet per second (cfs). The described reduction in SAWS pumping would add approximately 15 cfs during the worst month of a drought similar to the drought of record (an average of 46 cfs during that worst year) to spring flow at Comal Springs and approximately 29 cfs during the worst month of drought similar to the drought of record (an average of 14 cfs during that worst year) to spring flow at San Marcos Springs according to the

MODFLOW model simulations. These results are also predicated on the layered approach and the regional efforts of VISPO (Dry Year Option) and conservation strategies being implemented.

Arranged in the order described, the modeling indicates that the VISPO and Regional Conservation Programs will provide approximately 14 cfs spring flow at Comal Springs during the driest period of the drought of record. These strategies provide more benefit than 14 cfs during the Intermittent Period of the drought of record because they are triggered earlier.

The key to the SAWS ASR contribution to the protection of the Endangered Species is to reduce SAWS' pumping as per the volumes reflected in Graph #1.

GRAPH 1



Preparation for the Drought of Record

SAWS will continue its weather related, cost effective relaxed filling of the ASR with a goal to have at least 120,000 acre-feet in storage prior to the arrival of a decade reminiscent of the drought of record. Eighty-thousand acre-feet of that water will be dedicated to the Regional HCP to protect spring flow. A key and important factor will be identifying the presence of such a drought with enough time to "top-off" the ASR strategy. SAWS suggests monitoring the instrumental records 10-year rolling average of recharge information included in the Edwards Aquifer Authority's (EAA) annual hydrologic report. This can be like the proverbial canary in the coal mine helping to identify which droughts might require aggressive action.

SAWS Responsibilities in Fulfilling the Regional Commitment

The key to the SAWS ASR contribution to the protection of the Endangered Species at the Springs is to reduce Edwards Aquifer pumping as per the volumes modeled and reflected in Graph #1.

The modeling represented in Graph #1 utilizes the capabilities of the SAWS ASR at the current time.

As SAWS 2009 Water Management Plan Update is implemented, the pumping reduction at 630 ft msl at J-17 and spring flow of 75 cfs at Comal Springs may be accomplished through the use of the SAWS ASR, or some combination of other water supplies implemented as part of SAWS 2009 Water Management Plan. SAWS integration infrastructure is a carefully timed activity to balance many factors. A portion of the planned offset may be attributed to molecules of water coming from Local Carrizo or brackish desalination activities. It is important to remember that these supplies are for future growth and integration infrastructure for ASR opportunities will be expanded in coordination with diversification.

Costs in the EARIP Regional HCP are calculated for use of the SAWS ASR, the least expensive source of water of the planned new projects.

Identifying the Drought of Record and Managing the SAWS ASR in that Period

The advent of the early drought of record will be identified when the 10-year average of recharge falls below 500,000 acre-feet. At that point SAWS will **increase storage** (relative to the fact that SAWS has been targeting 120,000 acre-feet 2/3 for the Region and 1/3 available for use per the SAWS 2009 Water Management Plan Update) to an average of approximately 16.25 MGD. It is expected that this pattern will continue for three years at which time the 10-year recharge level will have fallen to 450,000 acre-feet and be on a trajectory towards 320,000 acre-feet.

HDR and Todd Engineers initially utilized the MODFLOW model with the SAWS ASR as being completely empty (0 acre-feet in storage). The model period began in 1947. At this time, the 10-year rolling average of recharge, according to estimates maintained by the EAA, was 489,000 acre-feet. Since the SAWS ASR has over 90,000 acre-feet stored, using the 500,000 acre-feet 10-year rolling average provides an additional level or degree of conservatism.

