April 14, 2016

San Bernardino Valley Municipal Water District
Attn: Wen Huang, P.E., Manager of Engineering
380 East Vanderbilt Way
San Bernardino, CA 92408

Re: Active Recharge Project – Preliminary Basin, Diversion Design and Recharge Modeling (Draft Report)

Dear Mr. Huang:

This report provides a summary of the preliminary design analysis and groundwater recharge modeling performed by Scheevel Engineering for the development of various basins and features associated with the San Bernardino Valley Municipal Water District's (Valley's) Active Recharge Project (ARP). A total of 8 new sites were evaluated for the feasibility of adding new groundwater recharge basins and/or in-channel recharge features. Additionally, there were a total of 5 existing San Bernardino County Flood Control District (SBCFCD) sites and 1 San Bernardino Valley Water Conservation District (SBVWCD) facility that were evaluated for modifications and re-operation which would enhance groundwater recharge opportunities in the area.

Operations and maintenance (O&M) modeling, historical data review, existing technical document review, new technical analysis, stakeholder meetings and site visits have been completed which provide the basis for the designs and recommendations presented in this report. The preliminary designs presented here represent a 15%-30% level of design effort.

Scheevel Engineering greatly appreciates the opportunity to provide consulting services to Valley and looks forward to working with you on the next phase of this project. Please do not hesitate to contact me with any questions you might have.

Sincerely,
Scheevel Engineering

Nate Scheevel, P.E.
President

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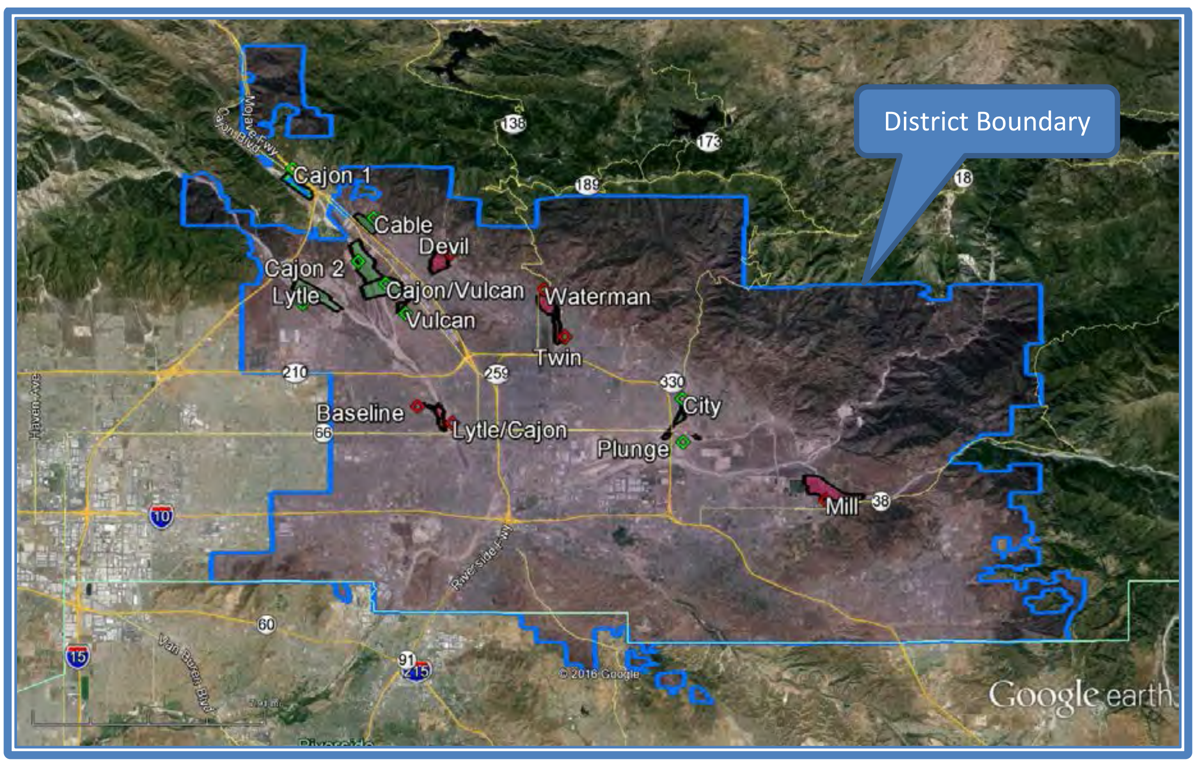
Background Information & Site Selection

The Active Recharge Project (ARP) is being cooperatively developed through a three agency agreement between Valley, City of Riverside Public Utilities (RPU) and Western Municipal Water District (Western), with Valley acting as the lead agency. The project benefit will be realized by constructing new basins, in-channel recharge features, existing facilities improvements and re-operating existing basins to capture and infiltrate storm water in basins immediately adjacent to the creeks, as well as in the creeks themselves.

The ARP includes the construction of multiple storm water capture and groundwater recharge basins, diversions and in-channel recharge features in various creeks in San Bernardino County, CA. The project sites are located within Valley District's boundary area outlined in blue in Figure 1 . The sites considered for the ARP were selected, in part, based on their proximity to a water course which has the potential to provide significant storm flow, the sites position within the groundwater basin. From a hydrogeology standpoint, it is considered beneficial to perform groundwater recharge activities at higher elevations within a groundwater basin. The following considerations also played a major role in selecting the sites for the ARP; 1) availability of the property for long-term uses associated with groundwater recharge facilities, 2) the relative level of environmental impact, 3) the opportunity to enhance native habitat types, 4) the ability to maintain and/or complement flood control objectives, 5) the opportunity to enhance the groundwater recharge capabilities of existing facilities and, 6) construction feasibility including capital cost and long term O&M considerations.

Figure 1: Project Site Overview Map



A total of 14 sites were selected for preliminary screening and evaluation. The proposed sites for new facilities can be seen in Figure 1 as delineated by green shaded polygons and green diamond callouts. The proposed sites for the improvement and/or re-operation of exciting facilities can be seen in Figure 1 as delineated by red shaded polygons and red diamond callouts. The preliminary evaluation included site visits, topographic survey reviews, conceptual design renderings of basins/diversions and/or in-channel design features, and preliminary hydraulic analysis. Additionally, a series of stakeholder meetings occurred which helped develop design concepts and reveal "fatal flaws" with a given site or design concept. Through the preliminary evaluation process a total of 2 sites were removed from further evaluation.

The 2 sites screened out during the preliminary evaluation included the Baseline site and the Cajon 2 site. The Cajon 2 site was initially planned to include 75 acres of in-channel recharge zones spread over a 470 acre area in Cajon Creek immediately upstream of Institution Road. Through inter-agency coordination with SBCFCD it was determined that large portions of the proposed Cajon 2 improvement area conflicted with zones set aside as mitigation areas.

The Baseline site is a series of 3 existing flood control/storm water attenuation basins. The proposed improvements at the Baseline site included minor improvements to the existing inlet and outlet structures along with re-operating the low-level drain tubes to hold storm water at higher elevations for longer durations. Constraints regarding available information of the existing basins and their operation, as well as project advancement constraints prevented a full evaluation of this site for the ARP. Further evaluation of the Baseline site at a future date may be prudent to reveal the full potential of the groundwater recharge capabilities of the existing Baseline Basins.

Twelve of the original 14 sites were selected for a more thorough analysis and preliminary design development. Additional hydraulic analysis was performed in order to better position the diversion structures and locate the extents of the proposed new basins relative to the existing flow paths of the adjacent creeks. Additional design details were also developed and added to each conceptual design to better identify the improvements needed at each site to achieve the desired function and benefit of the proposed recharge facility.

Groundwater Recharge Operations Modeling

A detailed groundwater recharge operations model was also developed for each new, and existing, recharge site to predict the storm water capture and groundwater recharge benefit of each proposed improvement. The groundwater recharge model was also used to help select the diversion style (adjustable dam or sand berm), optimize the diversion design capacity and define the operational parameters of each diversion.

The groundwater recharge model for each site provided valuable information used to determine the maintenance requirements of a given design configuration. Primarily, the recharge models help estimate the sedimentation rates and infiltration rate decays for each diversion and basin configuration. The sedimentation rate estimates and infiltration rate decays provide the basis for developing basin cleaning schedules and material handling and disposal requirements.

Once a conceptual design was established for each site, then a recharge operations model was developed specific to the conceptual design. A series of 31 day model runs were then performed using different diversion types, diversion flow rates and operational assumptions. The model iterations were used to determine the final design parameters for each site.

After each design was optimized through the iterative process described above, then an 11 year flow data set was run through each model for each proposed recharge site. The results of the 11 year model runs define the project benefit for each proposed recharge site in the ARP. A summary of all of the recharge sites and their respective 11 year model runs can be found below in Table 1, a more detailed description of each model and analysis can be found later in this report.

Table 1: Project Benefit Summary

Recharge Site Name	Total 11 Year Project Benefit (af)	Average Annual Project Benefit (af/yr)
Station #1 (Mill Creek) Existing North 55 cfs	57,299	5,209
Station #1 (Mill Creek) North 110 cfs	59,455	5,405
Station #1 (Mill Creek) North 210 cfs	67,051	6,096
Station #2 (Plunge Creek 1)	27,286	2,481
Station #2 (Plunge Creek 2)	11,555	1,050
Station #3 (City Creek)	57,713	5,247
Station #5 (Waterman)	18,421	1,675
Station #6 (Twin Creek)	44,956	4,087
Station #7 (Lytle Creek)	44,256	4,023
Station #8 (Cable Creek)	32,760	2,978
Station #10 (Devil Creek)	39,937	3,631
Station #11 (Cajon Creek)	13,533	1,230
Station #12 (Cajon Creek/Vulcan 1)	15,902	1,446
Station #13 (Vulcan 2)	37,850	3,441
Station #14 (Lytle-Cajon Creek)	37,485	3,408

The 11 year flow series for each site was developed through a watershed model by Geoscience Support Services, Inc. and provided to Scheevel Engineering for use as the input to the groundwater recharge operations model for each site. A flow station was identified which is geographically specific to each site. Each station was selected to be immediately upstream of a proposed diversion or at the upstream end of an in-channel recharge facility. The station numbers referenced in Table 1 can be seen geographically in Figure 2 - Figure 5. The station numbers are also referenced throughout the remainder of this report as a way to identify each site and each site's available flow.

The flows used in the recharge models are average flow rates at 1 hour time steps with units in cubic feet per second (cfs). Station numbers 4 and 9 were omitted from the analysis because the project alternatives that were originally intended for those locations were removed from the preliminary evaluation due to redundancy and based on professional judgment relating to excessive cost associated with placing diversions at those locations.

Figure 2: Flow Stations 1-4

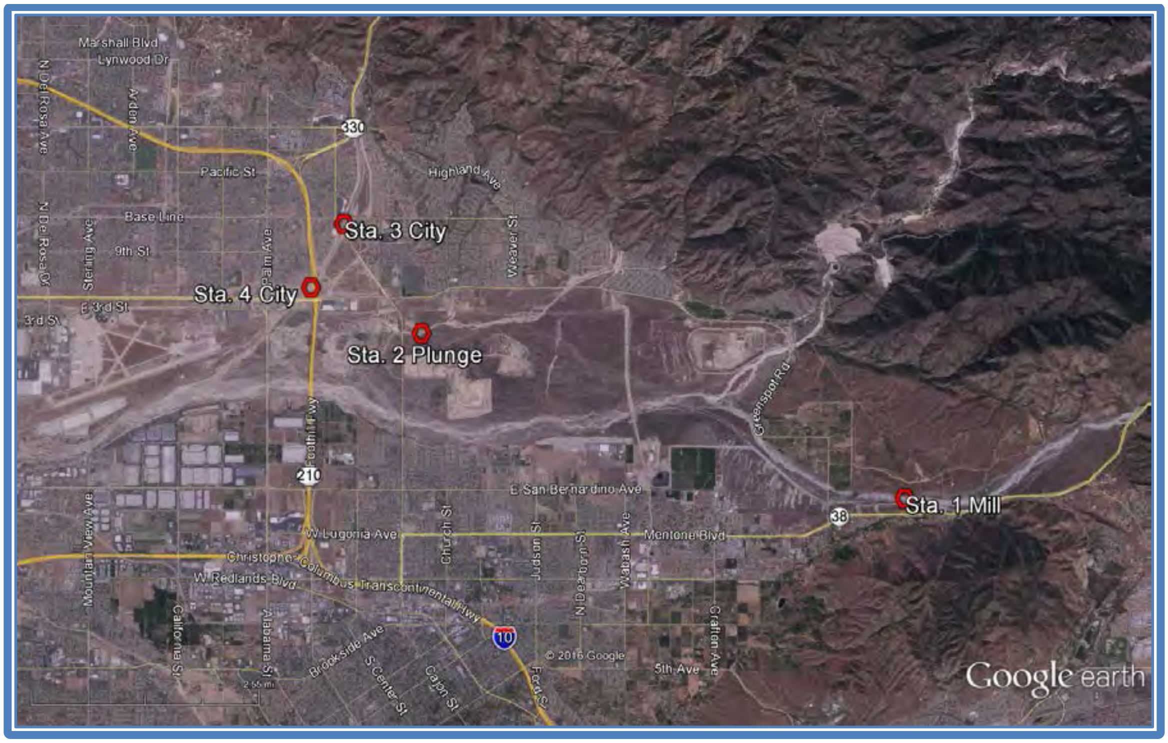


Figure 3: Flow Stations 5 & 6

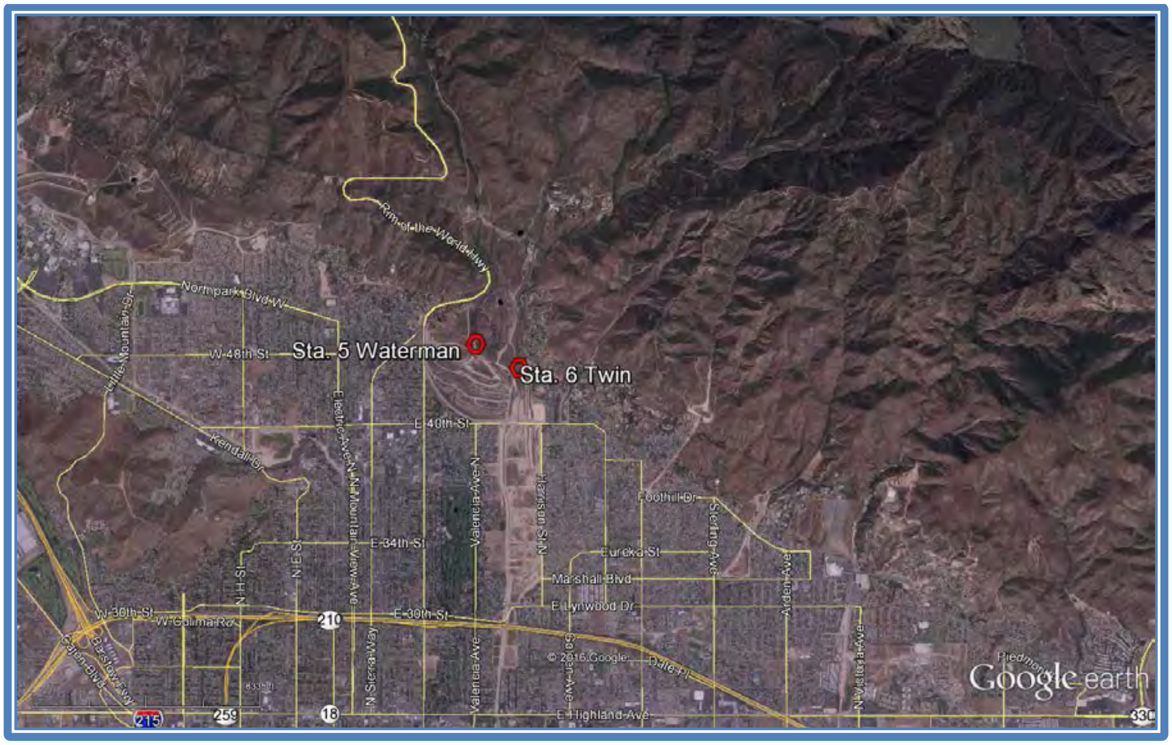


Figure 4: Flow Stations 7-13

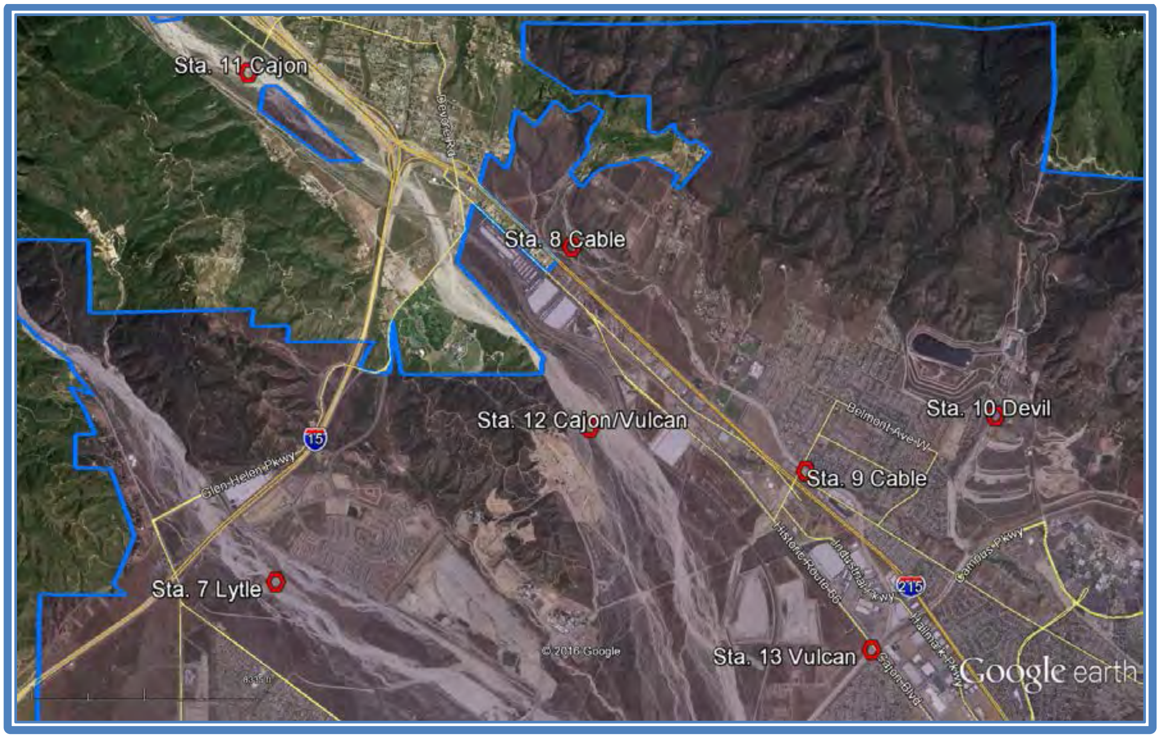


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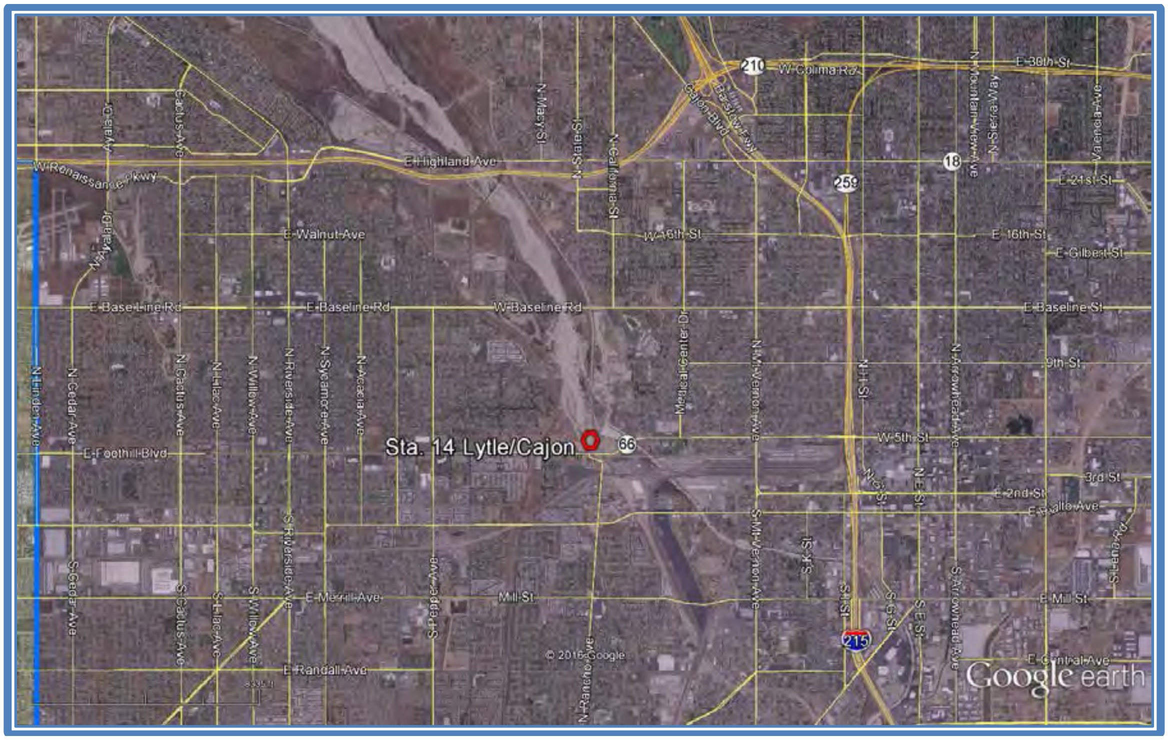
Figure 5: Flow Station 14



Site Specific Evaluations

The following sections provide a detailed description of the analyses and results for each of the 12 recharge sites selected for detailed evaluation. The conceptual designs and analysis presented here provide the basis for the cost analysis for each recharge site. The evaluations are listed in numerical order according to flow station ID number and do not represent a ranking or prioritization of any kind. Additional discussion between project stakeholders should occur regarding the pros and cons of implementing a project at each recharge site.

The general format and layout of each of the following sections in this report are very similar to allow for ease of comparison between projects. Each of projects selected for detailed evaluation have a limited number of conceptual design figures included here. A more complete and detailed conceptual design has been provided under separate submittal in video format.

Mill Creek (Station 1)

Existing Conditions

The SBVWCD owns and operates the Mill Creek Spreading Facilities located along the southern edge of Mill Creek approximately 3.0 miles south of Seven Oaks Dam. The spreading facilities include approximately 53 small (each less than 3 acres) recharge

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basins with a total maximum wetted are of 47 acres and total storage volume of approximately 160 af.

Storm flow is diverted out of Mill Creek by a series of berms and then conveyed along the toe of the southern U.S. Army Corps of Engineers (USASCE) levee to the diversion headworks (Figure 6). A project is currently underway to improve the diversion headworks which will allow for the diversion of higher flows for longer periods of time. If the diversion improvements can be designed to utilize the carrying capacity of the downstream diversion channel, then an estimated 300 cfs can be diverted at the headworks. Flows that are diverted at the diversion headworks are then conveyed to the west along the toe of the USACE levee to a canal inlet/flow splitting structure (Figure 7). Flows are then split to the South Canal, or to the North Canal or bypassed back into Mill Creek. Flows that enter one of the canal systems are then conveyed to the recharge basins for infiltration into the groundwater basin. Currently the flow capacity at the South Canal turnout is approximately 175 cfs and the flow capacity at the North Canal turnout is approximately 55 cfs for a total combined capacity of 230 cfs.

Figure 6: Mill Creek Diversion Headworks (Looking West)

Figure 7: Mill Creek Canal Inlets (Looking West)

Proposed Improvements

Restrictions in the diversion and canal inlet structures result in an underutilization of the full wetted area and storage volume of the existing Mill Creek Basins. The diversion project currently underway will increase the diversion flow capacity at the diversion headworks and reduce the frequency of diversion berm/soft plug blow-outs. The next restriction in the system is the canal inlet structure. The South Canal inlet flow capacity is approximately 175 cfs which is more than 3 times greater than the North Canal inlet flow capacity of 55 cfs.

The proposed project for the ARP is to demolish the existing inlet and reconstruct the canal inlet structure while at the same time increasing the diversion flow capacity of the North Canal Inlet. Additionally, the bypass outlet of the structure will be re-designed and re-constructed to increase the sediment bypass function of the structure.