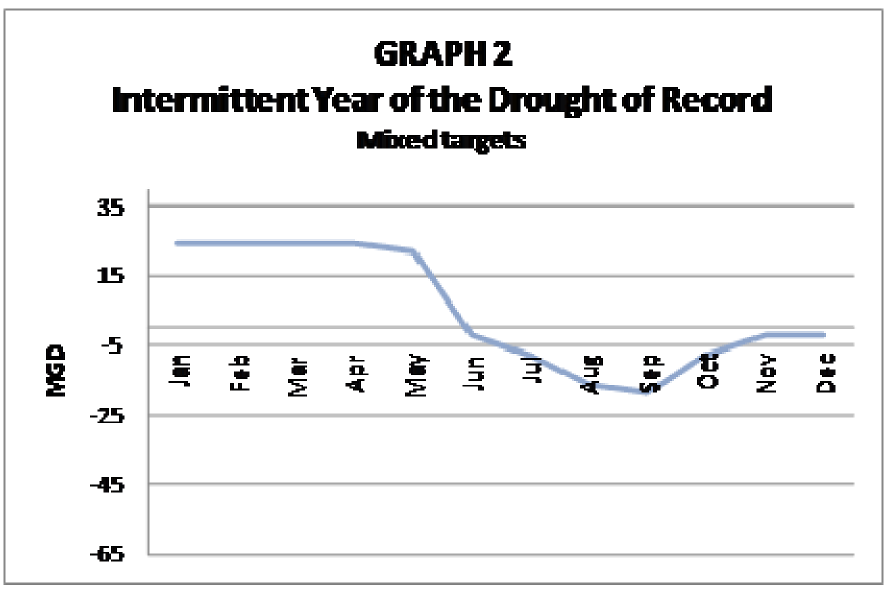
At the time when the 10-year rolling recharge rate has fallen to a range of <450,000 to >320,000 acre-feet per year, SAWS will revise its injection and recovery pattern to one of storage in quarters one and four of approximately 13.5 MGD to recovery of approximately 14.25 MGD in quarters two and three when J-17 levels and spring flow triggers dictate similar to the simulations. This period is known as the intermittent operations.

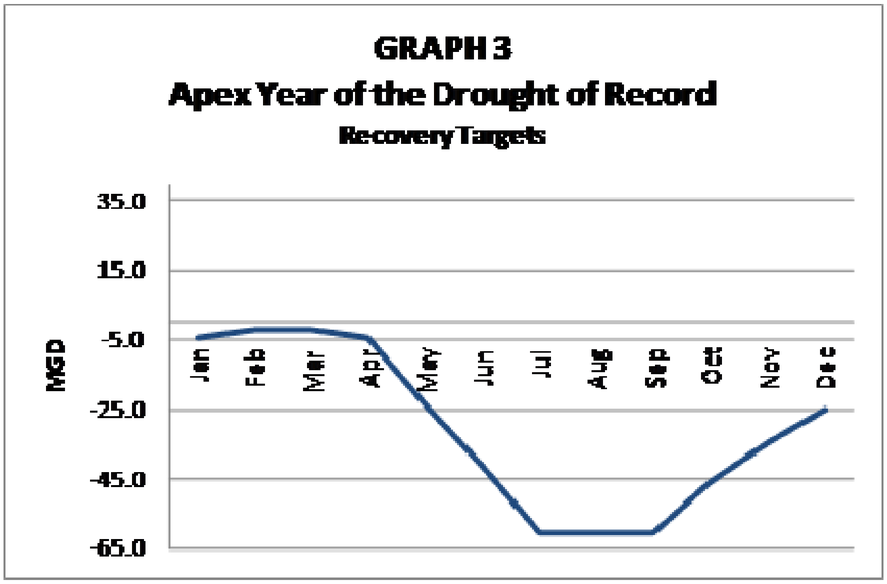
During years of the drought of record when the 10-year average recharge rate has fallen from the intermittent range to ≤320,000 acre-feet will be the most difficult to manage. Groundwater modeling results call for an average recovery rate of 33 MGD and show brief 3rd quarter periods when the recovery will be at the full capacity of 60 MGD when the aquifer level is at or below 630 feet msl and spring flow at Comal Springs is at or below 75 cfs. The modeling calls for considerable discretion in determining the recovery rate.

The recovery rate may be less than 60 MGD when SAWS management determines that spring flow is not likely to continue to fall because rainy weather is forecast or the spring flow levels and/or aquifer levels are on an upward trend. This period in the management of SAWS ASR is to insure that spring flow does not fall below 30 cfs, paralleling the management that occurred in 2009, that resulted in a stabilization of aquifer levels just above 640 feet; preventing a drop into Stage 3.

During the apex of a decadal drought, SAWS ASR will be in full recovery mode with an average of approximately 40 MGD. During this period the SAWS ASR is expected to be operating at full capacity, 60 MGD during the 3rd quarter of the worst two years of the drought of record.

Graphs #2 reflects the concepts described as the intermittent year of the drought of record. Graph #3 reflects the concepts described for the apex year of the drought of record. The graphs collectively represent planning averages for intra-year variation based on modeling simulations.





The following tables represent illustrative monthly targets in MGD, which are episodic when considering traditional water utility operations. The tables reflect having a minimum of 80,000 acre-feet (2/3 of the target) ready for regional use during the implementation of the ASR strategy. All of the leasing options are in place by this point and the ASR strategy would be implemented in a way to be as representative as possible of the modeling performed for the EARIP by its technical experts. The regional advisory group would make recommendations to best optimize the SAWS ASR strategy during the intermittent and apex periods.

EARLY PERIOD – Illustrations:

This period is indicative of a topping off resulting in ~54,000 acre-feet of water stored in addition to the targeted start-up

ADVENT PERIOD-INJECTION TARGETS			
Month	**Year1**	**Year2**	**Year3**
January	20	20	15
February	20	20	15
March	20	20	15
April	20	15	15
May	20	15	15
June	20	15	15
July	15	15	15
August	15	15	15
September	15	15	15
October	15	15	15
November	15	15	15
December	15	15	15

INTERMITTENT PERIOD – Illustrations:

This period represents continued timely storage of an amount of water (1st and 4th quarters primarily) ~41,500 acre-feet of water and a beginning of more intense recovery modes to account for a return to SAWS customers of ~18,500 acre-feet, which provides the relief on the Edwards required for spring flow benefits.

INTERMITTENT PERIOD-INJECTION TARGETS				
Month	Year4	Year5	Year6	Year7
January	15	15	10	15
February	15	15	10	15
March	15	15	10	15
April	15	15	10	10
May	15	15	10	10
June	15	15	nuetral	nuetral
July	15			
August		RECOVERY		
September				
October	15	15		
November	15	15	nuetral	
December	15	15	10	nuetral

INTERMITTENT PERIOD-RECOVERY TARGETS				
Month	Year4	Year5	Year6	Year7
January				
February				
March				
April		INJECTION		
May				
June				
July		10	10	10
August	10	10	30	20
September	10	10	30	20
October			10	10
November	INJECTION			10
December				

APEX PERIOD – Illustrations:

This period is primarily protection of deep drought of record conditions returning ~109,000 acre-feet to assist in reducing focused drought stress sufficient enough to maintain the plans prescribed spring flow.

APEX PERIOD-INJECTION TARGETS				
Month	Year8	Year9	Year10	Reset
January	10	nuetral		
February	10	nuetral		
March	10	nuetral		
April	10			
May	10			
June				
July		RECOVERY		
August				nuetral
September				nuetral
October				nuetral
November				15
December				15

APEX PERIOD-RECOVERY TARGETS				
Month	Year8	Year9	Year10	Reset
January			20	40
February	INJECTION		20	30
March			10	30
April		10	20	20
May		20	40	20
June	10	40	60	10
July	30	60	60	10
August	40	60	60	
September	40	60	60	
October	30	40	60	
November	10	30	50	
December	10	20	40	

*neutral in all practical terms falls in as a "recovery" activity and could be the Local Carrizo returned with a smaller amount of stored Edwards as a blend (10 MGD) to ensure that the overall recovery falls in line with the commitment – 126,000 acre-feet.

Regional Discussion Group

The decisions that accomplished the 2009 stabilization of aquifer levels were made by SAWS management with advice from the Aquifer Management Team, a group of SAWS administrators and technical staff representing various SAWS departments.

A similar 10 member discussion group will be formed to advise SAWS management on SAWS ASR use during the intermittent and apex periods. In addition to five SAWS representatives, the Regional Aquifer Discussion Group will include two representatives of the Edwards Aquifer Authority, and single representatives of the EARIP representing downstream interests, agricultural pumpers, and environmental group. The SAWS administration will call meetings of the Regional Discussion Group to consider the advice related to regional aquifer management, but retain ultimate SAWS ASR management decision power.