A series of model iterations were performed to help determine the target design flow for the new North Canal inlet. Two new North Canal inlet flow rates were considered for this project, 110 cfs and 210 cfs. Based on the analysis presented in the modeling results it

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was determined that a significant benefit (approx. 690 af/yr more) would be realized by increasing the North Canal inlet flow capacity to 210 cfs instead of 110 cfs. If the North Canal inlet is increased to 210 cfs, then there will be the need to increase the flow capacity of one additional downstream structure to allow the diverted flow to reach the recharge basins. The existing North Canal piping under the USACE flood control wall has a capacity of approximately 110 cfs, this conveyance will also need to be upgraded to allow a total of 210 cfs to pass underneath the USACE flood control wall.

The proposed improvements for the ARP at the Mill Creek Spreading Facilities include removal of the existing canal inlet structure, construction of a new North Canal inlet with a capacity of 210 cfs, construction a new South Canal inlet gate, construction a new bypass outlet structure with sediment transport features and improvements to increase the capacity of the conveyance under the USACE flood control wall. The following figures provide a conceptual design of the proposed improvements.

Figure 8: Mill Creek Canal Inlet Conceptual Design (Plan View)

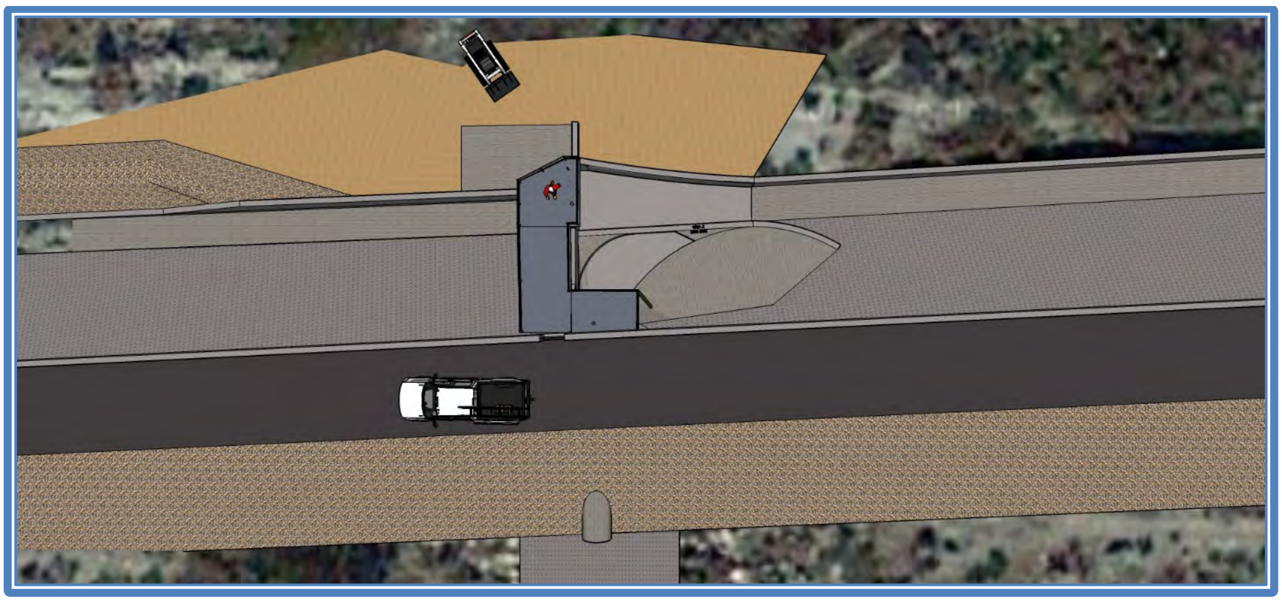

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Figure 9: Mill Creek Canal Inlet Conceptual Design (Looking Downstream)

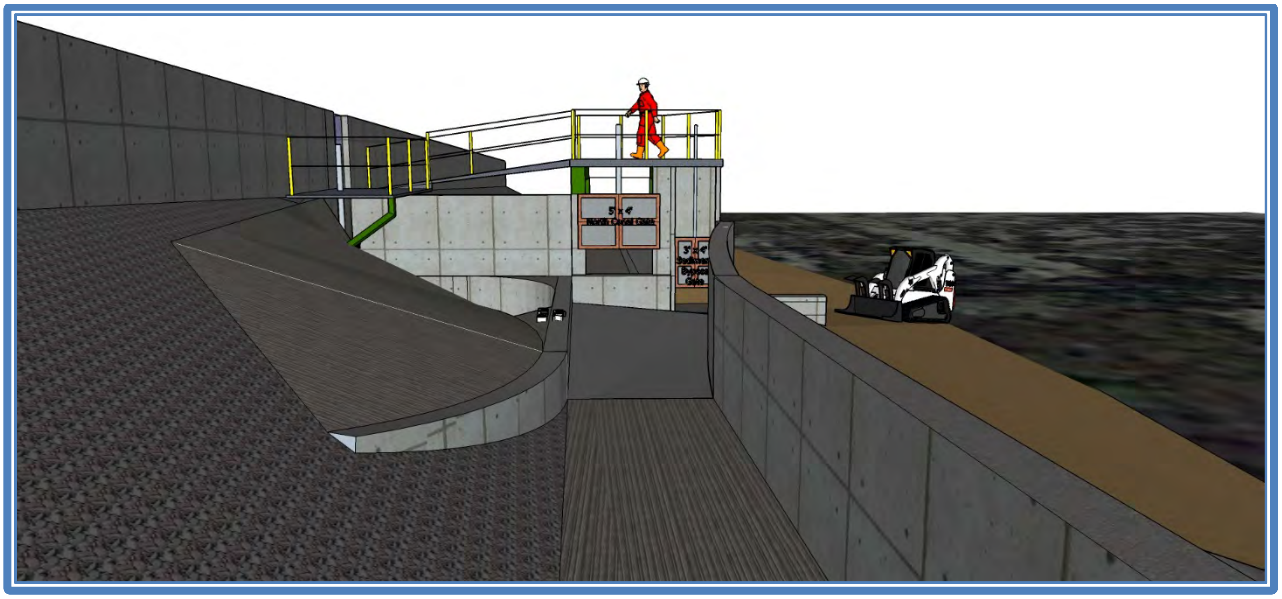

Figure 10: Mill Creek Canal Inlet Conceptual Design (North Canal Gate)

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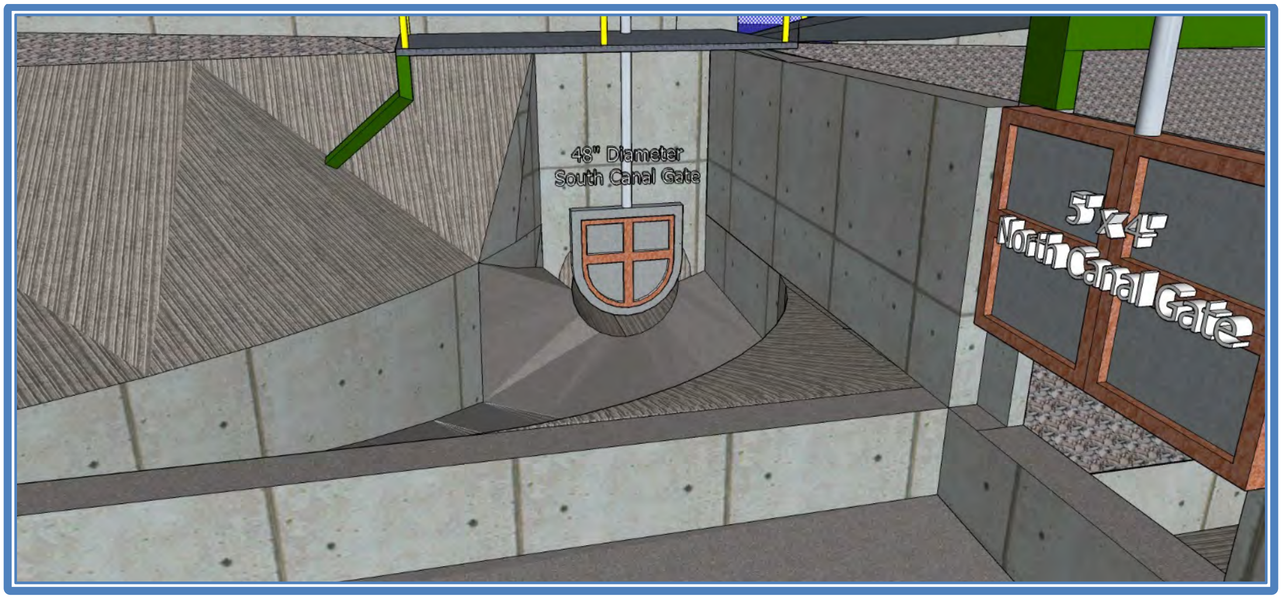
Figure 11: Mill Creek Canal Inlet Conceptual Design (South Canal Gate)



Modeling Results & Design Optimization

A recharge operations model was developed to estimate the potential benefit due to the proposed improvements. The primary model variables required to model the system include the following;

1) Mill Creek flow hydrographs,
2) Basin areas and volumes,
3) Initial infiltration rates,
4) Infiltration rate decay parameters,
5) Diversion flow capacity,
6) Canal inlet flow capacity, and;
7) Soft plug wash-out flow rate.

Unlike other recharge sites in the ARP, Mill Creek is currently managed and operated specifically for groundwater recharge purposes, requiring more extensive analysis to determine the relative benefit from the proposed improvements. A model was developed to estimate the benefit due to the existing conditions at the site. The results of the base case scenario were then compared to 2 alternatives (110 cfs North Inlet and 210 cfs North Inlet). Recall that the existing North Canal inlet has a capacity of approximately 55 cfs. The model assumptions used in the base case scenario can be seen in Table 2. Please note that only 1 example of 1 basin's infiltration rate decay curve has been included in this report. The infiltration rate decay of each basin varies with every storm event, and in order to illustrate the rate at which the infiltration rate decays a continuous flow was run through the model for 31 days.

Table 2: Mill Creek Model Base Case Assumptions

Mill Creek flow hydrographs	See Figure 12
Basin areas and volumes	Area = 47 acres, Volume = 160 af
Initial infiltration rates	3.4 ft/day
Infiltration rate decay parameters	See Figure 13 (200 cfs continuous flow)
Diversion flow capacity	300 cfs
Canal inlet flow capacity	South = 175 cfs, North = 55 cfs
Soft plug wash-out flow rate	500 cfs

Figure 12: Mill Creek Flows

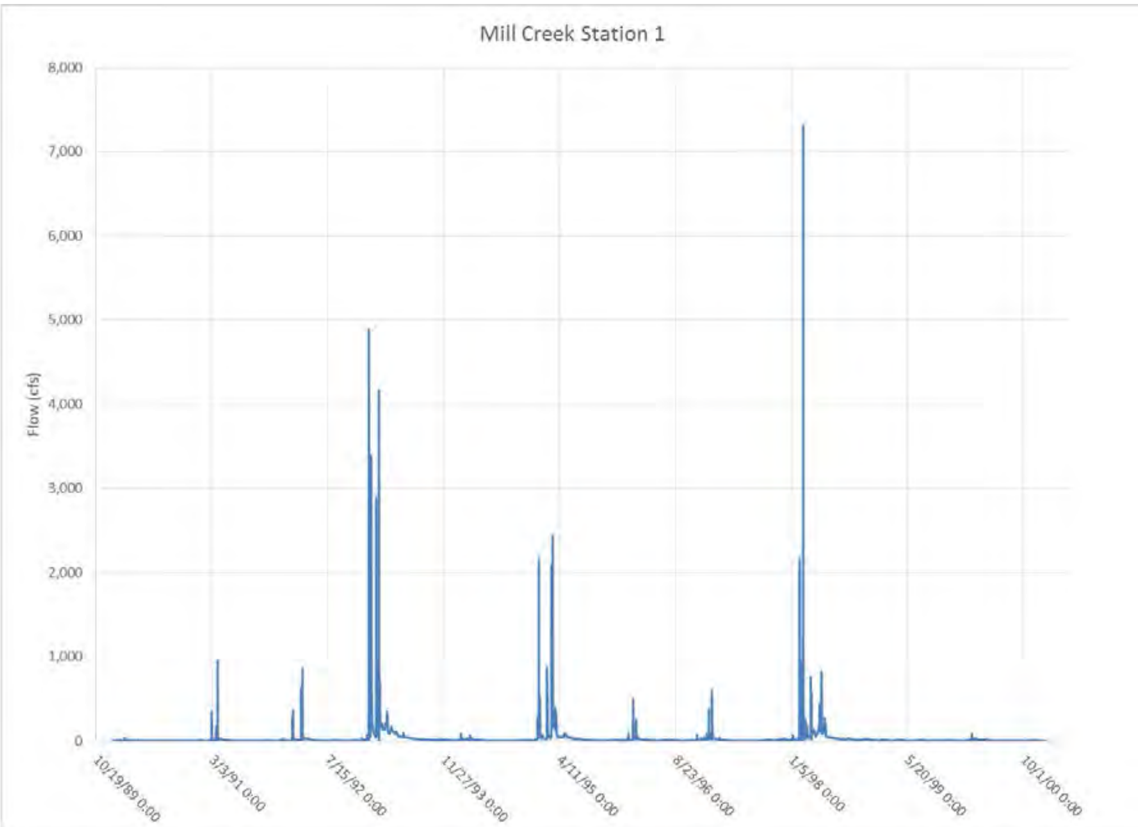


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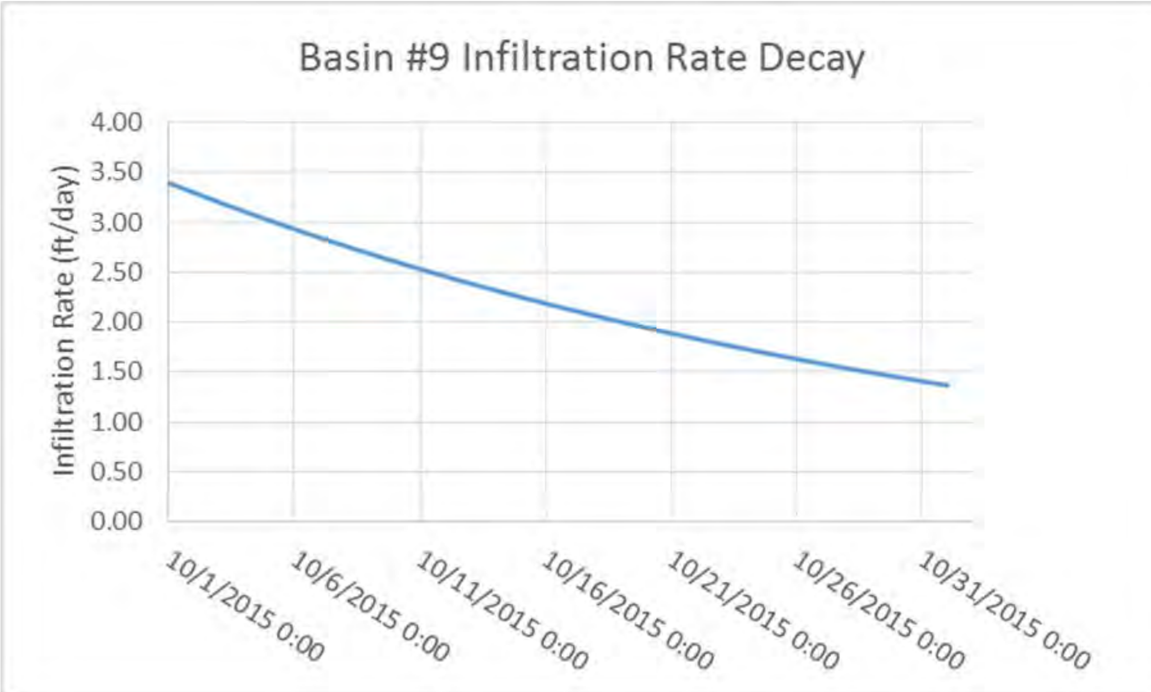
Figure 13: Mill Creek Infiltration Rate Decay North 55 cfs (First 2 Basins on North Canal)



All of the flow from the 11 year data set was run through the base case model to produce the total amount of storm water captured and recharged during that period. The final base case model results can be seen in Table 3.

Table 3: Mill Creek 11 Year Model Results (55 cfs)

Total Available Flow (af)	171,558
Total Flow Captured & Recharged (af)	57,299
Total Flow Bypassed (af)	114,259
Annual Average Flow Captured & Recharged (af)	5,209

Proposed North Canal – 110 cfs

The groundwater recharge model that was developed for the base case scenario was then modified to account for an increase in the flow capacity of the North Canal inlet. All of the model variables were held constant except for the North Canal inlet flow capacity which was increased to 110 cfs. The existing capacity of the conveyance at the USACE flood control wall is 110 cfs. This project alternative would require no improvements to the flood control wall undercrossing.

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Table 4: Mill Creek Model North Canal 110 cfs Assumptions

Mill Creek flow hydrographs	*See Figure 12
Basin areas and volumes	*Area = 47 acres, Volume = 160 af
Initial infiltration rates	*3.4 ft/day
Infiltration rate decay parameters	*See Figure 13 (200 cfs continuous flow)
Diversion flow capacity	*300 cfs
Canal inlet flow capacity	South = 175 cfs, North = 110 cfs
Soft plug wash-out flow rate	*500 cfs

*Same as base case scenario

All of the flow from the 11 year data set was run through the North Canal inlet 110 cfs scenario model to produce the total amount of storm water captured and recharged during that period. The final results can be seen in Table 5

Table 5: Mill Creek 11 Year Model Results (110 cfs)

Total Available Flow (af)	171,558
Total Flow Captured & Recharged (af)	59,455
Total Flow Bypassed (af)	112,103
Annual Average Flow Captured & Recharged (af)	5,405

The 110 cfs scenario results in an average annual increase of 200 af/yr of additional storm water capture and recharge over the base case scenario.

Proposed North Canal – 210 cfs

The base case groundwater recharge model was once again modified to account for an increase in the flow capacity of the North Canal inlet. All of the model variables were held constant except for the North Canal inlet flow capacity, which was increased to 210 cfs. The existing capacity of the conveyance at the USACE flood control wall is 110 cfs. This project alternative would require an increase to the capacity of the conveyance system at the flood control wall undercrossing.

Table 6: Mill Creek Model North Canal 210 cfs Assumptions

Mill Creek flow hydrographs	*See Figure 12
Basin areas and volumes	*Area = 47 acres, Volume = 160 af
Initial infiltration rates	*3.4 ft/day
Infiltration rate decay parameters	*See Figure 13 (200 cfs continuous flow)
Diversion flow capacity	*300 cfs
Canal inlet flow capacity	South = 175 cfs, North = 210 cfs
Soft plug wash-out flow rate	*500 cfs

*Same as base case scenario

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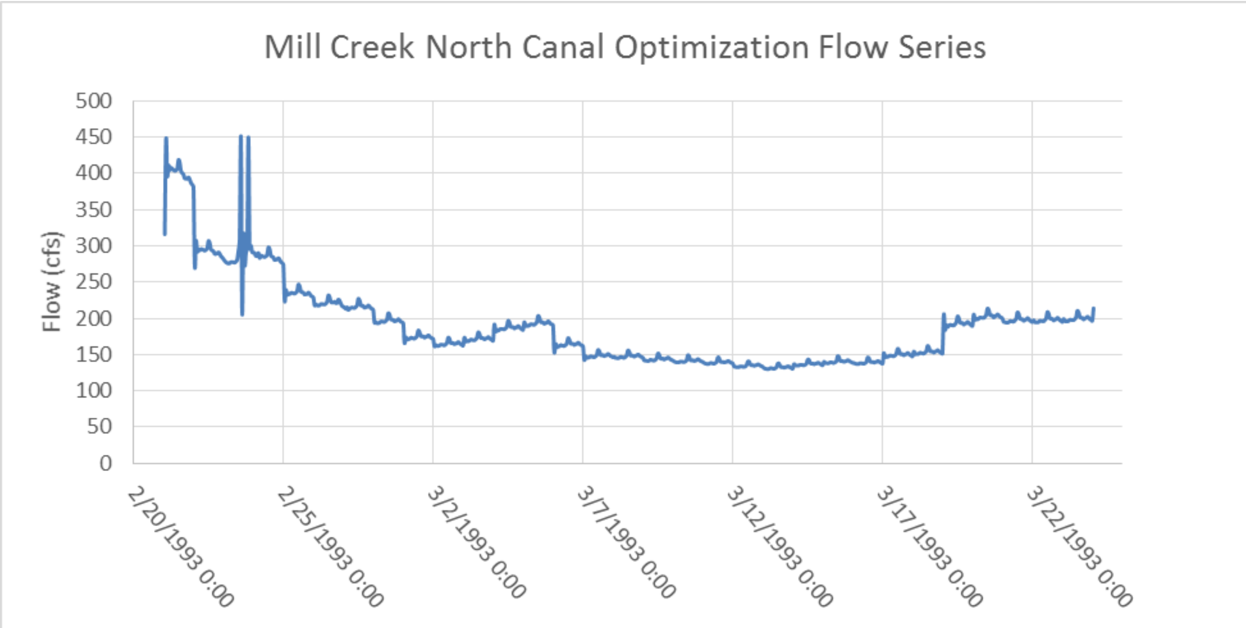
All of the flow from the 11 year data set was run through the North Canal inlet 210 cfs scenario model to produce the total amount of storm water captured and recharged during that period. The final results can be seen in Table 7

Table 7: Mill Creek 11 Year Model Results (210 cfs)

Total Available Flow (af)	171,558
Total Flow Captured & Recharged (af)	67,051
Total Flow Bypassed (af)	104,507
Annual Average Flow Captured & Recharged (af)	6,096

The 210 cfs scenario results in an average annual increase of 887 af/yr of additional storm water capture and recharge over the initial base case scenario. The increase in the benefit as the capacity of the North Canal increase is not linear because of the system's ability to fill otherwise un-wetted basins at the higher inlet rates. In order to explore whether or not an even higher North Canal inlet capacity would be beneficial, a series of 31 day model runs were performed to test the sensitivity of the benefit to the North Canal inlet size. All model parameters were held constant except for the North Canal inlet size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 12 as the inflow for the optimization model period (Figure 14).

Figure 14: Mill Creek Optimization Flow Series



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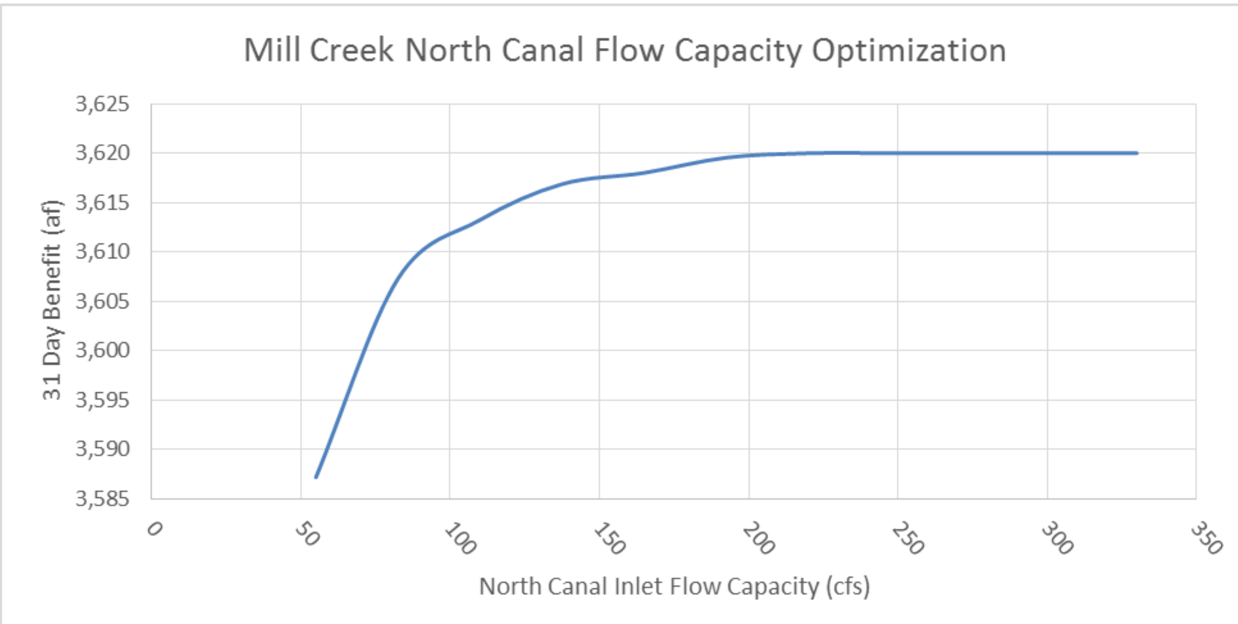
The existing inlet size flow capacity was increased by 50 cfs, in steps up to 330 cfs. The total benefit for the 31 day flow series given each North Canal inlet flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 15). It should be noted that approximately 50 af of water is bypassed around the system even at the highest North Canal inlet flow rates, this is because all of the basins are full and operating at maximum capacity. The optimum size for the North Inlet is approximately 210 cfs. In order to achieve an even higher benefit, additional basins would need to be constructed and/or existing basins would need to be expanded.

Figure 15: Mill Creek North Canal Inlet Optimization Results



Operation & Maintenance

The operation and maintenance of the Mill Creek Spreading Facilities would increase from what is currently experienced if the North Inlet capacity is increased. The proposed project would require that operators visit the spreading facilities more frequently because the higher inlet capacity will fill more of the basins in shorter durations. Additionally, basins that seldom receive water would become wetted more frequently which in turn would increase the clogging (silt and clay) loading in the basins and the rate at which vegetation grows. While there is expected to be an increase in clogging sediments delivered to the basins, the overall sediment loading of the basins are expected to decrease by re-designing the canal Inlet/Bypass structure to flush and bypass more bedload sediment back into Mill Creek. Based on infiltration rate decay trends observed

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in the groundwater recharge model it has been assumed that the basins will require 1 cleaning per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basins. The 11 year total, and annual average, sediment loading for the base case (55 cfs) and the preferred alternative (210 cfs) is presented in Table 8. The overall reduction in loading could be realized by constructing bed-load sediment bypass features into the system.

Table 8: Mill Creek Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Existing Condition	7,010	637
Proposed Project	5,635	512

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

Table 9: Mill Creek Cost Estimate

Capital Costs			Mill Creek Inlet		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 35,000	$ 35,000
2	SWPPP	L.S.	-	$ 75,000	$ -
3	Sheeting/Shoring/Bracing	L.S.	1	$ 15,000	$ 15,000
4	Survey	L.S.	1	$ 5,000	$ 5,000
5	Construction Water	L.S.	1	$ 3,500	$ 3,500
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	-	$ 25,000	$ -
8	Clearing & Grubbing	AC	1	$ 1,500	$ 1,500
9	On-Site Grading	Yd^3	500	$ 5	$ 2,500
10	Material Export	Yd^3	50	$ 12	$ 600
11	Finish Grading	AC	1	$ 300	$ 300
12	Access Roads	AC	-	$ 90,000	$ -
13	Dam Foundation	L.F.	-	$ 12,000	$ -
14	Rubber Dam & Equipment	L.S.	-	$ 800,000	$ -
15	Downstream Channel Improvements	L.F.	50	$ 500	$ 25,000
16	Diversion Structure	L.S.	1	$ 750,000	$ 750,000
17	USACE Flood Wall Crossing	L.S.	2	$ 150,000	$ 300,000
18	Control Building	L.S.	1	$ 45,000	$ 45,000
19	Rip Rap Slopes	S.F.	850	$ 12	$ 10,200
20	Diversion Piping (48-inch RCP)	L.F.	100	$ 500	$ 50,000
21	Transfer Piping (72-inch dia. RCP)	L.F.	-	$ 800	$ -
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	-	$ 450	$ -
23	Flood Wall Inlet Structure	L.S.	1	$ 45,000	$ 45,000
24	Laydown Pad	L.S.	1	$ 10,000	$ 10,000
25	Flood Wall Outlet Structure	L.S.	1	$ 25,000	$ 25,000
26	Surface Transfer Structure (Weir)	L.S.	-	$ 850,000	$ -
27	Outlet Energy Dissipaters	L.S.	-	$ 30,000	$ -
28	5' x 4' Gate	L.S.	1	$ 60,000	$ 60,000
29	48-inch Gate	L.S.	2	$ 45,000	$ 90,000
30	3' x 4' Gate	L.S.	1	$ 40,000	$ 40,000
31	Catwalks	L.S.	1	$ 45,000	$ 45,000
32	Equipment Electrical	L.S.	1	$ 35,000	$ 35,000
33	Flow Control Gate Electrical	L.S.	1	$ 25,000	$ 25,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	-	$ 175,000	$ -
36	SCADA	L.S.	-	$ 350,000	$ -
37	Diversion Flow Meter	L.S.	2	$ 25,000	$ 50,000
38	Low Flow Meter	L.S.	1	$ 20,000	$ 20,000
39	Level Sensor	L.S.	2	$ 10,000	$ 20,000
40	Monitoring Well	L.S.	-	$ 75,000	$ -
41	Start-Up & Testing	L.S.	1	$ 15,000	$ 15,000
42	Perimeter Fencing (Chain Link)	L.F.	250	$ 45	$ 11,250
43	Mitigation	AC	1.0	$ 25,000	$ 25,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 35,000	$ 35,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 109,743
48	Material Testing	%	0.5%		$ 10,974
49	Contingency	%	10%		$ 219,485
	Total Capital Costs				$ 2,595,052
	Annual Debt Service (5% @ 30 years)		0.06505		$ 168,808

Annual O&M Costs			Mill Creek Inlet		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Diversion Berm & Bypass	L.S.	-	$ 15,000	$ -
2	Inlet Structure	L.S.	1	$ 15,000	$ 15,000
3	Sediment Bypass Outlet	Day	20	$ 1,000	$ 20,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 50,000	$ 500
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 10,000	$ 10,000
6	Valve & Gates	L.S.	1	$ 8,500	$ 8,500
7	Fences, Access Roads & Control Building	L.S.	1	$ 5,000	$ 5,000
8	Basin Cleanings	Yd^3	-	$ 2	$ -
9	Material Export	Yd^3	-	$ 12	$ -
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 69,000

Project Benefit Summary			Mill Creek Inlet		
	Total Annual Project Cost	$			$ 237,808
	Average Annual Benefit	AF/YR			887
	Average Annual Recharge Unit Cost	$/AF			$ 268

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Plunge Creek (Station 2) – Basin 1

Existing Conditions

The Plunge Creek Basin 1 site is located approximately 800 feet north-west of the Orange Street/Plunge Creek crossing in the City of Highland. The proposed diversion and basin would be situated within the existing flow path of Plunge Creek in an area approximately 13 acres in size. The site is located in a wide area of the channel which would allow for flows to be diverted around the basin but still remain in the active Plunge Creek channel.

Water flows to the site from east to west under Orange Street before dropping approximately 28 feet in elevation, down a sloped reinforced concrete drop structure into the forebay of the proposed diversion area. The project site is currently aggrading due to sedimentation from relatively lower flow velocities in the wide area of the channel. Coordination with SBCFCD revealed that the north-east corner of the project area is planned to receive a new storm water inlet from drainage areas to the east.

Figure 16: Plunge Creek Basin 1 Overview

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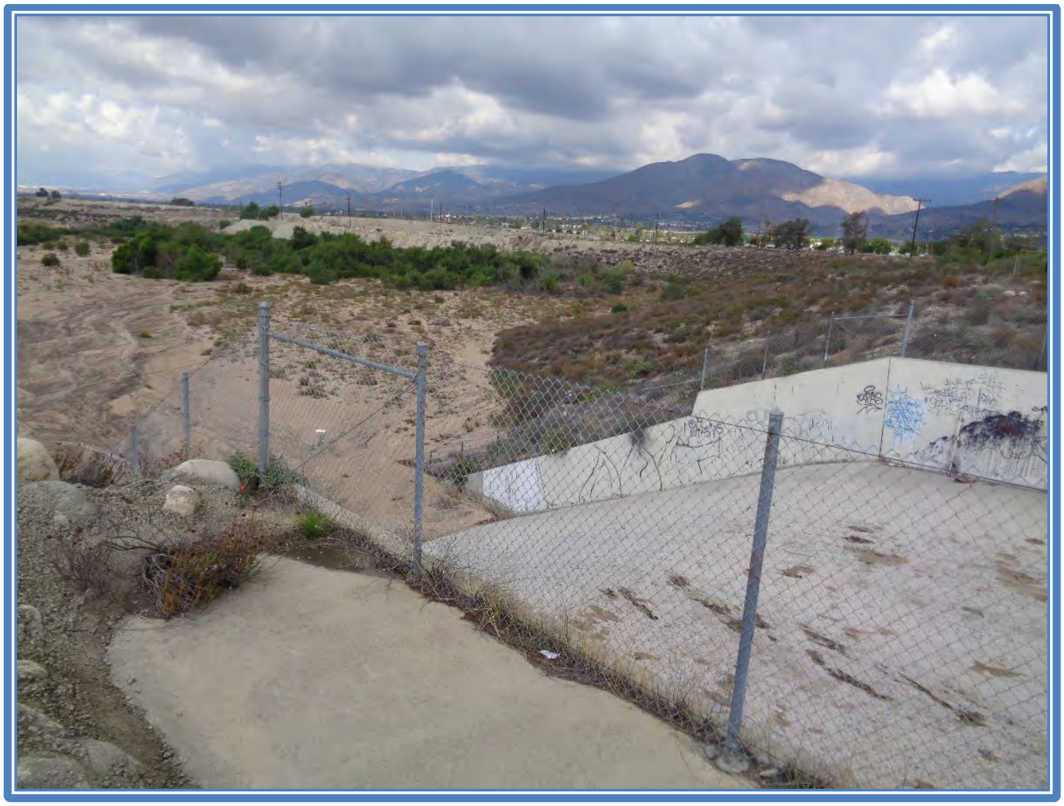
Figure 17: Plunge Creek Basin 1 Site (Looking North-West)



Proposed Improvements

The proposed improvements at Plunge Creek site 1 for the ARP is to construct a basin, 7' diameter x 210' long rubber dam and diversion structure within Plunge Creek. The basin layout has been developed with adequate setback from the reinforced concrete drop structure and the SBCFCD storm water inlet project. The southern edge of the new basin will act as a levee to channelize flow past the basin. The southern tip of the proposed basin will be the point at which the basin berm constricts Plunge Creek, this will also be the location for the construction of an inflatable rubber dam diversion.

The rubber dam diversion was intentionally placed near the creek constriction to increase velocities and help encourage sediment transport past the dam and diversion structure. A rubber dam was selected for this site due to the frequent and high flow rates predicted to occur at the diversion site.

The perimeter berms of the basin along the south-east and south-west sides will be approximately 10 feet in height. The maximum operating level within the basin will be approximately 8 feet deep for a total wetted area of 6.0 acres and a storage volume of 40 af. The Division of Safety of Dams (DSOD) regulations state that any basin with a berm height less than 25 feet tall may have a storage capacity of up to 50 acre feet and still remain a non-jurisdictional facility.

The area above the rubber dam diversion will act as the forebay for the diversion structure. During periods when the dam is inflated this area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in Plunge Creek. The wetted area above the rubber dam (while the dam is inflated) is approximately 4 acres in size with a volume capacity of approximately 16 af.

A series of model iterations were performed to help determine a target design flow rate of 250 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 2,481 af/yr) would be realized by constructing the Plunge Creek Basin 1 Project.

The proposed improvements for the ARP at the Plunge Creek Basin 1 site include the construction of a 6 acre basin, construction of a 165' long by 8' tall inflatable rubber dam, construction of a 250 cfs diversion/inlet structure, construction of a basin overflow structure and the construction of a 36-inch diameter basin drain. The site should also include the addition of a flow measuring station in Plunge Creek at the diversion and flow metering in the diversion conduits to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

Figure 18: Plunge Creek Basin 1 Conceptual Design (Plan View)

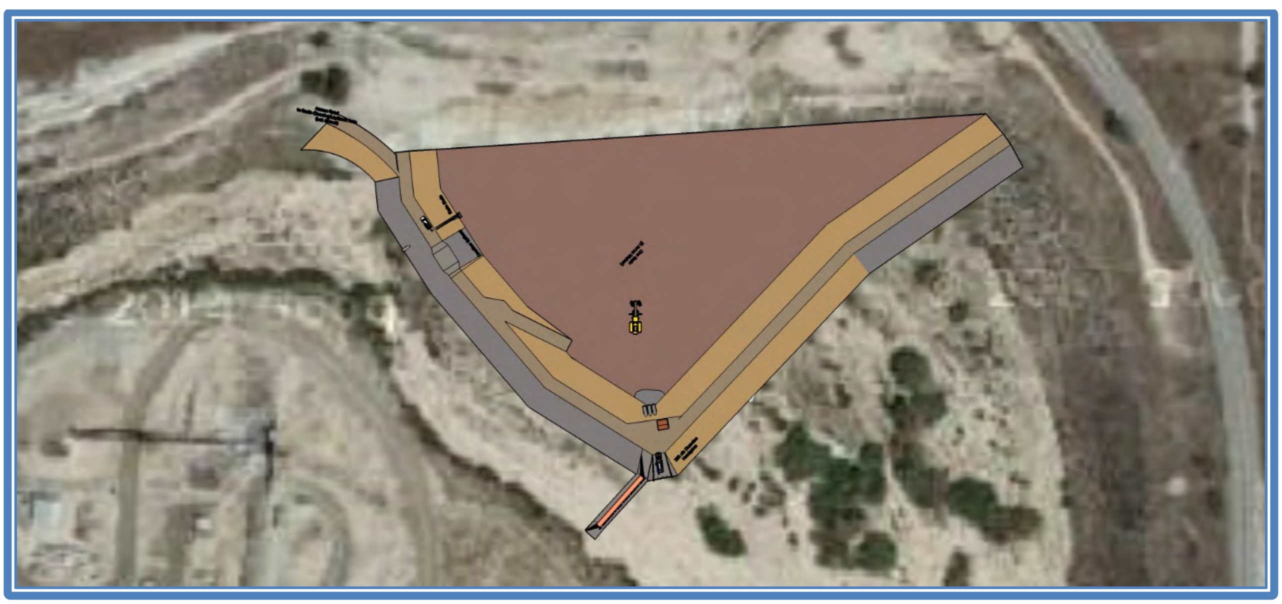


Figure 19: Plunge Creek Basin 1 Conceptual Design (Diversion View)

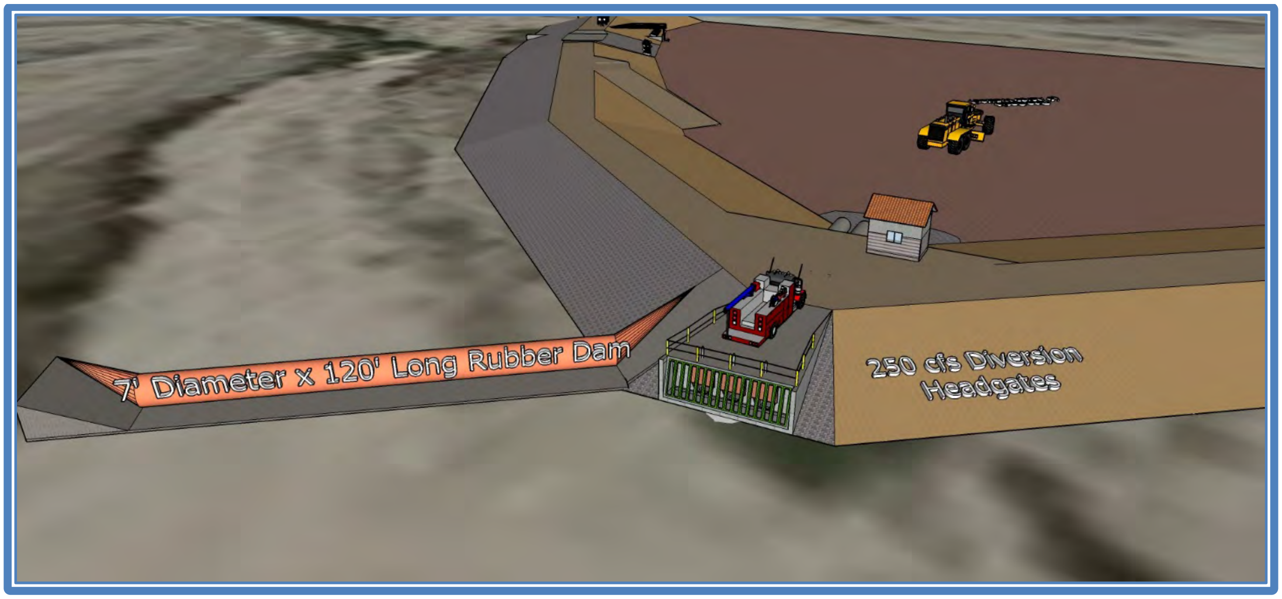


Figure 20: Plunge Creek Basin 1 Conceptual Design (Isometric View)

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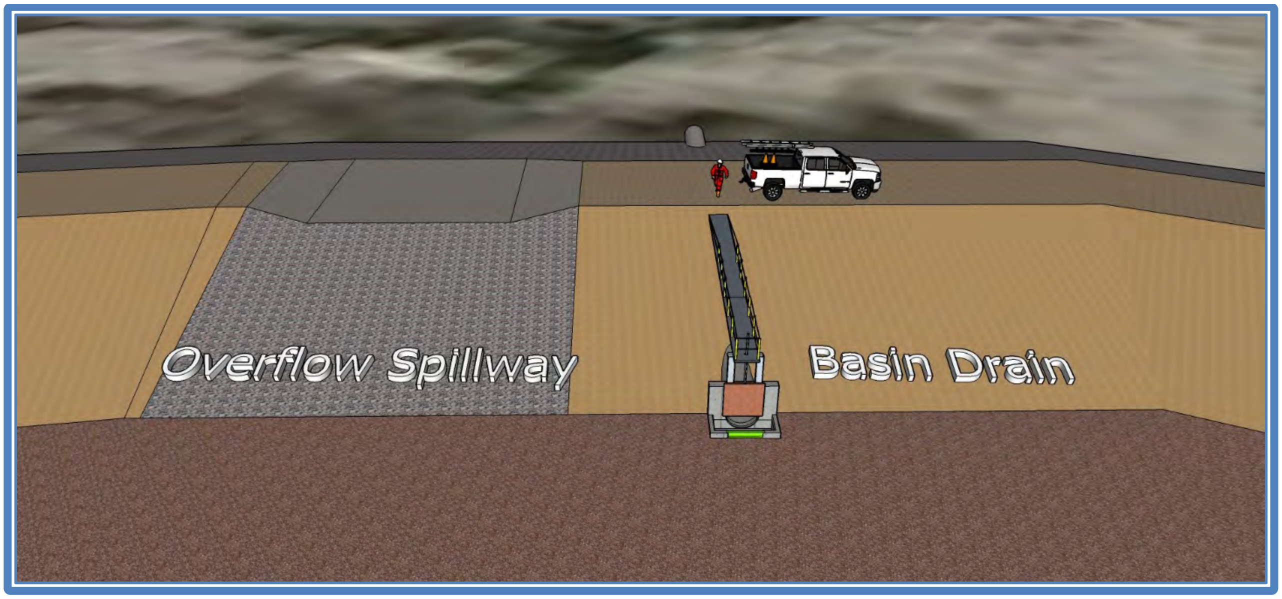
Figure 21: Plunge Creek Basin 1 Conceptual Design (Basin Outlet)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Plunge Creek Basin 1 Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 9. The forebay area above the rubber dam diversion was also included in the model to better capture the full benefit of the project. Due to the probability of high sedimentation rates in the forebay area, the infiltration rate decay was assumed to be more severe in the forebay than what is expected to occur in the basin.

Please note that only 1 example of a Plunge Creek Basin 1 infiltration rate decay curve has been included in this report. The infiltration rate decay of the basin varies with every storm event. To illustrate how the infiltration rate decays, a sample 31 day flow series and the associated infiltration rate decay curve have been provided in Figure 23 and Figure 24.

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Table 10: Plunge Creek Basin 1 Model Assumptions

Plunge Creek flow hydrograph	See Figure 22
Basin area and volume	Area = 6 acres, Volume = 40 af
Forebay area and volume	Area = 4 acres, Volume = 16 af
Initial infiltration rates	3.4 ft/day
Infiltration rate decay parameters	See Figure 24 (using Figure 23 flow series)
Diversion flow capacity	250 cfs
Dam deflation set point	2,000 cfs
Diversion flow rate with dam deflated	25 cfs

Figure 22: Plunge Creek Flows

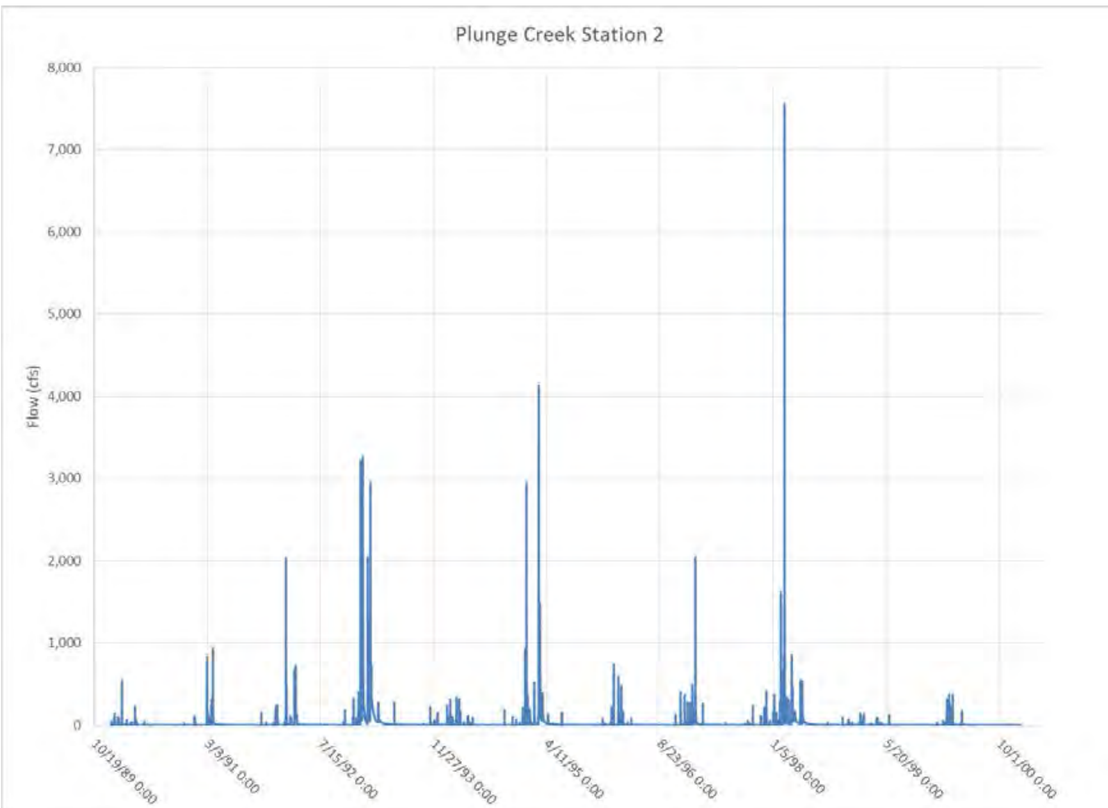

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Figure 23: Plunge Creek Basin 1 Optimization Flow Series