Other Droughts

The Bottom Up slate of activities was organized to maintain minimum spring flow at or near 30 cfs during the drought of record.

The question has been raised asking, "what about other droughts?" If the Regional portion of SAWS ASR is reserved for the drought of record as identified by the "10-year Cumulative Recharge Average" what about the droughts in 1984 and 1996 when Comal spring flow fell below 75 cfs but the "10-year Cumulative Recharge Average" was still relatively high. The SAWS ASR would in fact address those droughts without reducing its capability to address the drought of record.

Examining the Senate Bill 3 modeling results for the period 1960 – 2000, there are five droughts that would reach ASR Regional trigger levels.

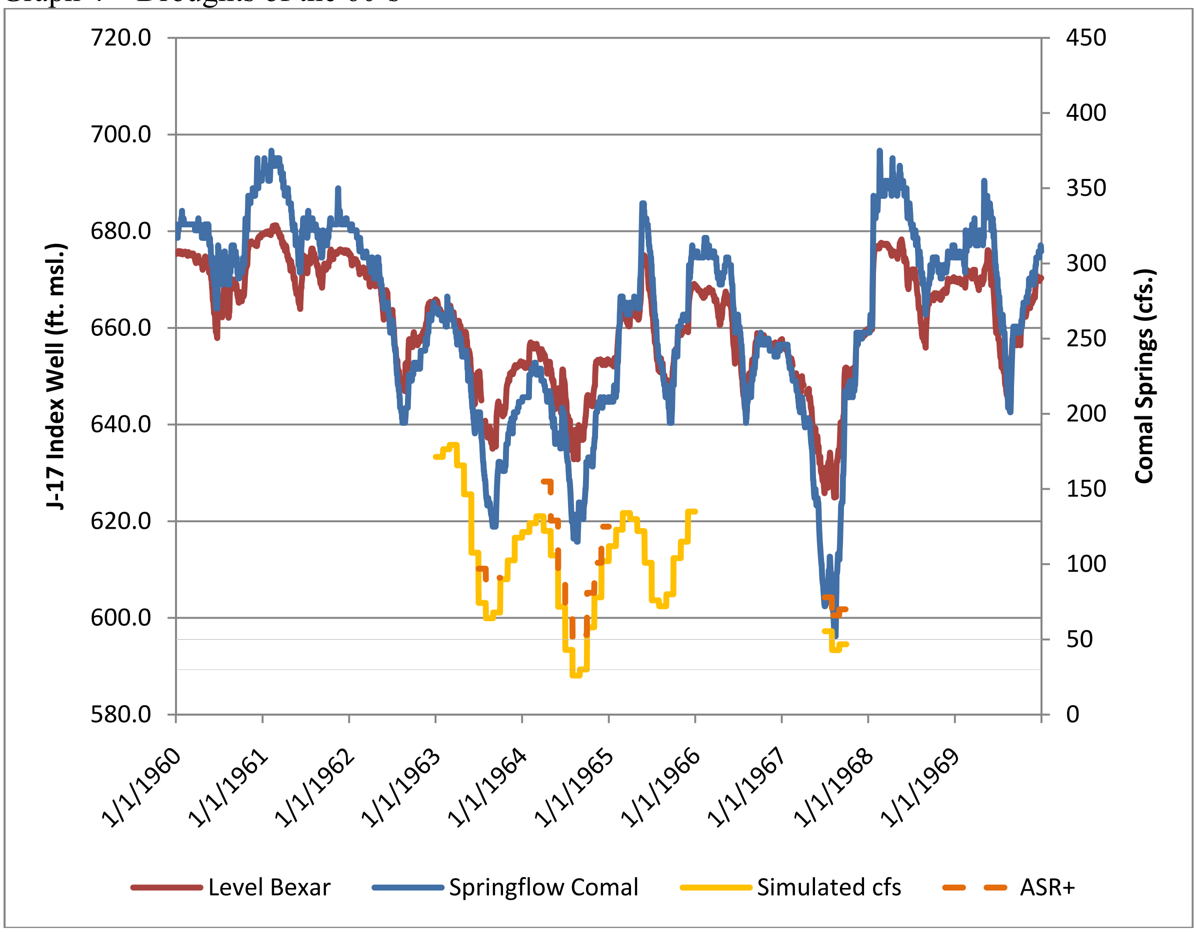
In the 60's there are three such droughts (see graph 4) with one drought each occurring in the 1980's and one drought in the 1990's. See graphs 5 and 6 respectively.

As the notes under the graph indicate, the triggered droughts in 1963, 1964 and 1967 would require 7,950 acre-feet, 23,850 acre-feet and 7,950 acre-feet of water from the ASR to maintain the minimum spring flow. The total for the decade of the 60's would be approximately 40,000 acre-feet of water. The 40,000 acre-feet of water from the ASR would provide over 20,000 acre-feet of extra spring flow.

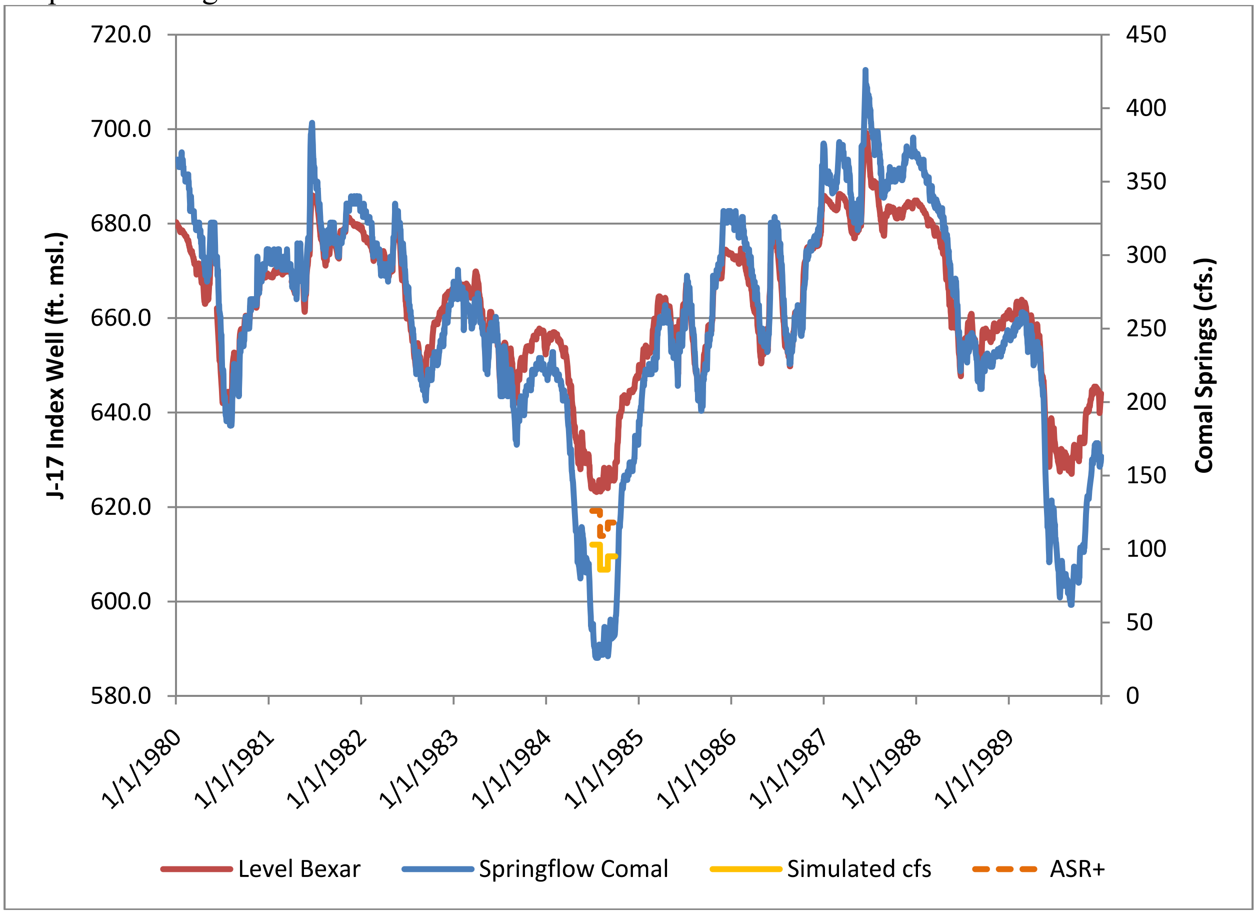
The model simulated droughts in 1984 and 1996 would require approximately 7,950 acre-feet of water from the ASR. The contribution from the ASR would add approximately 4,000 acre-feet of spring flow during each of the two droughts.