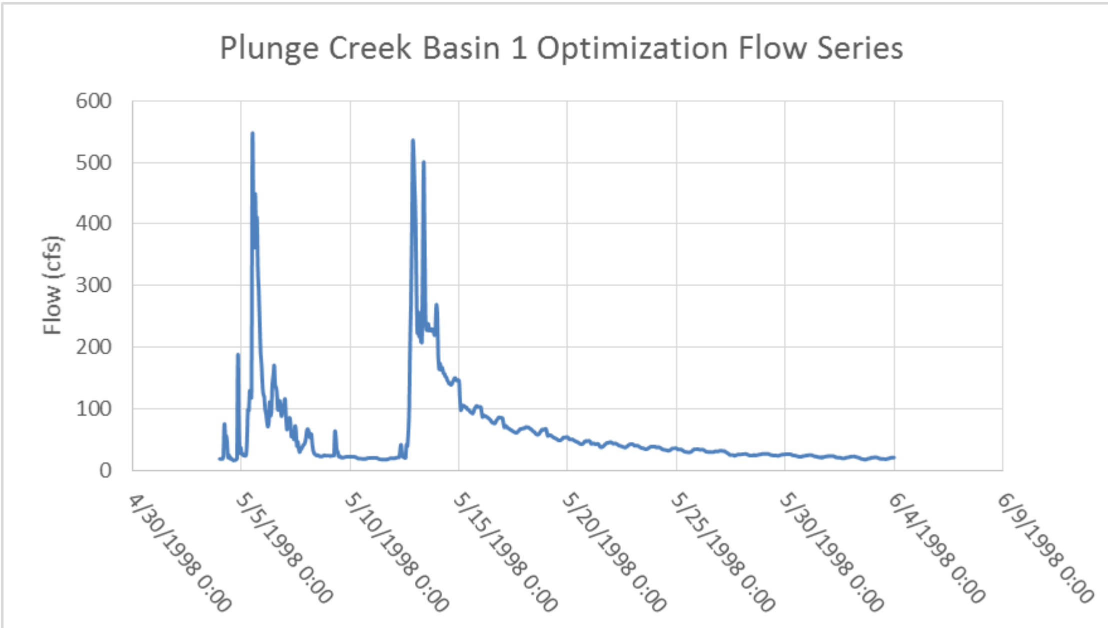
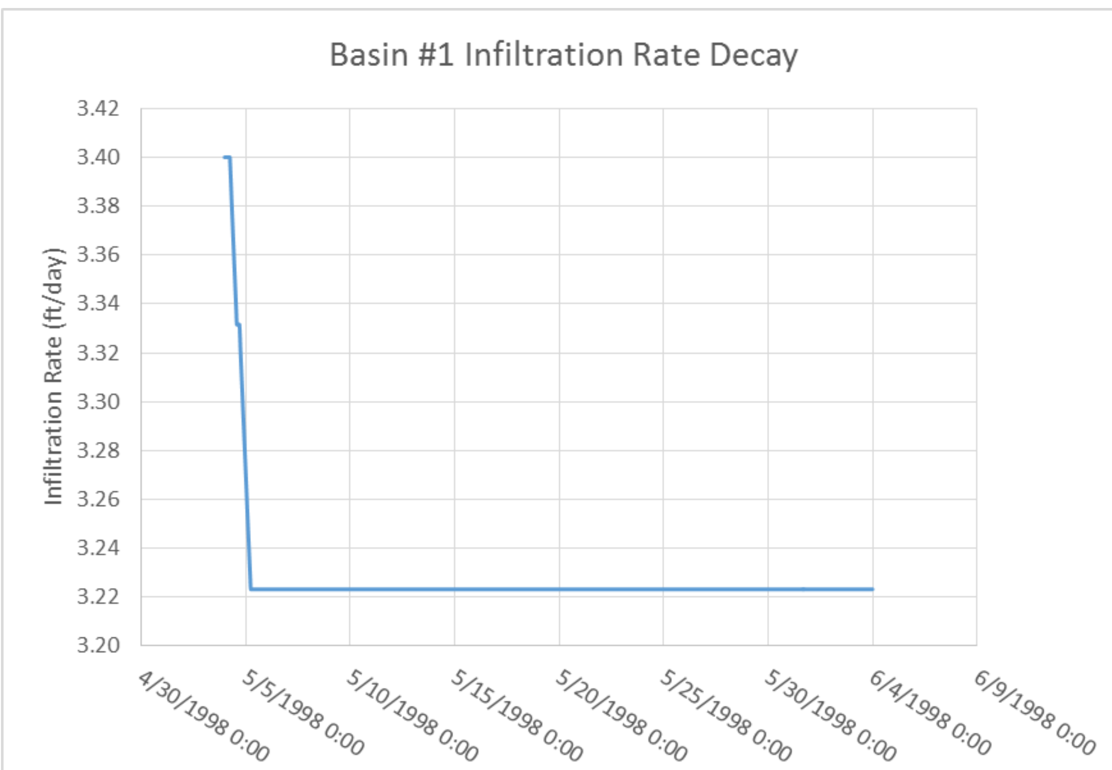


Figure 24: Plunge Creek Basin 1 Infiltration Rate Decay



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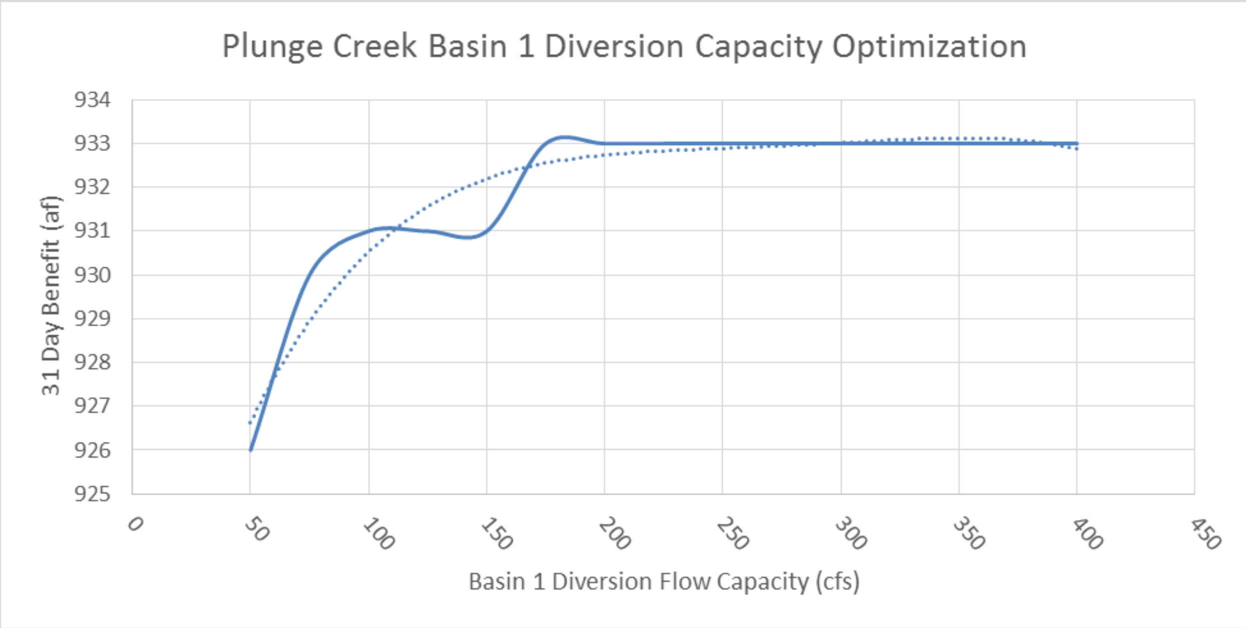
In order to determine the optimum diversion flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 22 as the inflow for the optimization flow series for the diversion (Figure 23).

The diversion flow capacity was increased in 25 cfs increments from 50 cfs up to 400 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 25). It should be noted that approximately 2,775 af of water is bypassed around the system at a 400 cfs diversion flow rate capacity. Bypassed water occurs because the basin fills rapidly early in the storm event and then only requires a diversion flow rate equivalent to the infiltration rate of the basin.

The maximum benefit first occurs at a diversion flow rate of approximately 175 cfs. Scheevel Engineering recommends that a diversion design flow rate of 250 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm flows. The optimum size for the Plunge Creek Basin 1 diversion is approximately 250 cfs. In order to achieve a greater benefit, additional basin volume is required.

Figure 25: Plunge Creek Basin 1 Diversion Optimization Results



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The 11 year flow series was modeled using the 250 cfs diversion capacity to predict the total amount of storm water captured and recharged during the model period. The final Plunge Creek Basin 1 Project model results can be seen in Table 11.

Table 11: Plunge Creek Basin 1 11 Year Model Results

Total Available Flow (af)	123,078
Total Flow Captured & Recharged (af)	27,286
Total Flow Bypassed (af)	95,792
Annual Average Flow Captured & Recharged (af)	2,481

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the rubber dam operates properly. During periods of especially high sedimentation or debris buildup in the forebay area operators may find it beneficial to purposely deflate the rubber dam for short periods to encourage the natural transport of sediment downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates and rubber dam mechanical and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basin will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Plunge Creek Basin 1 Project is presented in Table 12.

Table 12: Plunge Creek Basin 1 Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	1,060	96

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 13: Plunge Creek Basin 1 Cost Estimate

Capital Costs			Plunge Creek Basin 1		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 35,000	$ 35,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 10,000	$ 10,000
4	Survey	L.S.	1	$ 30,000	$ 30,000
5	Construction Water	L.S.	1	$ 25,000	$ 25,000
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	1	$ 25,000	$ 25,000
8	Clearing & Grubbing	AC	10	$ 1,500	$ 15,000
9	On-Site Grading	Yd^3	45,000	$ 5	$ 225,000
10	Material Export	Yd^3	10,000	$ 12	$ 120,000
11	Finish Grading	AC	10	$ 300	$ 3,000
12	Access Roads	AC	1.0	$ 90,000	$ 90,000
13	Dam Foundation	L.F.	120	$ 12,000	$ 1,440,000
14	Rubber Dam & Equipment	L.S.	1	$ 900,000	$ 900,000
15	Dam Downstream Grade Stabilizer	L.F.	150	$ 500	$ 75,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	43,000	$ 12	$ 516,000
20	Frwy/Street Piping (60-inch dia. CMLC)	L.F.	-	$ 3,000	$ -
21	Transfer Piping (60-inch dia. RCP)	L.F.	300	$ 500	$ 150,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	100	$ 450	$ 45,000
23	InterCell Transfers & Drains	L.S.	-	$ 250,000	$ -
24	Overflow Spillways	L.S.	1	$ 250,000	$ 250,000
25	Basin Outlet Structure	L.S.	1	$ 65,000	$ 65,000
26	Surface Transfer Structure (Weir)	L.S.	-	$ 850,000	$ -
27	Outlet Energy Dissipaters	L.S.	1	$ 50,000	$ 50,000
28	Diversion Spillway Gate	L.S.	-	$ 250,000	$ -
29	60" Valves	L.S.	3	$ 45,000	$ 135,000
30	42" Valves	L.S.	1	$ 40,000	$ 40,000
31	Catwalks	L.S.	1	$ 45,000	$ 45,000
32	Dam & Equipment Electrical	L.S.	1	$ 150,000	$ 150,000
33	Flow Control Gate Electrical	L.S.	1	$ 50,000	$ 50,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	3	$ 25,000	$ 75,000
38	Low Flow Meter	L.S.	1	$ 20,000	$ 20,000
39	Level Sensor	L.S.	3	$ 10,000	$ 30,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	2,500	$ 100	$ 250,000
43	Mitigation	AC	3.0	$ 25,000	$ 75,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 464,950
48	Material Testing	%	0.5%		$ 46,495
49	Contingency	%	10%		$ 929,900
	Total Capital Costs				$ 10,900,345
	Annual Debt Service (5% @ 30 years)		0.06505		$ 709,067

Annual O&M Costs			Plunge Creek Basin 1		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Rubber Dam	L.S.	1	$ 30,000	$ 30,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	20	$ 1,000	$ 20,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 195,000	$ 1,950
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 25,000	$ 25,000
8	Basin Cleanings	Yd^3	1,613	$ 2	$ 3,227
9	Material Export	Yd^3	2,113	$ 12	$ 25,360
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 180,537

Project Benefit Summary			Plunge Creek Basin 1		
	Total Annual Project Cost	$			$ 889,604
	Average Annual Benefit	AF/YR			2,481
	Average Annual Recharge Unit Cost	$/AF			$ 359

Plunge Creek (Station 2) – Basin 2

Existing Conditions

The Plunge Creek Basin 2 site is located approximately 350 feet west of the 210 Freeway/Plunge Creek crossing in the City of Highland (Figure 26). The proposed diversion and basin would be situated within the existing flow path of Plunge Creek in an area approximately 18 acres in size. The site is located in a wide area of the Plunge Creek channel. The site is currently bisected by the low flow channel of the creek. The proposed project would re-route the creek's flow path along the southern edge of the site.

Water flows through the site from east to west under the 210 Freeway and then continues west for approximately 2,000 feet before draining into City Creek. The south-west tip of the project site is at the confluence of Plunge and City Creeks.

The northern edge of the Plunge Creek Basin 2 site is immediately adjacent to the southernmost basin of the City Creek site discussed later in this report. If both sites are selected for further development a transfer pipe should be constructed from City Creek Basin to Plunge Creek Basin 2 in order to provide operational flexibility and better utilize Plunge Creek Basin 2.

Figure 26: Plunge Creek Basin 2 Overview

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Figure 27: Plunge Creek Basin 2 Site (Looking West)

Proposed Improvements

The proposed improvements at Plunge Creek site 2 for the ARP is to construct 2 basins, a 7' diameter by 90' long rubber dam and a diversion structure within Plunge Creek. The basin layout has been developed to maximize usage of the available area on the site while maintaining adequate flood control capacity in Plunge Creek Channel. The southern edge of the new basin will act as a levee to channelize high flows past the basin. The south-east corner of the proposed basin will be the point at which the basin berm constricts Plunge Creek, this will also be the location for the construction of an inflatable rubber dam diversion.

The rubber dam diversion was intentionally placed near the creek constriction to help encourage sediment transport past the dam and diversion structure. A rubber dam was selected for this site due to the frequent and high flow rates predicted to occur at the diversion site.

The perimeter berms of the basin along the east, south and west sides will be approximately 10 feet in height. The divider berm between the basins will be approximately 10 feet high as well. The maximum operating level within the basin will be approximately 8 feet deep for a total wetted area of 10.7 acres and a storage volume of 66 af. To avoid DSOD jurisdiction and de-silt water coming into the basins the 66 af basin will be split into 2 smaller basins. The upstream basin will be approximately 2.3 acres in area and have a volume of 16 af. The downstream basin will be approximately 8.4 acres in area and have a volume of 50 af. The Division of Safety of Dams (DSOD) regulations state that any basin with a berm height less than 25 feet tall may have a storage capacity of up to 50 acre feet and still remain a non-jurisdictional facility.

The area above the rubber dam diversion will act as the forebay for the diversion structure. During periods when the dam is inflated this area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in Plunge Creek. The wetted area above the rubber dam (while the dam is inflated) is approximately 0.4 acres with a volume capacity of approximately 1.5 af.

A series of model iterations were performed to help determine a target design flow rate of 350 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 1,050 af/yr) would be realized by constructing the Plunge Creek Basin 2 Project.

The proposed improvements for the ARP at the Plunge Creek Basin 2 site include the construction of 10.7 acres of basin, construction of a 90' long by 7' tall inflatable rubber dam, construction of a 350 cfs diversion/inlet structure, construction of a basin overflow structure and the construction of a 36-inch diameter basin drain. The site should also be improved by adding a flow measuring station in Plunge Creek at the diversion and flow meters in the diversion conduits to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

Figure 28: Plunge Creek Basin 2 Conceptual Design (Plan View)

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Figure 29: Plunge Creek Basin 2 Conceptual Design (Diversion View)

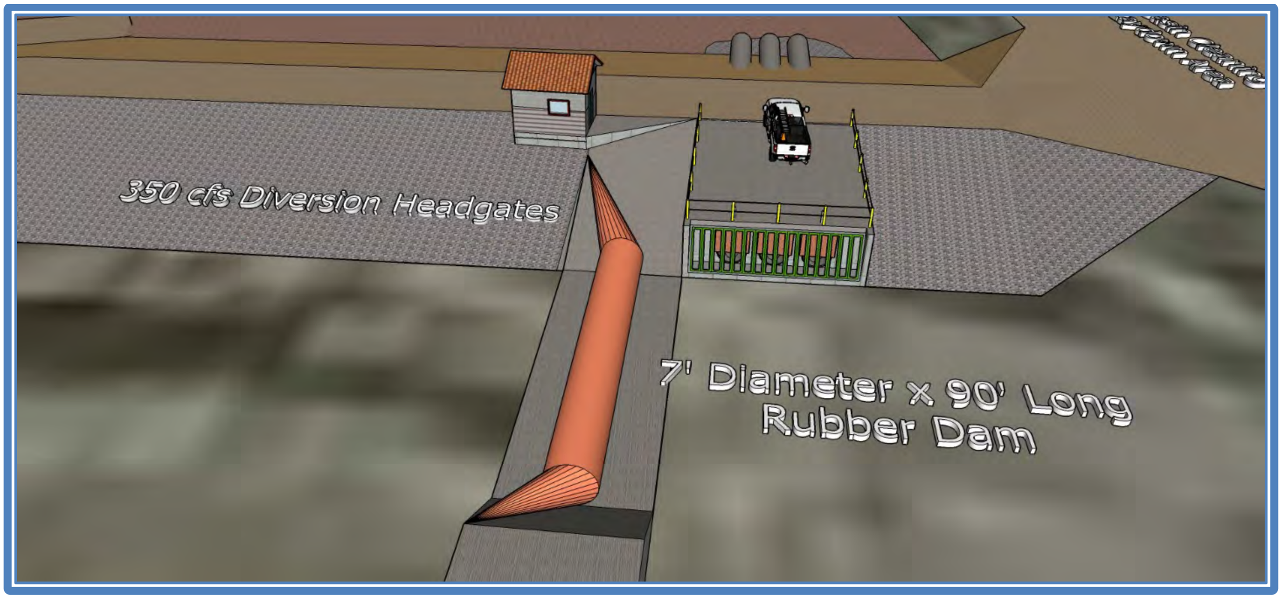

Figure 30: Plunge Creek Basin 2 Conceptual Design (Transfer Structure View)

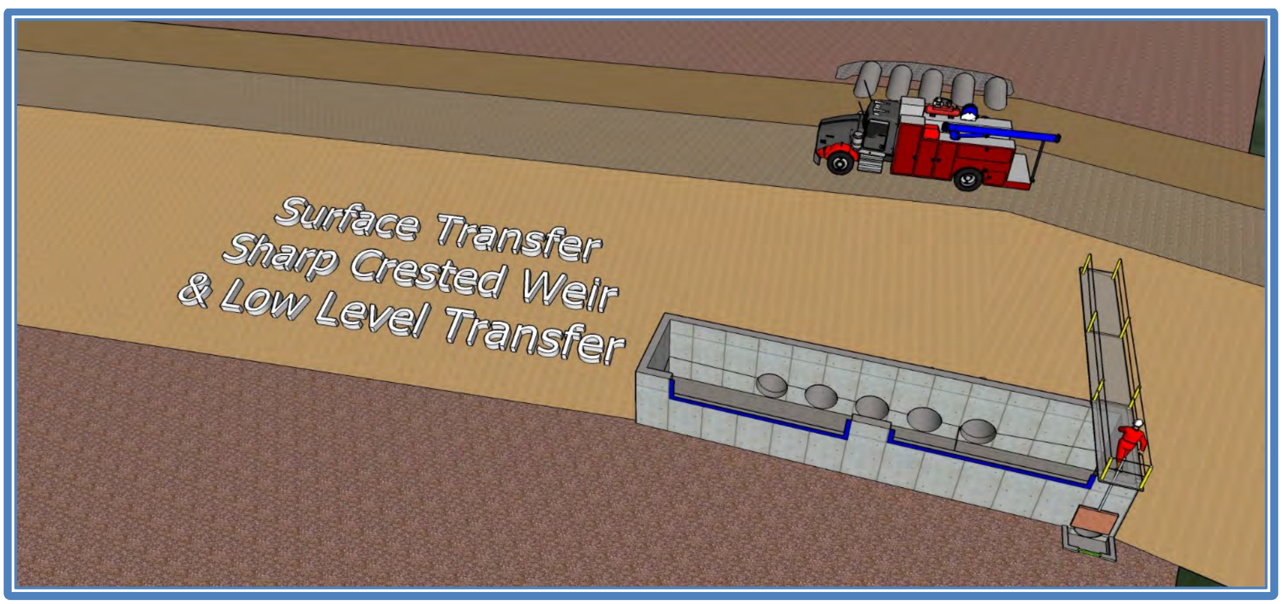

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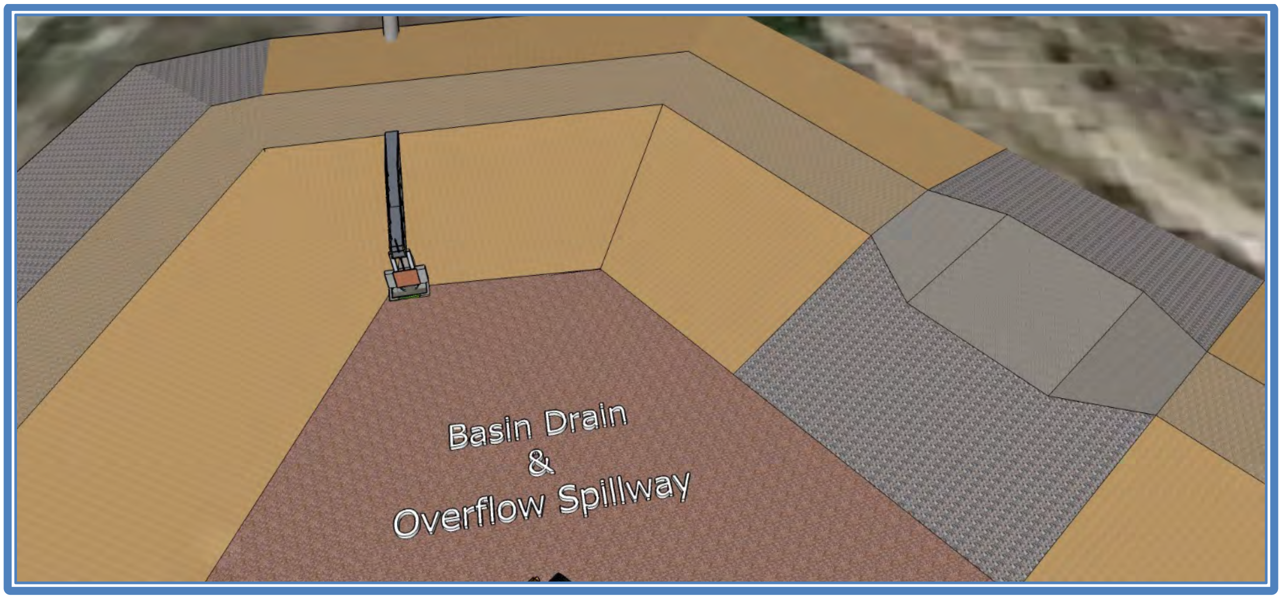
Figure 31: Plunge Creek Basin 2 Conceptual Design (Basin Outlet View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Plunge Creek Basin 2 Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 14. The forebay area above the rubber dam diversion was also included in the model to better capture the full benefit of the project. Due to the probability of high sedimentation rates in the forebay area, the infiltration rate decay was assumed to be more severe in the forebay than what is expected to occur in the basin.

The available flows at the Plunge Creek Basin 2 site were reduced by the flows captured and recharged at Plunge Creek Basin 1. The result of this assumption is that the Plunge Creek Basin 2 benefit estimate is very conservative. If the Plunge Creek Basin 1 Project were not to be constructed, then the benefit at Plunge Creek Basin 2 can reasonably be expected to be 2 to 2.5 times greater than what is presented here.

Please note that only 1 example of a Plunge Creek Basin 2 infiltration rate decay curve has been included in this report. The infiltration rate decay of the desilting basin varies with every storm event and in order to illustrate how the infiltration rate decays, a sample 31 day flow series and the associated infiltration rate decay curve have been provided in Figure 33 and Figure 34.