There is considerable question whether the modeled trigger levels at Comal Springs in the 60, 80 and 90's would actually be reached because of the impact of the VISPO, Regional Conservation, and SAWS 2009 Water Management Plan Update actions during Stage 3 and Stage 4 of the drought, but if they did, it is clear from this analysis that the water would be available from SAWS ASR to maintain minimum spring flow. The 80,000 acre-feet pre-drought of record reserve could handle the most demanding of the droughts identified in the modeling short of the drought of record.

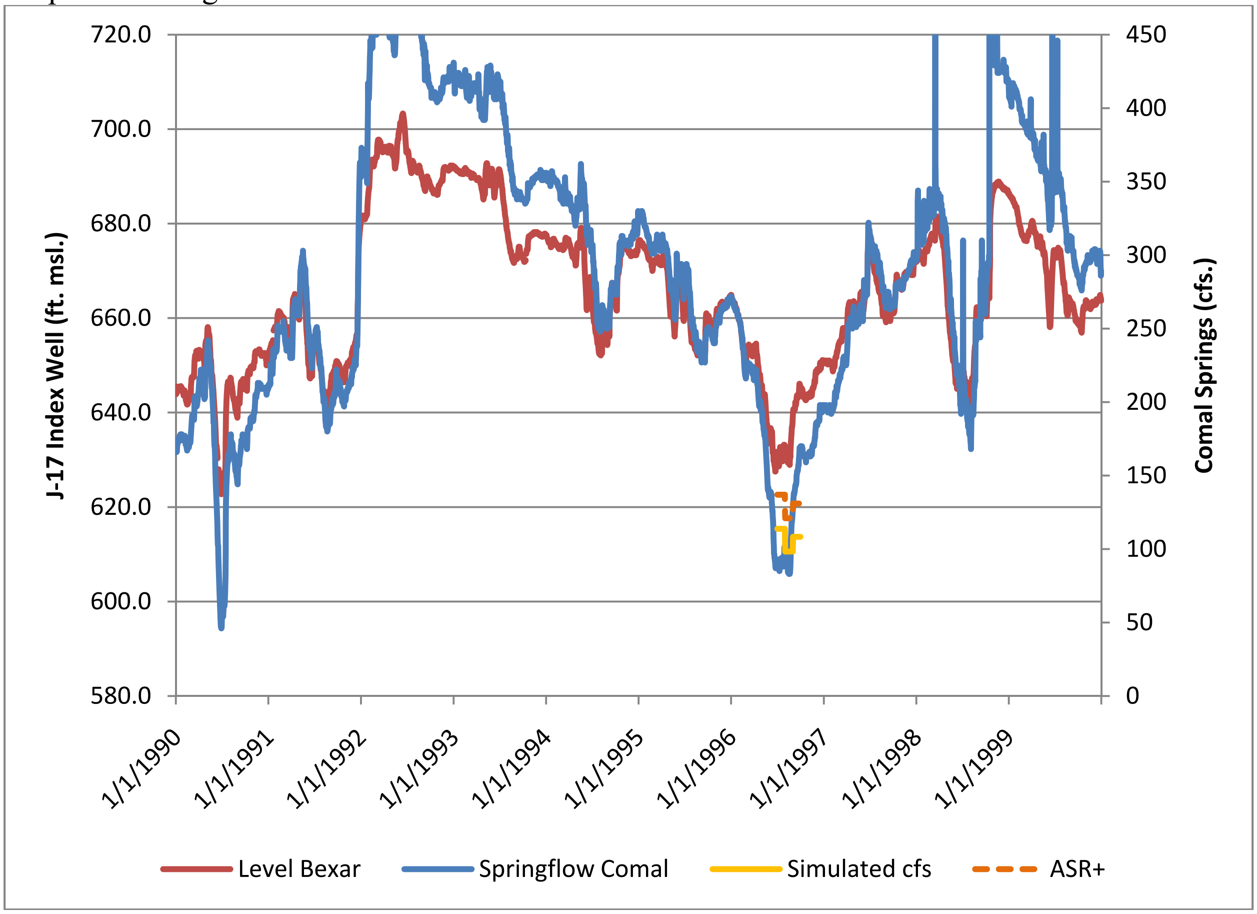
Graph 4 – Droughts of the 60's



Graph 5 – Droughts of the 80's



Graph 6 – Droughts of the 90's



<u>SAWS 2009 Water Management Plan Update ASR Activities</u>

The modeling in response to the SAWS original ASR inquiry, 20,000 acre-feet in Stage 3 and 20,000 acre-feet in Stage 4 did not impact modeled spring flow levels. The model assumed that the reduction in SAWS pumping in Stage 3 and Stage 4 would be pumped by other Edwards Aquifer pumpers. That pumping was labeled "enhanced pumping."

There was considerable debate whether the "enhanced pumping" was a real phenomenon. The experience in 2009 was cited where it appears that ASR replacement water kept Aquifer levels from dropping into the Stage 3 zone. There was no rain and water use continued at Stage 2 levels but with no evidence of "enhanced pumping" as the Aquifer levels at J-17 and spring flow stayed steady for two months in a deep summer drought.

It is a question that will be answered in thorough examination of the MODFLOW mechanisms during the Adaptive Management process but in the meantime it appears that SAWS ASR use in Stage 3 and 4 may, in fact, have more impact on spring flow than credited by the model. This activity at least provides insurance that the Bottom Up activities will be capable of maintaining minimum spring flow.

The use of 40,000 acre-feet of SAWS ASR to fulfill the SAWS 2009 Water Management Plan Update does not reduce the ASR's ability to fulfill the requirements of the Bottom Up activities, it complements them. It will address or nearly address the challenges of maintaining spring flow at the Springs during modeled droughts that are severe enough to bring Comal spring flows below the 75 cfs trigger level but do not qualify as the drought of record.

Water for the EARIP SAWS ASR Project

The project identifies the need for 200,000 acre-feet of water to be injected prior to and during the drought of record to provide 126,000 acre-feet of replacement water for SAWS use in lieu of pumping Edwards' water.

The water could potentially come from the 50,000 acre-feet of new leases modeled for the project; water already stored in the SAWS ASR; SAWS excess water; Section 1.14(h) water; or some combination of the sources.

Factors to consider when determining the best source of water to use for the EARIP SAWS ASR Project include:

- SAWS needs to fulfill its 2009 Water Management Plan Update expectations for the ASR;
- Capabilities of the infrastructure;
- Costs of various options of water sources;
- Modeling impact on the mix of water selected;
- Impact to the agriculture industry in the region; and
- Impact on the water market.

The most desirable water supply option for the project would be the one that does not limit SAWS flexibility to meet the 2009 Water Management Plan Update or stretch capability of the SAWS ASR infrastructure. It is also desirable that the water source selected be relatively inexpensive and contributes to the full modeling impact expected from the project. It would also be best if the option selected caused minimal disruption to the viability of the regional agricultural industry and to the stability of the Edwards water market.

The best way to proceed seems to use 80,000 acre-feet (2/3 of the 120,000 acre-foot target) of water that will already be stored in the SAWS ASR at the time of HCP implementation in combination with new water from two sources. One-third of the planned 50,000 acre-feet of new water (16,667 acre-feet) would be leased immediately with the remaining injection water being obtained from leases obtained as the Drought of Record nears. The 50,000 acre-feet target for modeling would still be utilized and its need further investigated through Adaptive Management and model feedbacks.

The combination of new water and SAWS water will meet the requirement for injection water if the drought of record arrives, and causes less disruption to the water market and the agricultural industry during the period of Adaptive Management.

Fifty Thousand Acre-Feet of Leased Water to Fill the ASR

The 50,000 acre-feet of leased water that is included as part of the SAWS ASR activity is not required to fill the ASR. SAWS has sufficient water rights during the period of the HCP (15 years) that the topping-off could be accomplished with SAWS rights. The significance of the 50,000 acre-feet is more for its impact for contributing to spring flow as a reduction in pumping during the drought of record.