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Table 14: Plunge Creek Basin 2 Model Assumptions

Plunge Creek flow hydrograph	See Figure 32
Basin area and volume	Area = 10.7 acres, Volume = 66 af
Forebay area and volume	Area = 0.4 acres, Volume = 1.5 af
Initial infiltration rates	3.4 ft/day
Infiltration rate decay parameters	See Figure 34 (using Figure 33 flow series)
Diversion flow capacity	350 cfs
Dam deflation set point	2,000 cfs
Diversion flow rate with dam deflated	25 cfs

Figure 32: Plunge Creek Reduced Flows

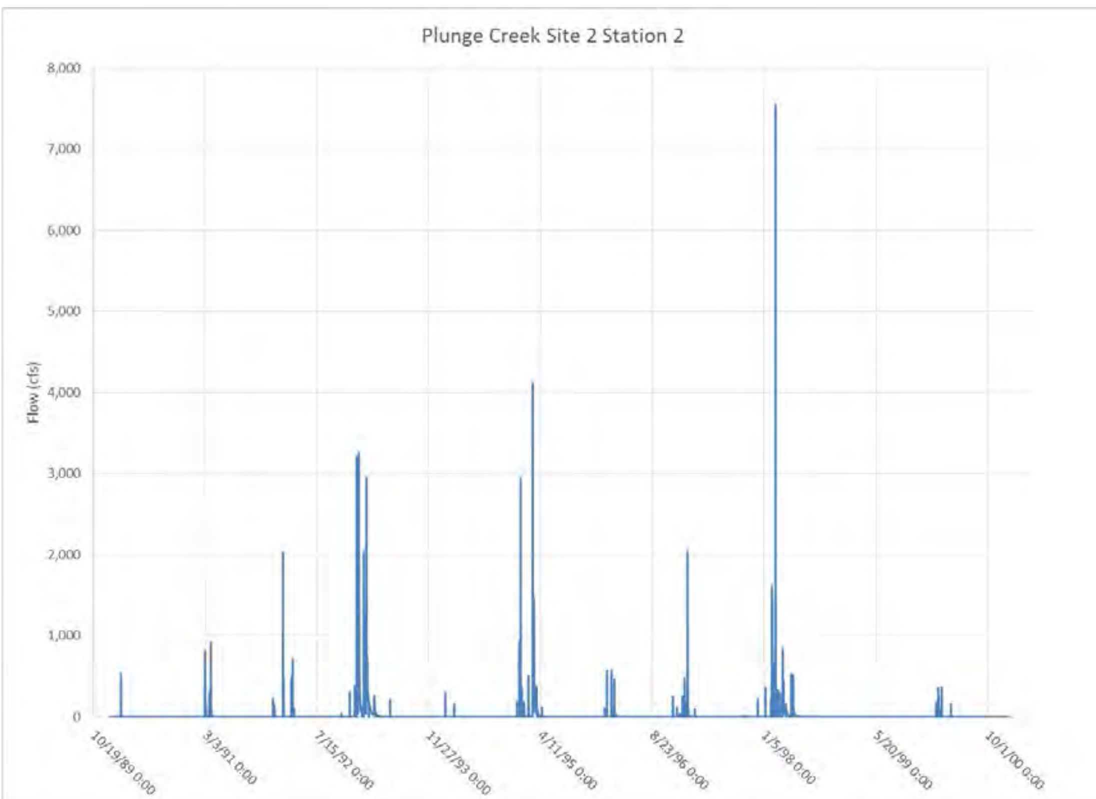

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Figure 33: Plunge Creek Basin 2 Optimization Flow Series

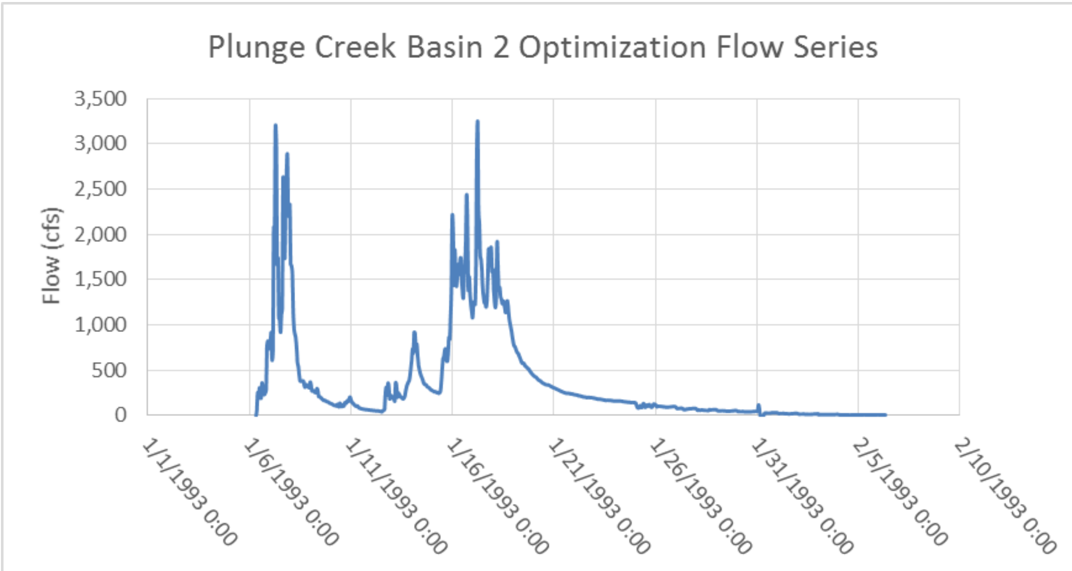
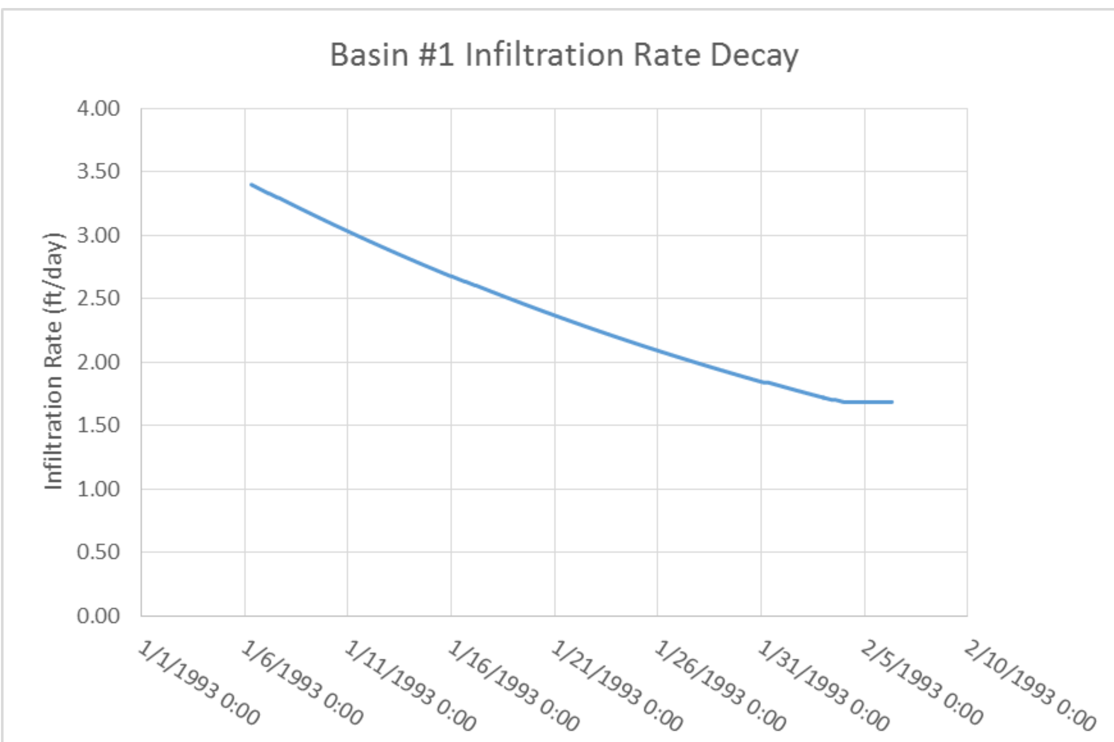


Figure 34: Plunge Creek Basin 2 Desilting Basin Infiltration Rate Decay



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In order to determine the optimum diversion flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 32 as the inflow for the optimization flow series for the diversion (Figure 33).

The diversion flow capacity was increased in 25 cfs increments from 50 cfs up to 400 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 35).

It should be noted that approximately 21,830 af of water is bypassed around the system with a 400 cfs diversion flow rate capacity, this is because the basin fills rapidly given the very high flow rates and then only requires a diversion flow rate equivalent to the infiltration rate of the basins.

The project benefit starts to plateau at a diversion flow rate of approximately 250 cfs with a slight increase again around 350 cfs. If the Plunge Creek Basin 1 is not selected for further development then the sensitivity analysis should be reevaluated with the original Station 2 flow series. At this time Scheevel Engineering recommends that a diversion design flow rate of 350 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm flows. In order to achieve a greater benefit, additional basin volume is required.

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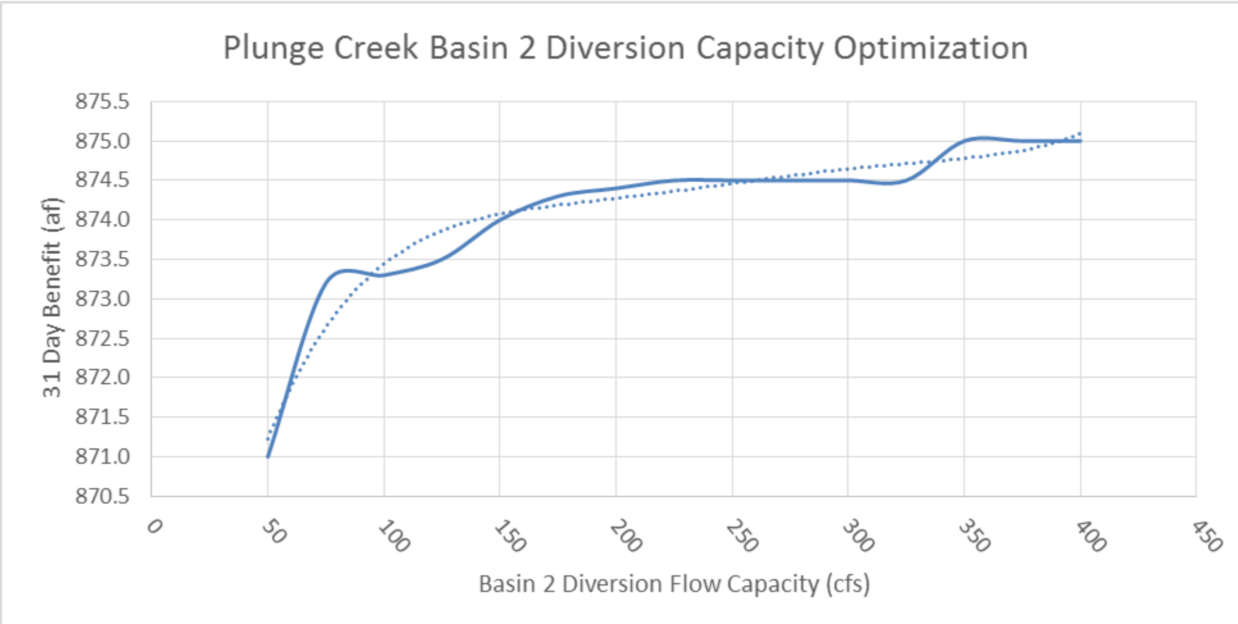
Figure 35: Plunge Creek Basin 2 Diversion Optimization Results



The 11 year flow series was modeled using the 350 cfs diversion capacity to predict the total amount of storm water captured and recharged during the model period. The final Plunge Creek Basin 2 Project model results can be seen in Table 15.

Table 15: Plunge Creek Basin 2 11 Year Model Results

Total Available Flow (af)	95,792
Total Flow Captured & Recharged (af)	11,555
Total Flow Bypassed (af)	84,237
Annual Average Flow Captured & Recharged (af)	1,050

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the rubber dam operates properly. During periods of especially high sedimentation or debris buildup in the forebay area operators may find it beneficial to purposely deflate the rubber dam for short periods of time to encourage the natural transport of the materials downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates and rubber dam mechanical and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the

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basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Plunge Creek Basin 2 Project is presented in Table 16.

Table 16: Plunge Creek Basin 2 Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	1,505	137

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 17: Plunge Creek Basin 2 Cost Estimate

Capital Costs			Plunge Creek Basin 2		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 35,000	$ 35,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 10,000	$ 10,000
4	Survey	L.S.	1	$ 30,000	$ 30,000
5	Construction Water	L.S.	1	$ 25,000	$ 25,000
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	1	$ 25,000	$ 25,000
8	Clearing & Grubbing	AC	13	$ 1,500	$ 19,500
9	On-Site Grading	Yd^3	75,000	$ 5	$ 375,000
10	Material Export	Yd^3	10,000	$ 12	$ 120,000
11	Finish Grading	AC	13	$ 300	$ 3,900
12	Access Roads	AC	2.0	$ 90,000	$ 180,000
13	Dam Foundation	L.F.	90	$ 12,000	$ 1,080,000
14	Rubber Dam & Equipment	L.S.	1	$ 800,000	$ 800,000
15	Dam Downstream Grade Stabilizer	L.F.	100	$ 500	$ 50,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	69,000	$ 12	$ 828,000
20	Frwy/Street Piping (60-inch dia. CMLC)	L.F.	-	$ 3,000	$ -
21	Transfer Piping (60-inch dia. RCP)	L.F.	300	$ 500	$ 150,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	700	$ 450	$ 315,000
23	InterCell Transfers & Drains	L.S.	-	$ 250,000	$ -
24	Overflow Spillways	L.S.	1	$ 250,000	$ 250,000
25	Basin Outlet Structure	L.S.	2	$ 65,000	$ 130,000
26	Surface Transfer Structure (Weir)	L.S.	1	$ 850,000	$ 850,000
27	Outlet Energy Dissipaters	L.S.	2	$ 50,000	$ 100,000
28	Diversion Spillway Gate	L.S.	-	$ 250,000	$ -
29	60" Valves	L.S.	3	$ 45,000	$ 135,000
30	42" Valves	L.S.	2	$ 40,000	$ 80,000
31	Catwalks	L.S.	2	$ 45,000	$ 90,000
32	Dam & Equipment Electrical	L.S.	1	$ 150,000	$ 150,000
33	Flow Control Gate Electrical	L.S.	1	$ 50,000	$ 50,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	3	$ 25,000	$ 75,000
38	Low Flow Meter	L.S.	1	$ 20,000	$ 20,000
39	Level Sensor	L.S.	4	$ 10,000	$ 40,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	5,000	$ 100	$ 500,000
43	Mitigation	AC	3.0	$ 25,000	$ 75,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 547,570
48	Material Testing	%	0.5%		$ 54,757
49	Contingency	%	10%		$ 1,095,140
	Total Capital Costs				$ 12,808,867
	Annual Debt Service (5% @ 30 years)		0.06505		$ 833,217

Annual O&M Costs			Plunge Creek Basin 2		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Rubber Dam	L.S.	1	$ 30,000	$ 30,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	10	$ 1,000	$ 10,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 465,000	$ 4,650
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 25,000	$ 25,000
8	Basin Cleanings	Yd^3	2,877	$ 2	$ 5,754
9	Material Export	Yd^3	3,377	$ 12	$ 40,525
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 190,930

Project Benefit Summary			Plunge Creek Basin 2		
	Total Annual Project Cost	$			$ 1,024,146
	Average Annual Benefit	AF/YR			1,050
	Average Annual Recharge Unit Cost	$/AF			$ 975

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City Creek (Station 3)

Existing Conditions

The City Creek site is located along City Creek and is bordered by Baseline Avenue to the north and Plunge Creek to the south. The proposed diversion would be located approximately 2,000 feet east of the 210 Freeway/Baseline Ave. crossing in the City of Highland (Figure 36). The proposed diversion and basin would be situated immediately south-east of City Creek over an area approximately 77 acres in size. The site crosses two city streets and one major freeway crossing (210 Freeway, Boulder Avenue and West 5th Street).

Water flows in City Creek from north-east to south-west parallel to the project site for approximately 7,300 feet before intercepting Plunge Creek. The southern end of the project site is located along the northern edge of the Plunge Creek Basin 2 site. As discussed previously, the Plunge Creek Basin 2 should be connected to the City Creek Basins to allow for operational flexibility and provide more storage for flows in the City Creek Basin system during periods when Plunge Creek basin 2 is under-utilized.

Overall the City Creek site has an elevation differential of approximately 84 feet over the 6,200 foot site (1.36%). The southernmost City Creek Basin is located at an elevation approximately 12 feet higher than the proposed Plunge Creek Basin 2.

Figure 36: City Creek Overview

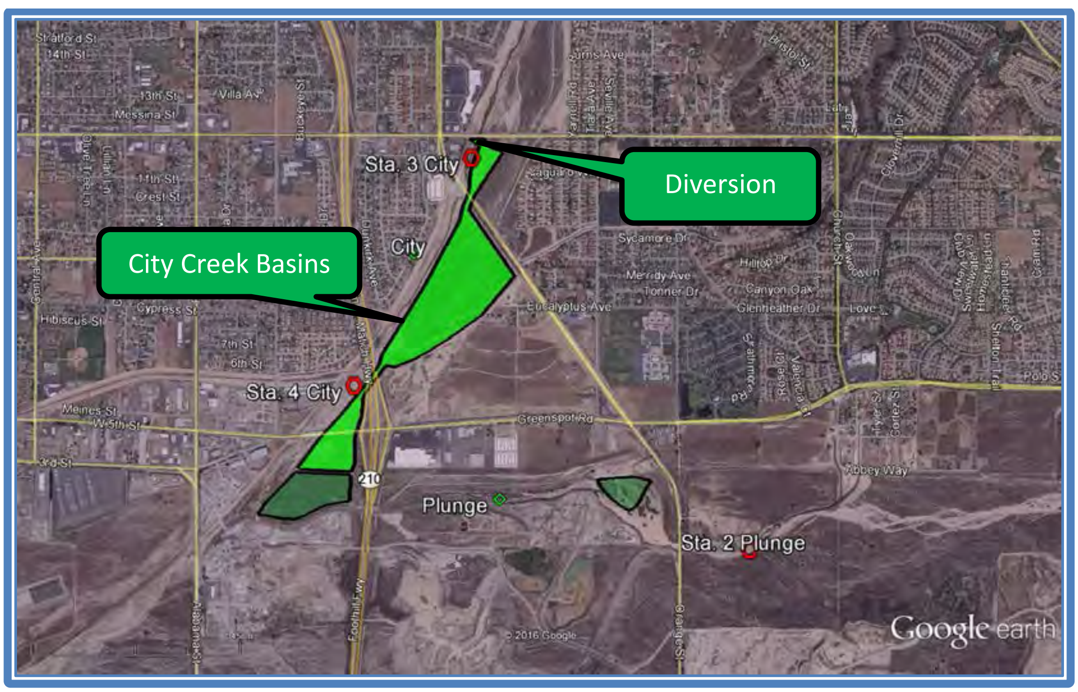

Figure 37: City Creek Site (Looking South Off Of Boulder Ave.)

Proposed Improvements

The proposed improvements at City Creek for the ARP is to construct an inflatable rubber dam diversion across City Creek and a series of basins from Baseline Avenue extending south-west 6,200 feet (approximately 9 basins total). The basin layout has been developed to utilize a gravity conveyance system and to maximize usage of the available area on the site while maintaining adequate flood control capacity in City Creek Channel. The north-west edge of the new basins will act as a levee to isolate uncontrolled high flows from the basin system. The northern most end of the basins system will be immediately downstream of the Baseline Avenue crossing and will be the location for the construction of an inflatable rubber dam diversion. An inflatable rubber dam was selected for this site due to the frequent and high flow rates predicted to occur at the diversion site. Inflatable rubber dam diversions also provide the ability to quickly transition operations from water conservation mode to flood control mode and vice versa.

In general, the perimeter basin berms will be approximately 10 feet in height. The divider berms between the basins will be also be approximately 10 feet high with slightly increased heights on the downstream slopes to terrace the basins to match the slope of the site. The maximum operating level within the basin will be approximately 8-10 feet deep for a total wetted area of 37.7 acres and a storage volume of 254 af. In order to

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avoid DSOD jurisdiction no single basin will have a berm height more than 25 feet or have a storage capacity volume greater than 50 af.

The area above the rubber dam diversion will act as the forebay for the diversion structure. While the dam is inflated the forebay area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in City Creek. The wetted area above the rubber dam (while the dam is inflated) is approximately 0.06 acres with a volume capacity of approximately 0.23 af.

A series of model iterations were performed to help determine a target design flow rate of 500 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 5,247 af/yr) would be realized by constructing the City Creek Basin Project.

The proposed improvements for the ARP at the City Creek Basin site include the construction of 37.7 acres of basin, construction of a 60' long by 8' tall inflatable rubber dam, construction of a 500 cfs diversion/inlet structure, construction of basin transfer and overflow structures, construction of 9, 36-inch diameter basin drains, a 500 cfs conveyance under Boulder Ave., a 250 cfs conveyance under the 210 Freeway and a 250 cfs crossing under West 5th Street. Each of the basins should include remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in City Creek at the diversion site and flow meters in the diversion structure to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

Figure 38: City Creek Basin Conceptual Design (Plan View)

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Figure 39: City Creek Basin Conceptual Design (Diversion View)

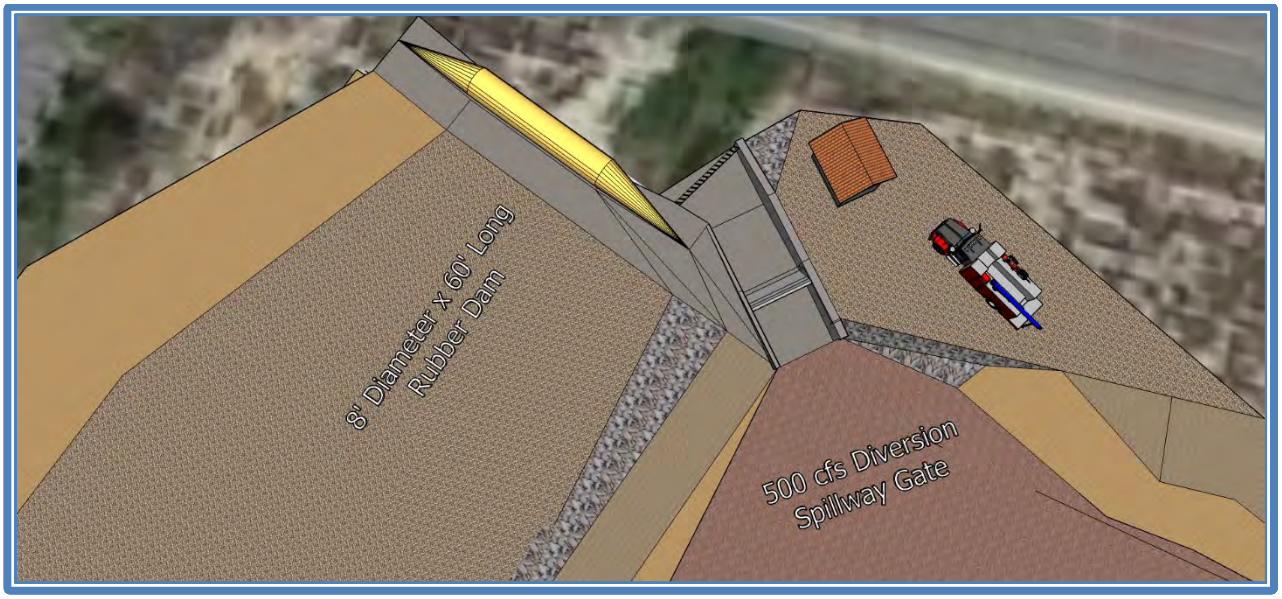

Figure 40: City Creek Basin Conceptual Design (Transfer Structure)

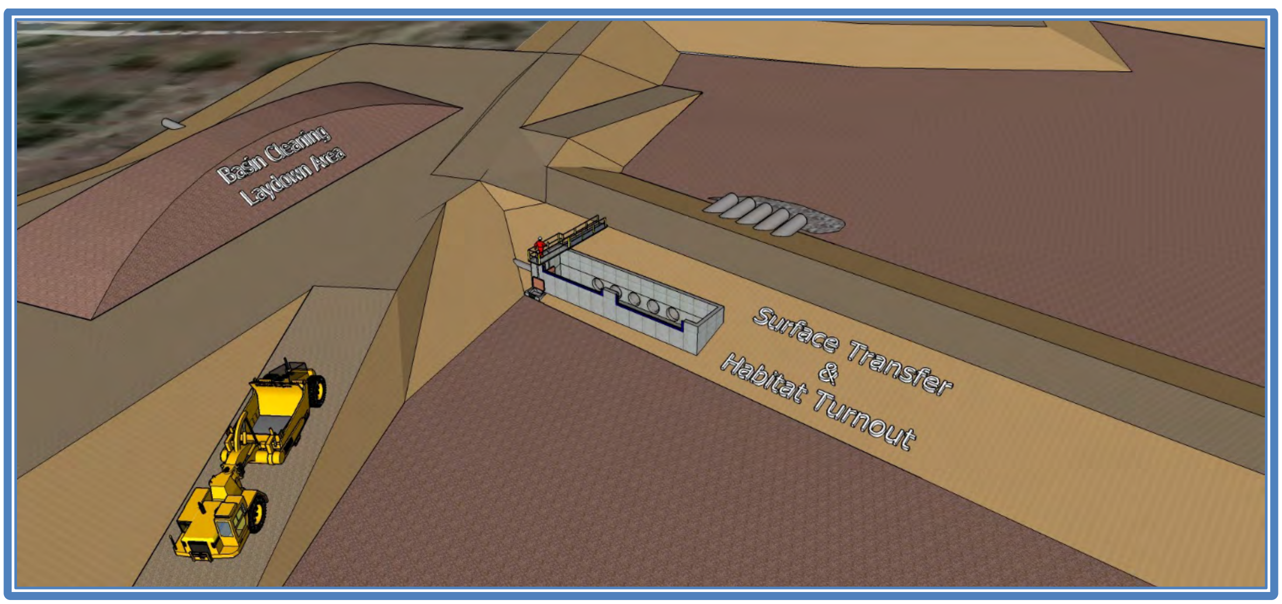

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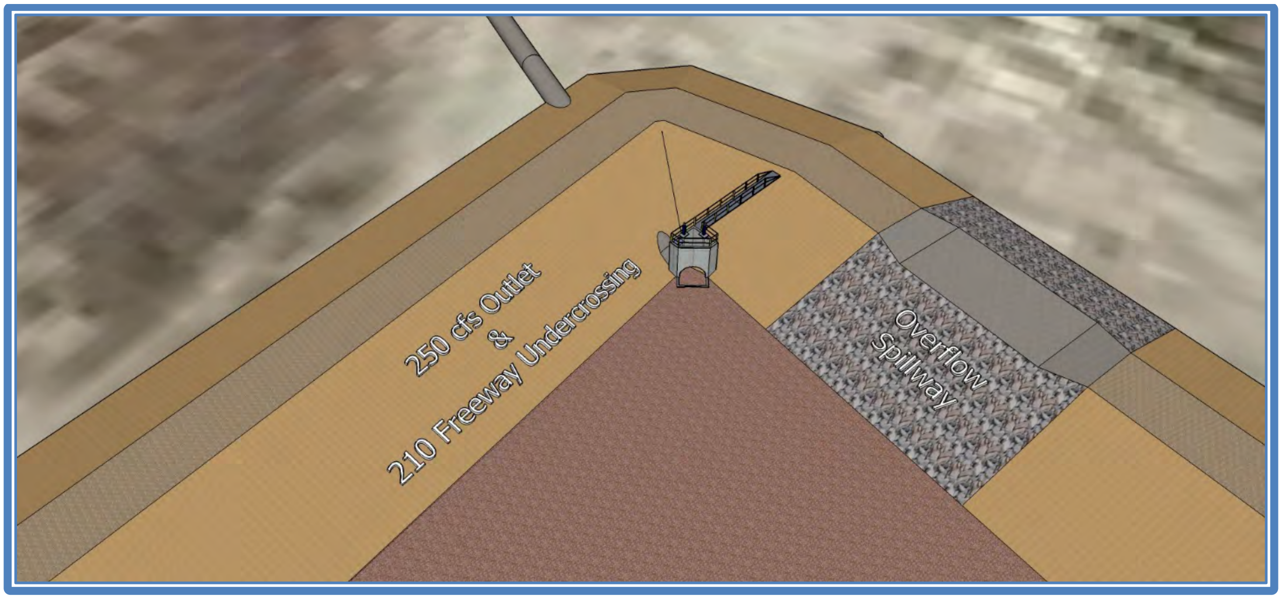
Figure 41: City Creek Basin Conceptual Design (Basin Outlet)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the City Creek Basin Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 18. The forebay area above the rubber dam diversion (although very small when compared to the basin system) was also included in the model to better capture the full benefit of the project.