HDR reports that approximately half of the impact on spring flow for the project is credited to the fact that this water is not being pumped except to refill the ASR.

This proposal attempts to duplicate the spring flow impact of the original SAWS ASR activity modeled by HDR in a manner that reduces costs and disruption to both by managing the leasing in a different manner than was originally visualized.

One-third of the 50,000 acre-feet of water will be leased with the implementation of the HCP. The second-third will be leased when the "10-year Rolling Recharge Average" reaches 572,000 acre-feet and the third portion will be leased when and if the average reaches 450,000 acre-feet. To insure that the water is available, options at $40 per year will be purchased with $150 per year paid when the options are called in.

The leases will be for five years with an option to extend for an additional five years. This system will allow the water to be used for ASR topping-off if necessary and will allow the water to be unpumped when SAWS ASR is returning water to SAWS during the drought of record.

It is believed that the majority of the spring flow impact from retirement of the 50,000 acre-feet occurs during the drought of record. Because of the "Enhanced Pumping" phenomenon, impact is minimal when the Edwards Aquifer is at Stages 1, 2, 3 and 4 levels or greater.

Costs

The SAWS ASR cost in excess of $250 million to construct. The SAWS ASR activity of the EARIP calls for use of approximately 2/3 of its capacity. Depreciating the asset over 52 years provides for $4.8 million depreciation per year. Two-thirds of that amount is $3.216 million.

Yearly maintenance costs, if the SAWS ASR is in a relaxed injection mode, are $2 million. During the drought of record "topping off" and pumping period costs will increase significantly, largely due to electric costs. The costs to inject an extra 160,000 acre-feet and pump back 126,000 acre-feet during the seven years drought of record period would be approximately $28 million. This would be costs in excess of the $2 million per year.

If only one drought of record occurred in the next 52 years (probability less than 0.03% over 15 years) the share of the maintenance cost due to the EARIP commitment would be $1.33 million due to 2/3 of regular costs and an extra $.54 million per year to pay for the reserve necessary to address a drought of record. Adding a second drought of record would increase the reserve to $1.08 million per year.

The SAWS ASR Project also calls for the leasing of 50,000 acre-feet of water to fill the SAWS ASR prior to the drought of record and to refill it after the drought of record. The cost of that water would be $6,250,000 at a lease price of $125 per acre foot per year.

The $6,250,000 per year has been identified to lease water in order to fill the ASR prior to its need for the drought of record. In the scenario where 16,667 acre-feet is immediately leased and the remaining 33,333 acre-feet is optional at $40 per year to be leased for 10 years when the drought of record is identified at $150 per acre-foot, remainder is leased as the arrival of the drought of record is identified by the 10-year recharge average, $3,351,625 per year would be accumulated until it reaches $50,250,000 (15 years), the estimated cost to lease the additional 33,333 acre-feet of Edwards water identified for filling the ASR in the modeling.

At that point, if the drought of record is not imminent, the collection of the $3,351,625 can be discontinued until the drought of record arrives. This arrangement can be altered as part of the Adaptive Management decision making process.

Note: At a lease price of $125 per acre-foot per year, the initial 16,667 acre-feet would cost $2,083,375 per year. The water obtained at the 572,000 acre-feet 10-year recharge target would cost $150 per year per acre-foot and the 16,667 acre-feet leased at 450,000 acre-feet 10-year recharge target would cost $150 per acre-foot. The water would be leased for 10 years during a drought of record. Total additional costs of that water would be $50,250,000 per Drought of Record.

If two occurrences of the drought of record are planned for in 52 years as per the costing analysis described, the cost would be $100,500,000 for the extra leased water to reach the 50,000 acre-feet identified in the HDR analysis.

With depreciation at $3.22 million, O&M at $3.08 million and water costs at $6.25 million per year, the SAWS ASR Project would cost $12.55 million per year.

Adaptive Management

The SAWS ASR activity as described lends itself to the Adaptive Management approach in several areas including management, water supplies and cost in addition to the primary issue of providing a certain amount of water for enhanced spring flow at Comal and San Marcos Springs.