The available flows at the City Creek Basin site used in the groundwater recharge operations model were from flow station 3 only. The flows at station 4 (immediately downstream of the 210 Freeway) include flow from the drainage area to the east of the basin site above Boulder Avenue. Flows from station 3 were sufficient to utilize all of the available basin volume and therefore another diversion structure to the east of the basins cannot be justified at this time. If however, the basins perform at a higher level than expected, or if the flow at station 3 is less than expected, another diversion in the future may be justified. On average there is 3,200 af/yr of flow in the east drainage area.

Please note that only 1 example of a City Creek Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basins. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 43 and Figure 44 to illustrate how the infiltration rates might decay in the City Creek Basins.

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Table 18: City Creek Basin Model Assumptions

City Creek flow hydrograph	See Figure 42
Basin area and volume	Area = 37.7 acres, Volume = 254 af
Forebay area and volume	Area = 0.06 acres, Volume = 0.23 af
Initial infiltration rates	3.4 ft/day
Infiltration rate decay parameters	See Figure 44 (using Figure 43 flow series)
Diversion flow capacity	500 cfs
Dam deflation set point	1,500 cfs
Diversion flow rate with dam deflated	10 cfs

Figure 42: City Creek Flows

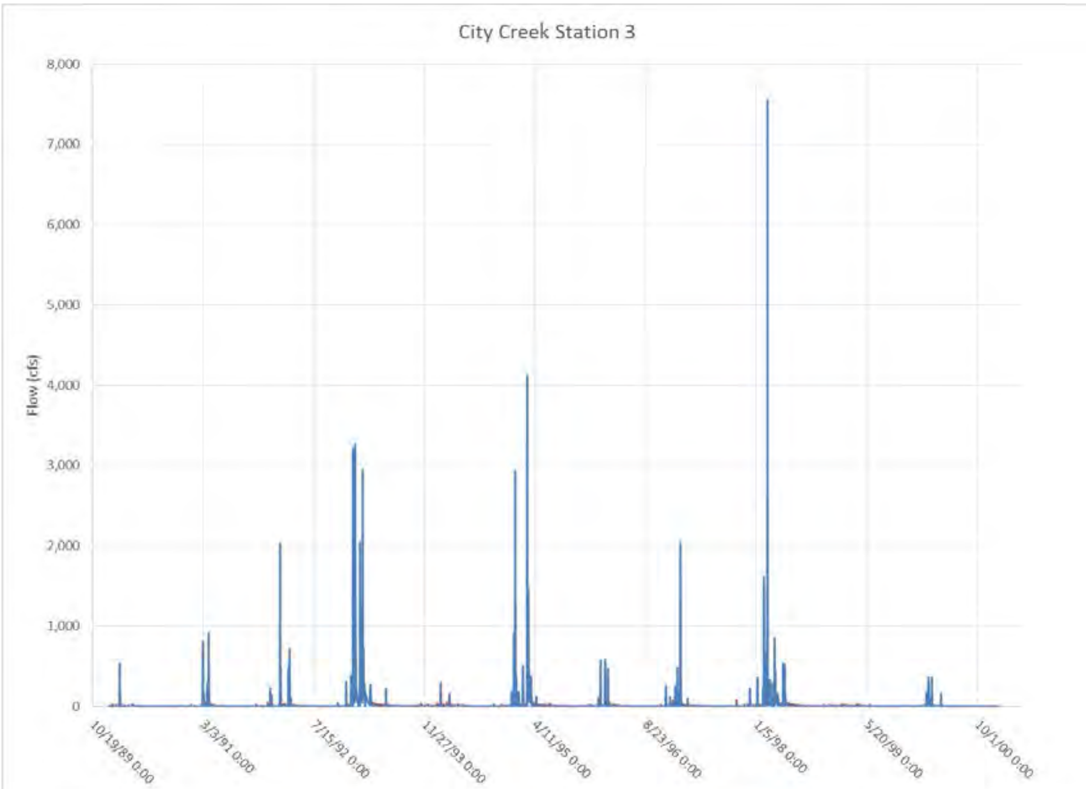


Figure 43: City Creek Basin Optimization Flow Series

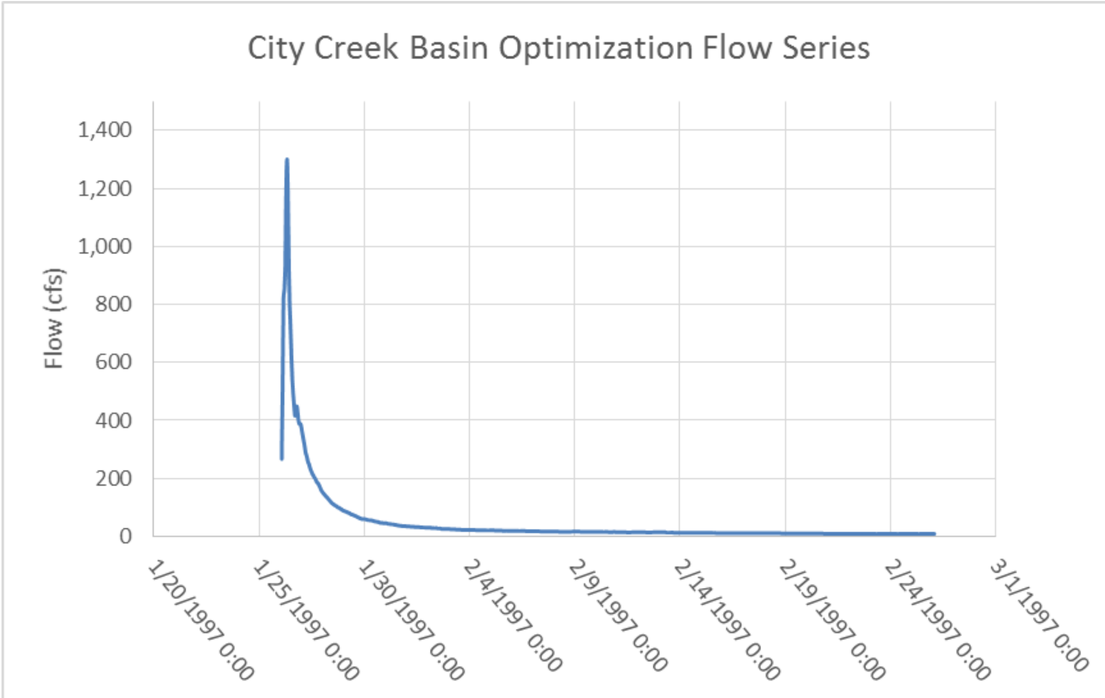
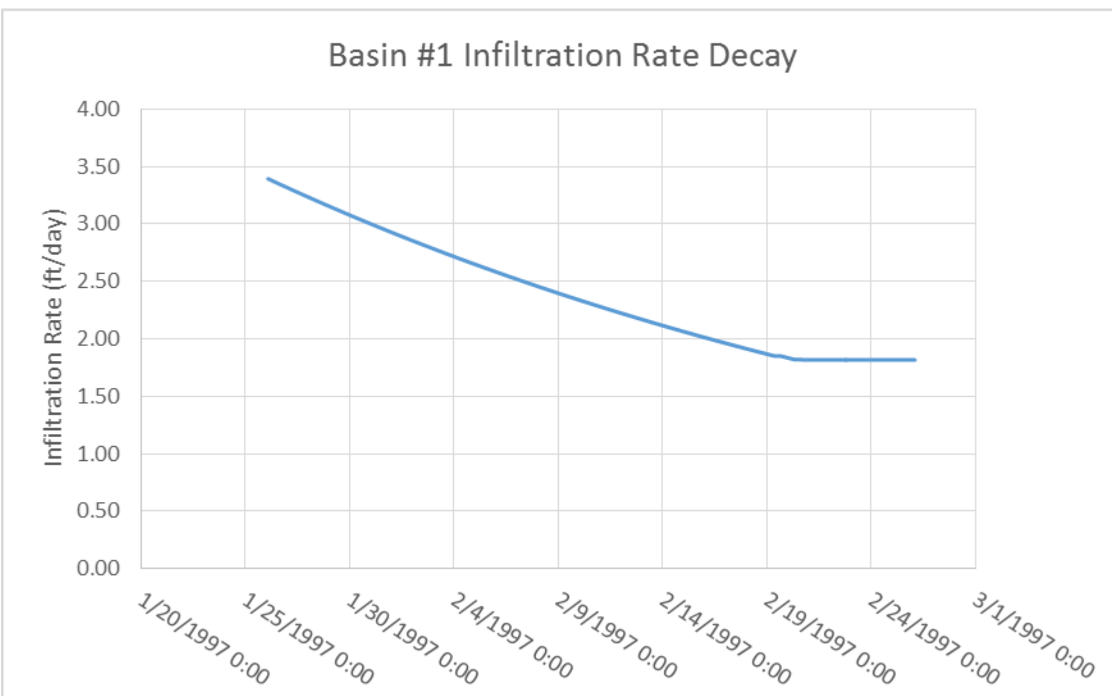


Figure 44: City Creek Basin Infiltration Rate Decay



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In order to determine the optimum diversion flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 42 as the inflow for the optimization flow series for the diversion (Figure 43).

The diversion flow capacity was increased in 25 cfs increments from 50 cfs up to 700 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 45).

Approximately 1,336 af of water is bypassed around the system at a 700 cfs diversion flow rate capacity, this is because the basins fill rapidly given the very high flow rates in the flow series selected and then only requires a diversion flow rate equivalent to the infiltration rate of the basins.

The project benefit starts to plateau at a diversion flow rate of approximately 400 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 500 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events. In order to achieve a greater benefit, additional basin volume is required.

The above analysis does not include Plunge Creek Basin 2. Another potential project alternative would be to construct Plunge Creek Basin 2 (and not construct the Plunge Creek Basin 2 Diversion at this time), and then feed Plunge Creek Basin 2 from the City Creek Basin System. This would provide additional capacity in the City Creek Basin system and eliminate the cost of a diversion in Plunge Creek. Another very valuable benefit of adding Plunge Creek Basin 2 to the City Creek System is that water delivered to Plunge Creek Basin 2 will have been de-silted through 9 basins, resulting in extended periods of operation at higher infiltration rates Plunge Creek Basin 2.

Some negative consequence of adding Plunge Creek Basin 2 (and not constructing the diversion) to the City Creek Basin System include the need to construct a larger conveyance underneath the 210 Freeway and West 5th Street, and during lower intensity storms the Plunge Creek Basin 2 may be underutilized.

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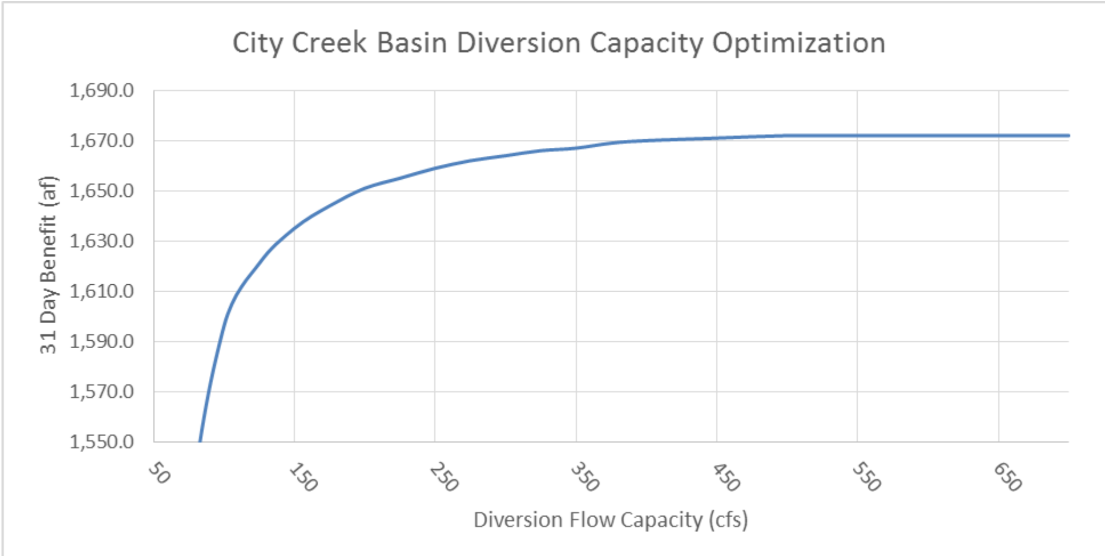
Figure 45: City Creek Basin Diversion Optimization Results



The 11 year flow series was modeled using the 500 cfs diversion capacity to predict the total amount of storm water captured and recharged during the model period. The final City Creek Basin Project model results can be seen in Table 19.

Table 19: City Creek Basin 11 Year Model Results

Total Available Flow (af)	87,424
Total Flow Captured & Recharged (af)	57,713
Total Flow Bypassed (af)	29,711
Annual Average Flow Captured & Recharged (af)	5,247

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the rubber dam operates properly. During periods of especially high sedimentation or debris buildup in the forebay area operators may find it beneficial to purposely deflate the rubber dam for short periods of time to encourage the natural transport of the materials downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates, meters, level sensors and rubber dam mechanical and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has

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been assumed that the basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the City Creek Basin Project is presented in Table 20.

Table 20: City Creek Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	3,515	320

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 21: City Creek Basin Cost Estimate

Capital Costs			City Creek Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 85,000	$ 85,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 200,000	$ 200,000
4	Survey	L.S.	1	$ 85,000	$ 85,000
5	Construction Water	L.S.	1	$ 95,000	$ 95,000
6	Temporary De-Watering	L.S.	1	$ 50,000	$ 50,000
7	Traffic Control	L.S.	1	$ 75,000	$ 75,000
8	Clearing & Grubbing	AC	40	$ 1,500	$ 60,000
9	On-Site Grading	Yd^3	375,000	$ 5	$ 1,875,000
10	Material Export	Yd^3	50,000	$ 12	$ 600,000
11	Finish Grading	AC	40	$ 300	$ 12,000
12	Access Roads	AC	7.5	$ 90,000	$ 675,000
13	Dam Foundation	L.F.	60	$ 12,000	$ 720,000
14	Rubber Dam & Equipment	L.S.	1	$ 600,000	$ 600,000
15	Dam Downstream Grade Stabilizer	L.F.	100	$ 500	$ 50,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	45,000	$ 12	$ 540,000
20	Frwy/Street Piping (60-inch dia. CMLC)	L.F.	1,200	$ 3,000	$ 3,600,000
21	Transfer Piping (60-inch dia. RCP)	L.F.	2,800	$ 500	$ 1,400,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	1,400	$ 450	$ 630,000
23	InterCell Transfers & Drains	L.S.	11	$ 250,000	$ 2,750,000
24	Overflow Spillways	L.S.	3	$ 250,000	$ 750,000
25	Basin Outlet Structure	L.S.	11	$ 65,000	$ 715,000
26	Surface Transfer Structure (Weir)	L.S.	4	$ 850,000	$ 3,400,000
27	Outlet Energy Dissipaters	L.S.	8	$ 50,000	$ 400,000
28	Diversion Spillway Gate	L.S.	1	$ 250,000	$ 250,000
29	60" Valves	L.S.	5	$ 45,000	$ 225,000
30	42" Valves	L.S.	22	$ 40,000	$ 880,000
31	Catwalks	L.S.	11	$ 45,000	$ 495,000
32	Dam & Equipment Electrical	L.S.	1	$ 150,000	$ 150,000
33	Flow Control Gate Electrical	L.S.	1	$ 500,000	$ 500,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	1	$ 25,000	$ 25,000
38	Low Flow Meter	L.S.	11	$ 20,000	$ 220,000
39	Level Sensor	L.S.	11	$ 10,000	$ 110,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	12,000	$ 100	$ 1,200,000
43	Mitigation	AC	3.0	$ 25,000	$ 75,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	1	$ 500,000	$ 500,000
47	Construction Management	%	5%		$ 1,392,350
48	Material Testing	%	0.5%		$ 139,235
49	Contingency	%	10%		$ 2,784,700
	Total Capital Costs				$ 32,823,285
	Annual Debt Service (5% @ 30 years)		0.06505		$ 2,135,155

Annual O&M Costs			City Creek Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Rubber Dam & Spillway Gate	L.S.	2	$ 30,000	$ 60,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	10	$ 1,000	$ 10,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 5,630,000	$ 56,300
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 25,000	$ 25,000
6	Valve & Gates	L.S.	1	$ 55,000	$ 55,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 45,000	$ 45,000
8	Basin Cleanings	Yd^3	10,137	$ 2	$ 20,274
9	Material Export	Yd^3	10,637	$ 12	$ 127,645
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 424,220

Project Benefit Summary			City Creek Basin		
	Total Annual Project Cost	$			$ 2,559,374
	Average Annual Benefit	AF/YR			5,247
	Average Annual Recharge Unit Cost	$/AF			$ 488

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Waterman Basins (Station 5)

Existing Conditions

The Waterman Basins site is located along the west branch of Waterman Creek and is bordered by North Waterman Avenue to the west and East 40th Street to the south. The basins are an existing SBCFCD facility (System # 2-403-4 A-D) located approximately 3.2 miles north-east of the 210 Freeway/215 Freeway interchange in the City of San Bernardino (Figure 46). The existing basins attenuate storm flows from Waterman Creek and the overall site covers an area approximately 192 acres in size.

Water flows into the Waterman Basins from north and is either bypassed around the basins and sent directly into Twin Creek, or routed through the basins by a radial gate diversion system (Figure 47). Flows that are diverted into the basin are discharged at the south-east corner of the site into Twin Creek. The west and south perimeter berms of the site are a USACE levee.

There are 4 primary basin groups within the Waterman Basins site which provide an opportunity to increase storm water capture and groundwater recharge in the basins. The basins are interconnected by a series of surface transfer structures and low-level drain tubes. The approximate volume available for storm water capture is 180 af across 31.5 wetted acres. Overall the Waterman Basins have an elevation differential of approximately 90 feet over the 2,800 foot site (3.2% grade).

Figure 46: Waterman Basins Overview

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Figure 47: Waterman Basins Site (Existing Diversion Radial Gates)

Proposed Improvements

The proposed improvements at Waterman Basins for the ARP are to construct an inflatable armored dam (Obermeyer Spillway Gate) diversion across the west branch Waterman Creek bypass channel to increase the diversion flow rate capacity. Additionally, the existing radial gate system will be refurbished along with the refurbishment of the inner-basin surface transfer structures and low-level outlets/drains.

A new operational plan would need to be implemented with SBCFCD in order realize the project benefit at Waterman Basins. In general, higher flows would be diverted into the basins more frequently and the basins would be operated at higher WSEs for longer durations to allow captured storm water to be infiltrated into the basins.

The existing basins will be cleaned to remove deposits of silt and clay. The average operating level within the basin will range between 7-10 feet for a total wetted area of 31.5 acres and a storage volume of 180 af. The groundwater recharge acreages and volumes proposed here are very conservative and may be expanded in the future after successfully demonstrating that there are no impacts to the flood control function of the

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basins. There will be no groundwater recharge operations in the zones directly adjacent to the USACE levees.

Based on field observations and preliminary hydraulic analysis it is estimated that the existing diversion capacity could be as high as 1,000 cfs with the proper hydraulic conditions. In order to create adequate hydraulic head to convey 1,000 cfs into the basins a new armored spillway gate will be needed. A series of model iterations were performed to help determine what diversion flow rate would be optimum to fully utilize the basins. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 1,675 af/yr) would be realized by constructing the proposed improvements and re-operating the Waterman Basins.

The proposed physical improvements for the ARP at the Waterman Basins include the construction of two 17' long by 8' tall spillway gates, refurbishment of 2 radial gate systems, refurbishment of 3 inner-basin surface transfer structures and 10 low-level outlets/drains. Each of the basins should include the construction of remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in Waterman Creek at the diversion site and flow meters in the diversion structure to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

Figure 48: Waterman Basins Conceptual Design (Plan View)

Figure 49: Waterman Basins Conceptual Design (Diversion Isometric View)

Figure 50: Waterman Basins Conceptual Design (Existing Radial Gates)

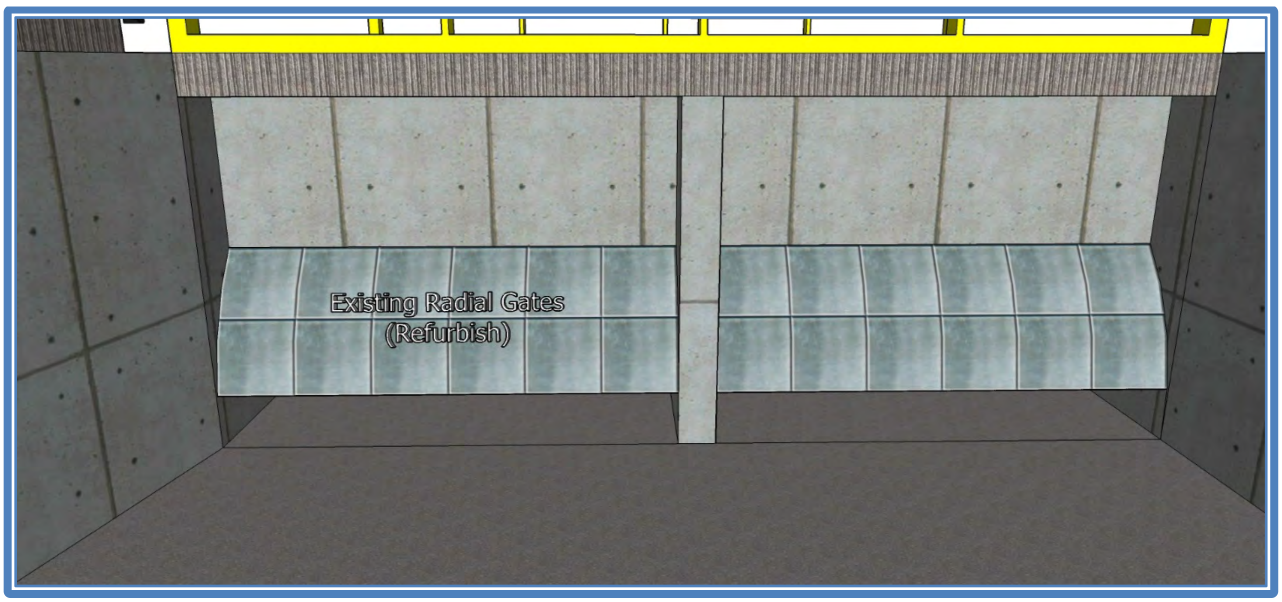

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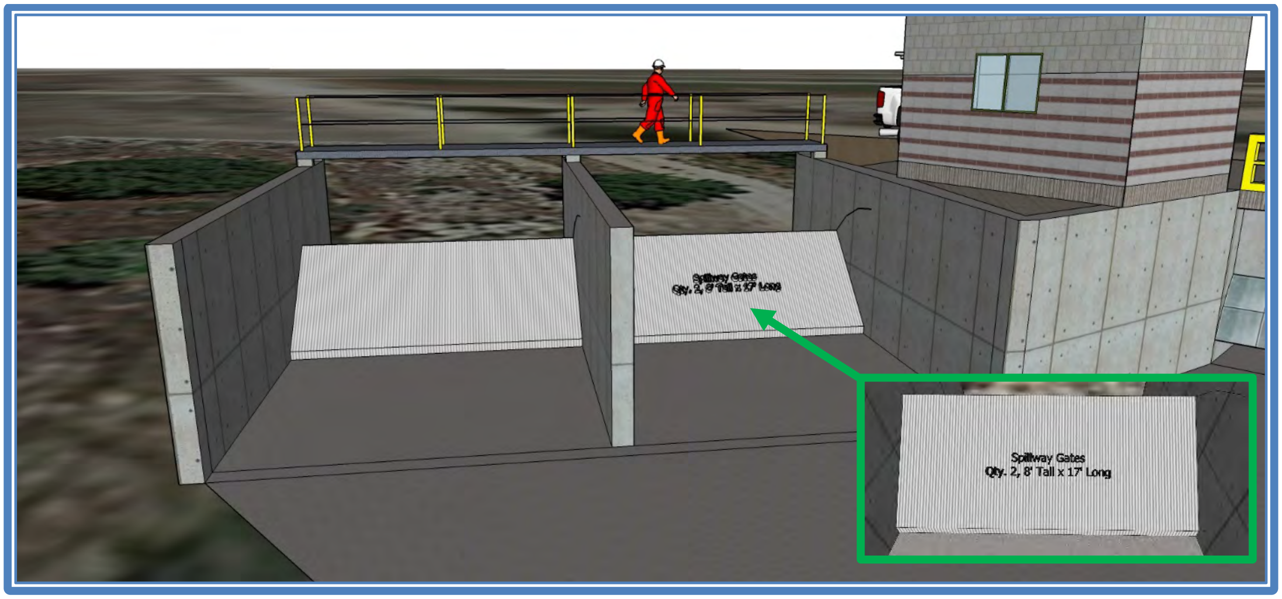
Figure 51: Waterman Basins Conceptual Design (Proposed Spillway Gates)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Waterman Basins Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 22. The forebay area above the radial gate diversion (although very small when compared to the basin system) was also included in the model to better capture the full benefit of the project.

The available flows at the Waterman Basins used in the groundwater recharge operations model were from flow station 5. Excess flows from station 5 (either due to bypass or discharged from the basins) were added to the flows into Twin Creek discussed late in this report. The 1,000 cfs diversion assumption is greater then what is required for the areas and volumes analyzed here, however, utilizing additional storage volume in Waterman Basins at a later date will require the higher diversion rates assumed in the model. Also, if the basins perform at a higher level than expected, then the increased diversion flow rate capacity will be required.

Please note that only 1 example of a Waterman Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 53 and Figure 54 to illustrate how the infiltration rates may decay in the Waterman Basins.

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Table 22: Waterman Basins Model Assumptions

Waterman Basins flow hydrograph	See Figure 52
Basin area and volume	Area = 31.5 acres, Volume = 180 af
Forebay area and volume	Area = 0.06 acres, Volume = 0.23 af
Initial infiltration rates	0.9 ft/day
Infiltration rate decay parameters	See Figure 54 (using Figure 53 flow series)
Diversion flow capacity	1,000 cfs
Dam deflation set point	1,000 cfs
Diversion flow rate with dam deflated	100 cfs

Figure 52: Waterman Basins Flows

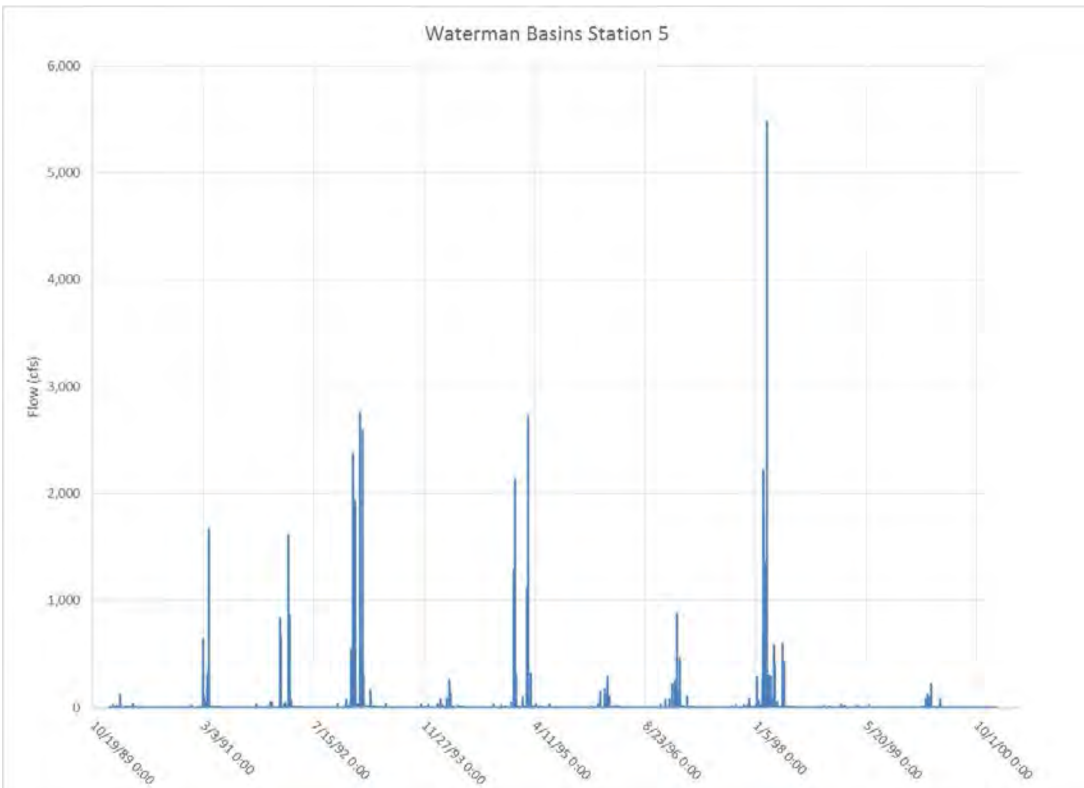

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Figure 53: Waterman Basins Optimization Flow Series

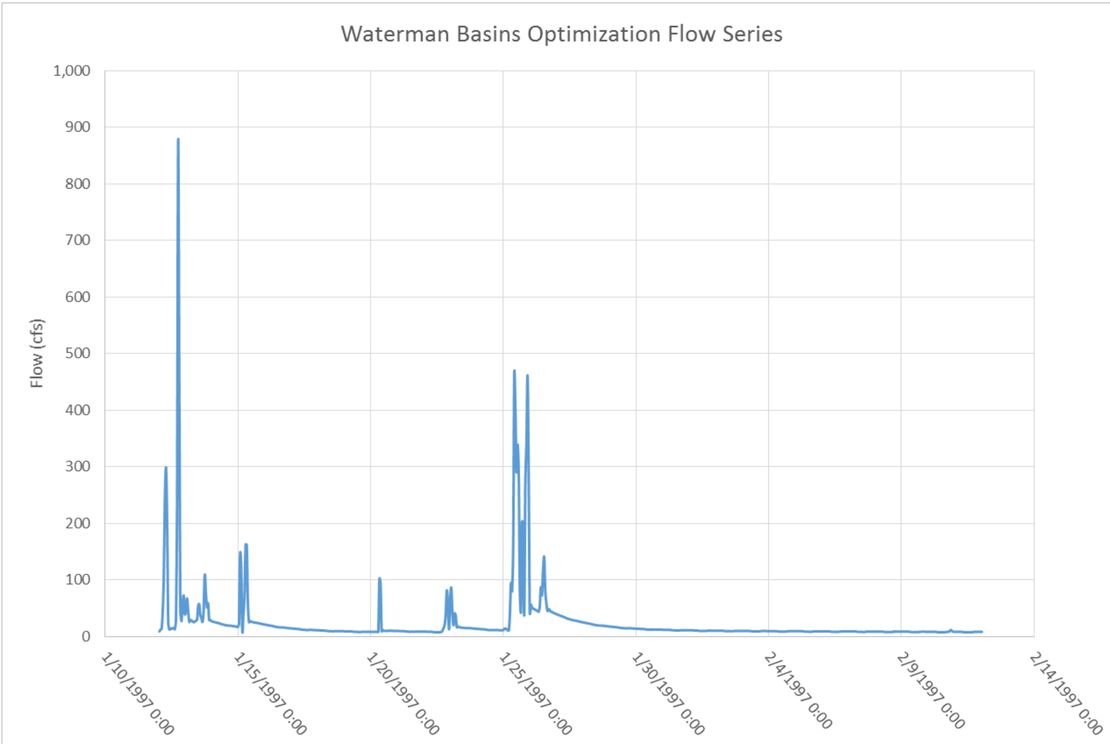
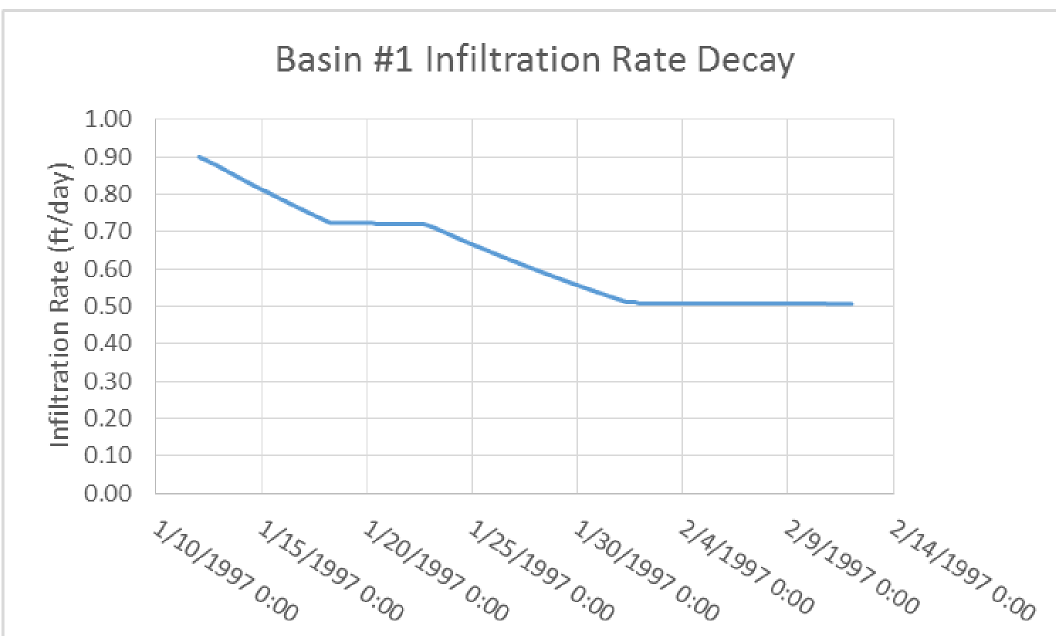


Figure 54: Waterman Basin Infiltration Rate Decay



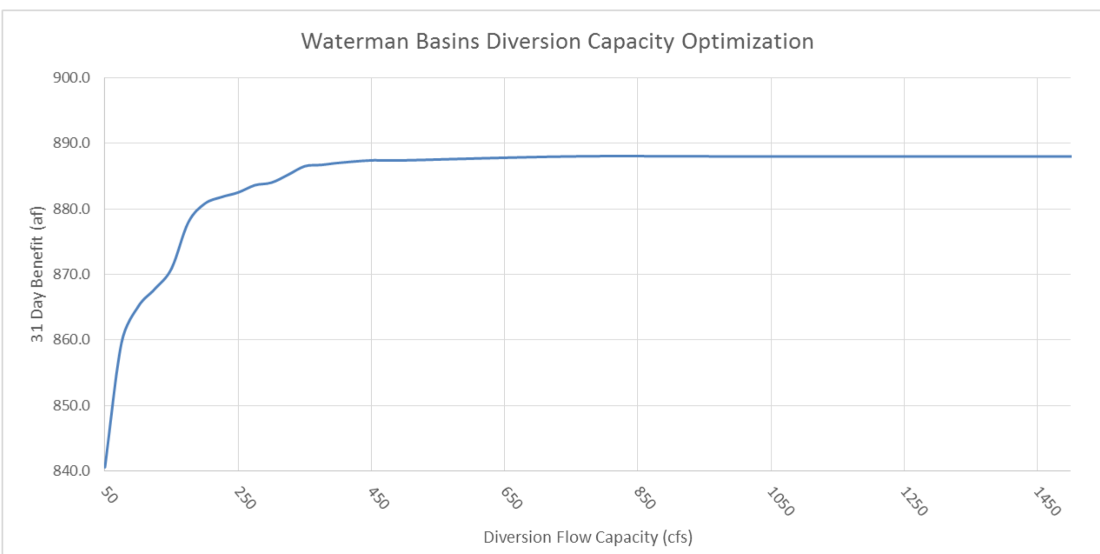
In order to determine the optimum diversion flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 52 as the inflow for the optimization flow series for the diversion (Figure 53).

The diversion flow capacity was increased in 25 cfs increments from 50 cfs up to 1,500 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 55).

Approximately 635 af of water is bypassed around the system at a 1,000 cfs diversion flow rate capacity, this is because the basins fill rapidly given the very high flow rates in the flow series selected and then only requires a diversion flow rate equivalent to the infiltration rate of the basins.

The project benefit plateaus at a diversion flow rate of approximately 500 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 1,000 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events. As higher operating levels are approved the ability to divert higher flows will already be in place. Also, the cost to construct/refurbish the diversion for 500 verses 1,000 cfs will be relatively small given that the diversion structure is already in place.

Figure 55: Waterman Basins Diversion Optimization Results



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The 11 year flow series was modeled using the 1,000 cfs diversion capacity to predict the total amount of storm water captured and recharged during the model period. The final Waterman Basins Project model results can be seen in Table 23.

Table 23: Waterman Basins 11 Year Model Results

Total Available Flow (af)	34,192
Total Flow Captured & Recharged (af)	18,421
Total Flow Bypassed (af)	15,771
Annual Average Flow Captured & Recharged (af)	1,675

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the radial gates and spillway gates operate properly. During periods of especially high sedimentation, vegetation or debris buildup in the forebay area operators may find it beneficial to purposely drop the spillway gate for short periods of time to encourage the natural bypass of the materials around the basins.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates, meters, level sensors and spillway gate mechanical and control systems. An armored spillway gate will be required in order to withstand the large rocks and cobles transported across it in high flow events. The gate will require regular maintenance and re-coating to repair surficial damage caused by the bedload transported across it. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 1 cleaning per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Waterman Basins Project is presented in Table 24.

Table 24: Waterman Basins Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	1,260	115

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Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 25: Waterman Basins Cost Estimate

Capital Costs			Waterman Basins		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 75,000	$ 75,000
2	SWPPP	L.S.	-	$ 85,000	$ -
3	Sheeting/Shoring/Bracing	L.S.	1	$ 45,000	$ 45,000
4	Survey	L.S.	1	$ 25,000	$ 25,000
5	Construction Water	L.S.	1	$ 35,000	$ 35,000
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	-	$ 75,000	$ -
8	Clearing & Grubbing	AC	10	$ 1,500	$ 15,000
9	On-Site Grading	Yd^3	5,000	$ 5	$ 25,000
10	Material Export	Yd^3	300	$ 12	$ 3,600
11	Finish Grading	AC	10	$ 300	$ 3,000
12	Access Roads	AC	1.0	$ 90,000	$ 90,000
13	Spillway Gate Foundation	L.F.	40	$ 12,000	$ 480,000
14	Spillway Gate & Equipment	L.S.	2	$ 250,000	$ 500,000
15	Spillway Downstream Grade Stabilizer	L.F.	40	$ 500	$ 20,000
16	Diversion Structure (Radial Gate Rehab)	L.S.	2	$ 75,000	$ 150,000
17	Trash Rack System (Automated)	L.S.	-	$ 1,500,000	$ -
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	4,500	$ 12	$ 54,000
20	Frwy/Street Piping (60-inch dia. CMLC)	L.F.	-	$ 3,000	$ -
21	Transfer Piping (60-inch dia. RCP)	L.F.	-	$ 500	$ -
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	1,300	$ 450	$ 585,000
23	InterCell Transfers & Drains	L.S.	10	$ 250,000	$ 2,500,000
24	Overflow Spillway Rehab	L.S.	3	$ 250,000	$ 750,000
25	Basin Outlet Structure	L.S.	10	$ 65,000	$ 650,000
26	Surface Transfer Structure (Weir)	L.S.	-	$ 850,000	$ -
27	Outlet Energy Dissipaters	L.S.	-	$ 50,000	$ -
28	Diversion Spillway Gate Channels	L.S.	2	$ 85,000	$ 170,000
29	60" Valves	L.S.	-	$ 45,000	$ -
30	42" Valves	L.S.	10	$ 40,000	$ 400,000
31	Catwalks	L.S.	10	$ 45,000	$ 450,000
32	Dam & Equipment Electrical	L.S.	1	$ 150,000	$ 150,000
33	Flow Control Gate Electrical	L.S.	-	$ 500,000	$ -
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	1	$ 25,000	$ 25,000
38	Low Flow Meter	L.S.	-	$ 20,000	$ -
39	Level Sensor	L.S.	12	$ 10,000	$ 120,000
40	Monitoring Well	L.S.	-	$ 75,000	$ -
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	-	$ 100	$ -
43	Mitigation	AC	5.0	$ 25,000	$ 125,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 432,780
48	Material Testing	%	0.5%		$ 43,278
49	Contingency	%	10%		$ 865,560
	Total Capital Costs				$ 10,207,218
	Annual Debt Service (5% @ 30 years)		0.06505		$ 663,980

Annual O&M Costs			Waterman Basins		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Spillway Gate	L.S.	2	$ 30,000	$ 60,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	-	$ 1,000	$ -
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 585,000	$ 5,850
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 10,000	$ 10,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 15,000	$ 15,000
8	Basin Cleanings	Yd^3	8,604	$ 2	$ 17,209
9	Material Export	Yd^3	9,104	$ 12	$ 109,253
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 277,312

Project Benefit Summary			Waterman Basins		
	Total Annual Project Cost	$			$ 941,292
	Average Annual Benefit	AF/YR			1,675
	Average Annual Recharge Unit Cost	$/AF			$ 562

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Twin Creek Spreading Grounds (Station 6)

Existing Conditions

The Twin Creeks Spreading Grounds are flow through basins located within Twin Creek. The spreading grounds are bordered by Harrison Street North to the east and East 40th Street to the north. The spreading grounds are an existing SBCFCD facility (System # 2-406-2A) located approximately 3.1 miles north-east of the 210 Freeway/215 Freeway interchange in the City of San Bernardino (Figure 56). The existing basins within the spreading grounds were originally meant to attenuate storm flows. However, the berms which separate one basin form the next have been eroded and/or purposely breached, and flows currently pass through the spreading grounds unobstructed. The overall site covers an area approximately 131 acres in size.

Water flows into the Twin Creek Spreading Grounds from the north and flows to the south (Figure 57). As discussed previously, excess flow (or flow that is purposely drained) from Waterman Basins enter the spreading grounds as well. The outer perimeter berms on the east and west of the site are a USACE levees.

There are a total of 8 basins within the spreading grounds and 1 area above East 40th Street. The downstream most basin is bound by a USACE levee on the south side and will not be used for groundwater recharge purposes. Eight of the nine basins on the site provide an opportunity to increase storm water capture and groundwater recharge. Once the inner berms are repaired the approximate storage volume available for storm water capture is 372 af over an area of 70.2 wetted acres. Overall the Twin Creek Spreading Grounds have an elevation differential of approximately 110 feet over the 6,200 foot site (1.8% grade).

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Figure 56: Twin Creek Spreading Grounds Overview

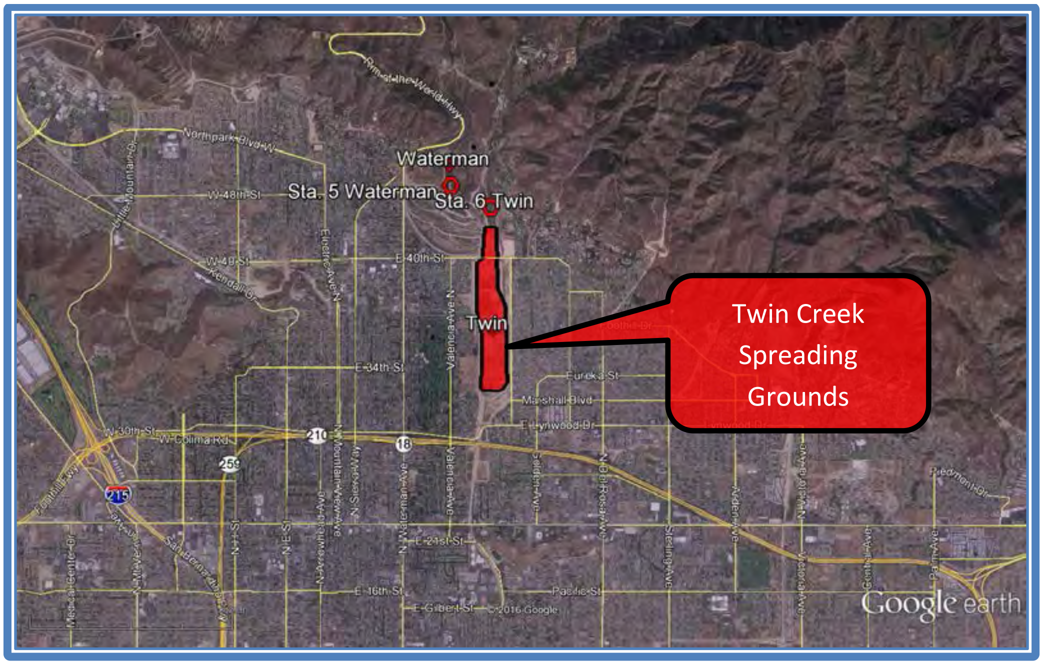

Figure 57: Twin Creek Spreading Grounds Site (Looking South-West)

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Proposed Improvements

The proposed improvements at the Twin Creek Spreading Grounds for the ARP include reconstructing and armoring the berms between each basin and adding low level outlets/drains to each basin. Additionally, portions of the basins will need to be re-graded to restore infiltration rates and achieve positive drainage.

A new operational plan will need to be implemented with SBCFCD in order to maximize the project benefit at the spreading grounds. In general, the basin drain tubes will remain closed and the basins will be operated at higher WSEs for longer durations to allow captured storm water to be infiltrated into the basins. During very high flow events the basins may need to be drained in order to preserve the flood control function of the system.

The existing basins will be cleaned to remove deposits of silt and clay. The average operating level within the basin will range between 4-8 feet for a total wetted area of 70.2 acres and a storage volume of 372 af. There will be no groundwater recharge operations in the zones directly adjacent to the USACE levees.

There are no diversion or inlet restrictions associated with this project. There were no model iterations needed to determine an optimum diversion flow rate. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 4,087 af/yr) would be realized by constructing the proposed improvements and re-operating the Twin Creek Spreading Grounds.

The proposed physical improvements for the ARP at the Twin Creek Spreading Grounds include the re-construction and armoring of 7 existing berms, construction of 1 new water conservation berm above East 40th Street, construction of 8 new low-level outlets/drains and basin re-grading. Each of the basins should include the construction of remote level sensing and inflow/outflow metering. The following figures provide conceptual design views of the proposed improvements.

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Figure 58: Twin Creek Spreading Grounds Conceptual Design (Plan View)

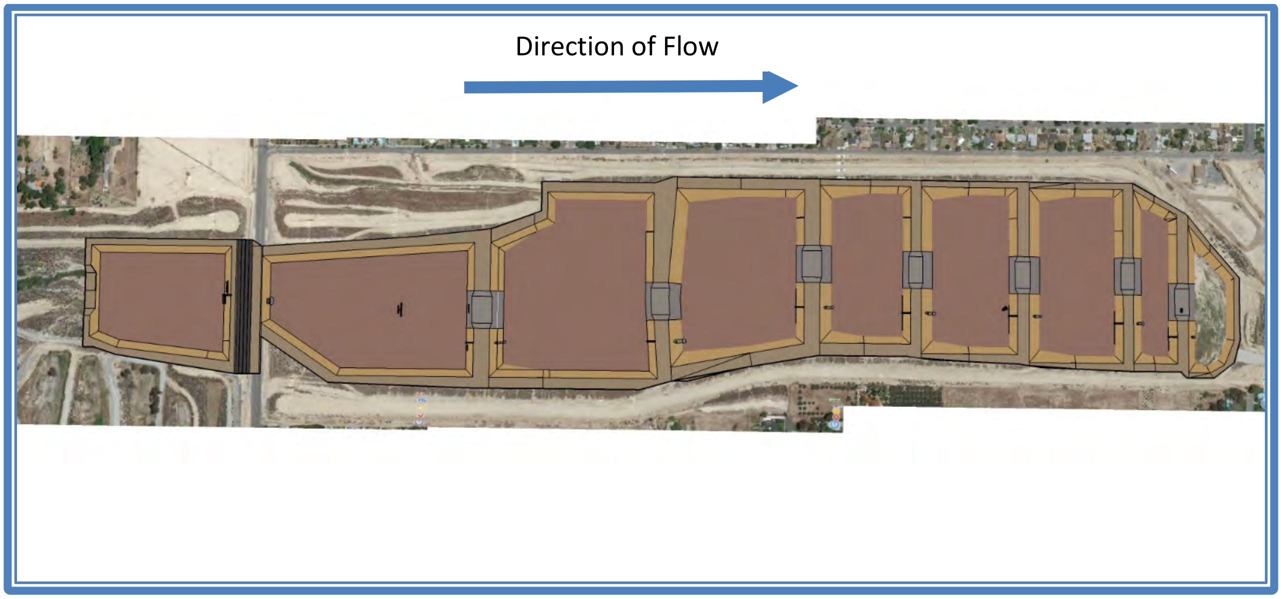

Figure 59: Twin Creek Spreading Grounds Conceptual Design (View Looking Downstream)

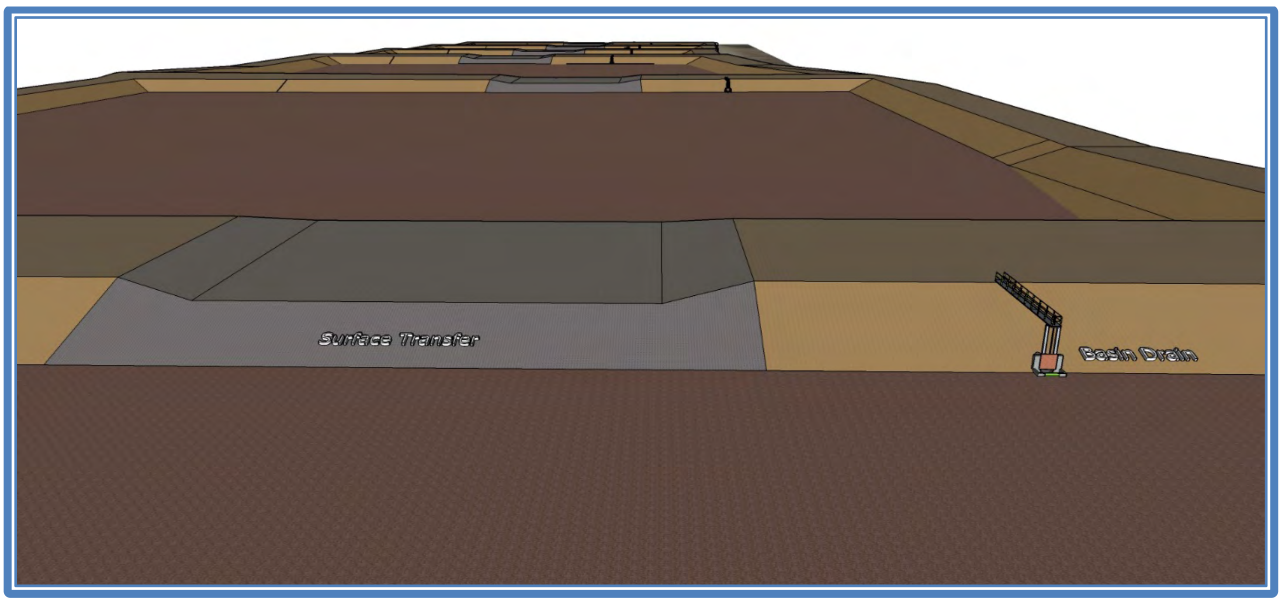

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Figure 60: Twin Creek Spreading Grounds Conceptual Design (Isometric View)

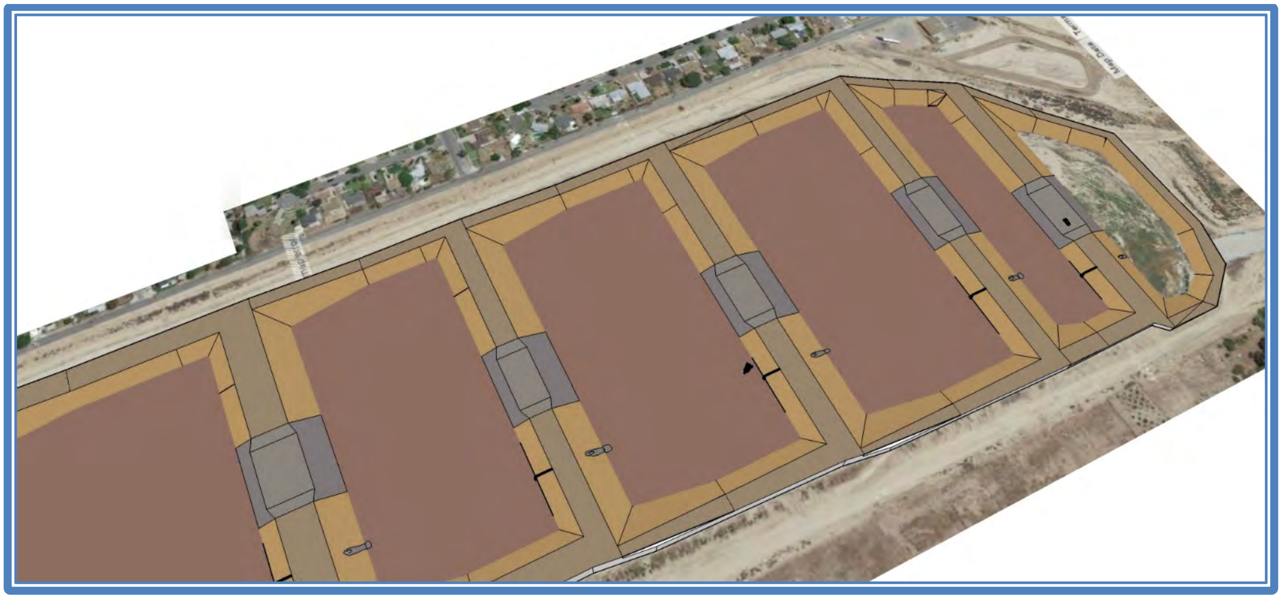
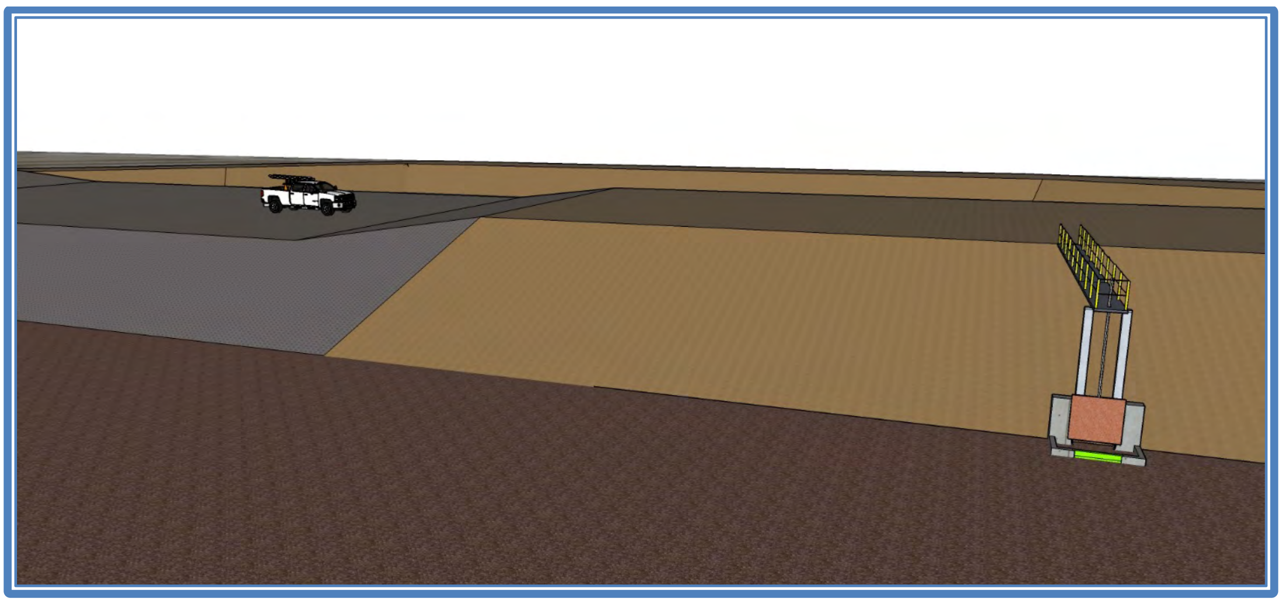


Figure 61: Twin Creek Spreading Grounds Conceptual Design (Outlet View)



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Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Twin Creek Spreading Grounds Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 26.

The available flows at the Twin Creek Spreading Grounds used in the groundwater recharge operations model were from flow station 6 with the addition of excess flows from Waterman Basins (station 5). There was no model limit set on the inflow rate from a groundwater recharge perspective.

Please note that only 1 example of a Twin Creek Spreading Grounds infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 53 and Figure 54 to illustrate how the infiltration rates may decay in the Twin Creek Spreading Grounds.

Table 26: Twin Creek Spreading Grounds Model Assumptions

Twin Creek flow hydrograph	See Figure 62
Basin area and volume	Area = 70.2 acres, Volume = 372 af
Forebay area and volume	NA
Initial infiltration rates	0.9 ft/day
Infiltration rate decay parameters	See Figure 64 (using Figure 63 flow series)
Diversion flow capacity	NA
Dam deflation set point	NA
Diversion flow rate with dam deflated	NA

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Figure 62: Twin Creek Spreading Grounds Flows

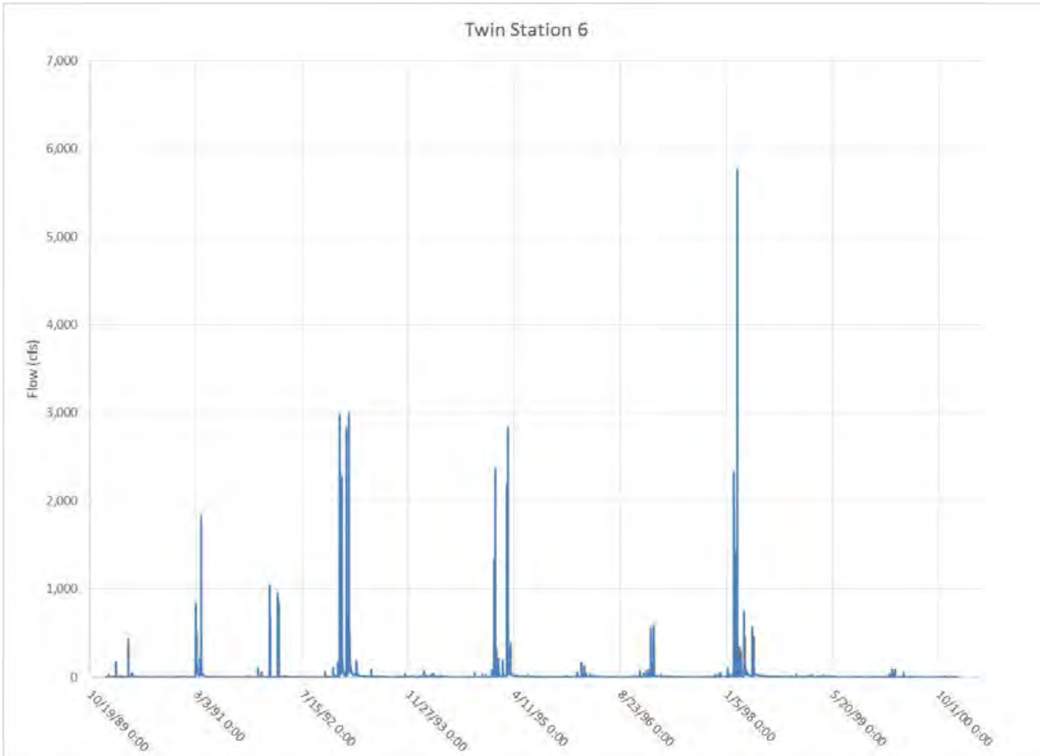

Figure 63: Twin Creek Spreading Grounds Infiltration Rate Decay Flow Series

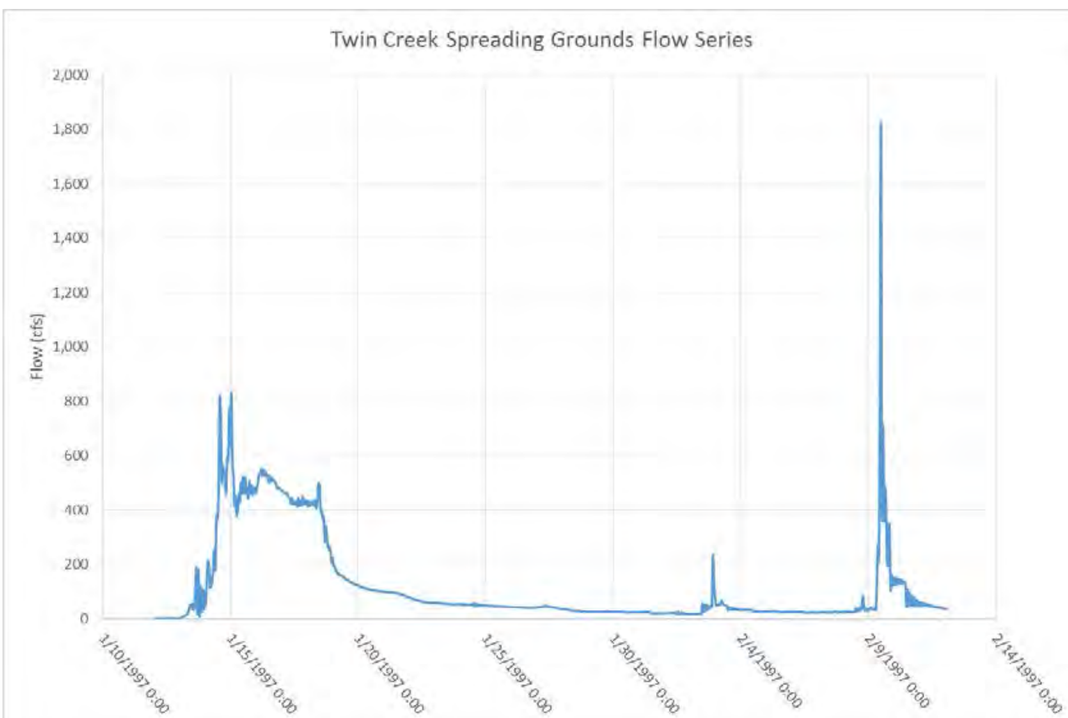

Figure 64: Twin Creek Spreading Grounds Infiltration Rate Decay

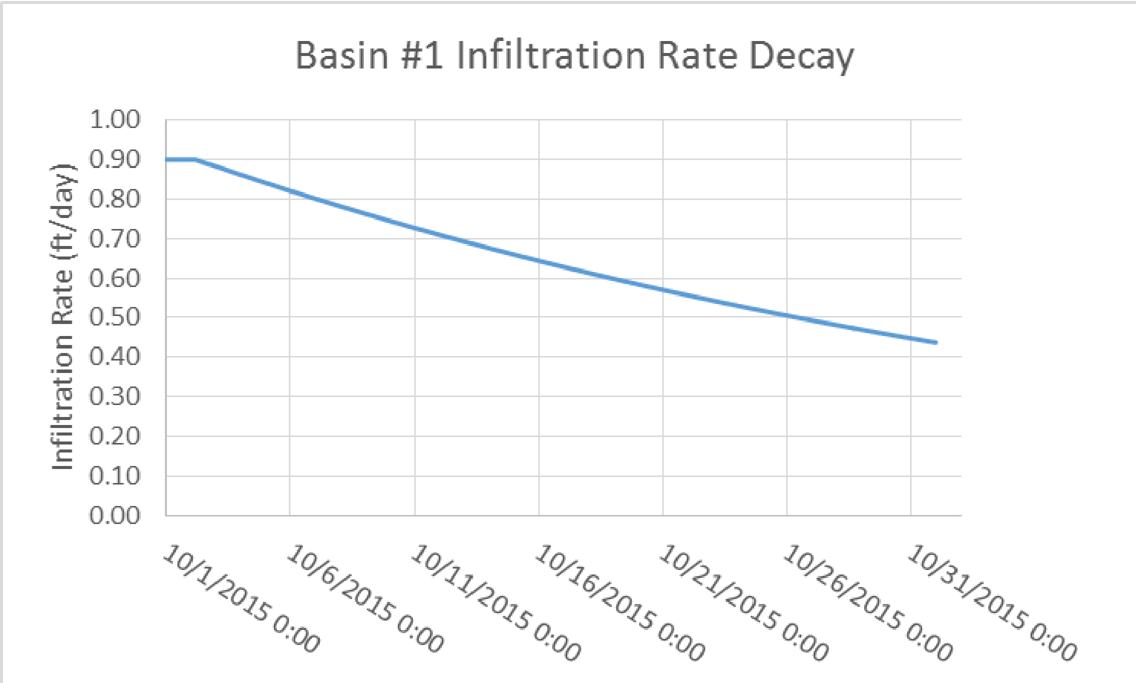

Figure 65: Twin Creek Spreading Grounds Diversion Optimization Results

No Diversion, Flow Thorugh System

The 11 year flow series was modeled to predict the total amount of storm water captured and recharged during the model period. The final Twin Creek Spreading Grounds Project model results can be seen in Table 27.

Table 27: Twin Creek Spreading Grounds 11 Year Model Results

Total Available Flow (af)	77,698
Total Flow Captured & Recharged (af)	44,956
Total Flow Bypassed (af)	32,742
Annual Average Flow Captured & Recharged (af)	4,087

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site occasionally during storm events to operate the drain tubes in advance of significant storm events.

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Maintenance activities will include the removal of sediment, vegetation and debris from the basin areas. Regular maintenance will also be required on the low-level flow control gates, meters and basin level sensors. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment that will deposit in the basins. The 11 year total, and annual average, sediment loading for the Twin Creek Spreading Grounds Project is presented in Table 28.

Table 28: Twin Creek Spreading Grounds Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	3,135	285

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 29: Twin Creek Spreading Grounds Cost Estimate

Capital Costs			Twin Creek Spreading Grounds		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 85,000	$ 85,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 75,000	$ 75,000
4	Survey	L.S.	1	$ 55,000	$ 55,000
5	Construction Water	L.S.	1	$ 110,000	$ 110,000
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	1	$ 45,000	$ 45,000
8	Clearing & Grubbing	AC	50	$ 1,500	$ 75,000
9	On-Site Grading	Yd^3	750,000	$ 5	$ 3,750,000
10	Material Export	Yd^3	5,000	$ 12	$ 60,000
11	Finish Grading	AC	130	$ 300	$ 39,000
12	Access Roads	AC	6.0	$ 90,000	$ 540,000
13	Spillway Gate Foundation	L.F.	-	$ 12,000	$ -
14	Spillway Gate & Equipment	L.S.	-	$ 350,000	$ -
15	Spillway Downstream Grade Stabilizer	L.F.	-	$ 500	$ -
16	Diversion Structure	L.S.	-	$ 1,250,000	$ -
17	Trash Rack System (Automated)	L.S.	-	$ 1,500,000	$ -
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	152,000	$ 12	$ 1,824,000
20	Diversion Piping (60-inch dia. RCP)	L.F.	-	$ 500	$ -
21	Jack Bore Transfer Piping (42-inch dia. RCI	L.F.	1,200	$ 2,000	$ 2,400,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	1,400	$ 450	$ 630,000
23	InterCell Transfers & Drains	L.S.	-	$ 250,000	$ -
24	Overflow Spillway Rehab	L.S.	-	$ 250,000	$ -
25	Basin Outlet Structure	L.S.	-	$ 65,000	$ -
26	Surface Transfer Structure (Weir)	L.S.	1	$ 850,000	$ 850,000
27	Outlet Energy Dissipaters	L.S.	8	$ 50,000	$ 400,000
28	Surface Transfer Rehab	L.S.	7	$ 125,000	$ 875,000
29	60" Valves	L.S.	-	$ 45,000	$ -
30	42" Valves	L.S.	8	$ 40,000	$ 320,000
31	Catwalks	L.S.	8	$ 45,000	$ 360,000
32	Spillway Gate & Equipment Electrical	L.S.	-	$ 150,000	$ -
33	Flow Control Gate Electrical	L.S.	-	$ 500,000	$ -
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	-	$ 25,000	$ -
38	Low Flow Meter	L.S.	-	$ 20,000	$ -
39	Level Sensor	L.S.	8	$ 10,000	$ 80,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	-	$ 100	$ -
43	Mitigation	AC	5.0	$ 25,000	$ 125,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 712,900
48	Material Testing	%	0.5%		$ 71,290
49	Contingency	%	10%		$ 1,425,800
	Total Capital Costs				$ 16,677,990
	Annual Debt Service (5% @ 30 years)		0.06505		$ 1,084,903

Annual O&M Costs			Twin Creek Spreading Grounds		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Spillway Gate	L.S.	-	$ 30,000	$ -
2	Diversion Head Works	L.S.	-	$ 15,000	$ -
3	Forebay Recharge Area	Day	-	$ 1,000	$ -
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 3,030,000	$ 30,300
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 15,000	$ 15,000
8	Basin Cleanings	Yd^3	26,889	$ 2	$ 53,778
9	Material Export	Yd^3	27,389	$ 12	$ 328,667
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 487,744

Project Benefit Summary			Twin Creek Spreading Grounds		
	Total Annual Project Cost	$			$ 1,572,648
	Average Annual Benefit	AF/YR			4,087
	Average Annual Recharge Unit Cost	$/AF			$ 385

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Lytle Creek (Station 7)

Existing Conditions

The Lytle Creek site is located within, and adjacent to, Lytle Creek and is bordered by North Riverside Avenue to the south-west. The site is approximately 3,700 feet south-east of the 15 Freeway/Lytle Creek crossing in the City of Rialto (Figure 66). The proposed diversion and basin system would be situated 3,200 feet to the north-west of the active CEMEX screening plant with the in-channel recharge site located immediately upstream of the basin inlet. The in-channel recharge and basin site covers an area approximately 200 acres in size.

The Basin area is currently open to flows from Lytle Creek, however, CEMEX is planning a project to construct a berm that would isolate the basin site from Lytle Creek. There is a potential opportunity to construct a basin inlet and internal basin berms to enhance groundwater recharge in the basin area. CEMEX has future plans to excavate the basin deeper which would require an agreement between Valley and CEMEX to define the duration, or other operational plans, for groundwater recharge operations in the basin.

Water flows in Lytle Creek from north-west to south-east. Flow in the creek is split by an island area which forces flow south toward the basin area or north around the basin and proposed in-channel recharge area. The south-east end of the basin area discharges flow across the CEMEX haul road.

Overall the Lytle Creek site has an elevation differential of approximately 270 feet over the 9,500 foot site (2.84%). The basin area is approximately 25 feet lower than Lytle Creek immediately to the north of the basin area.

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Figure 66: Lytle Creek Overview

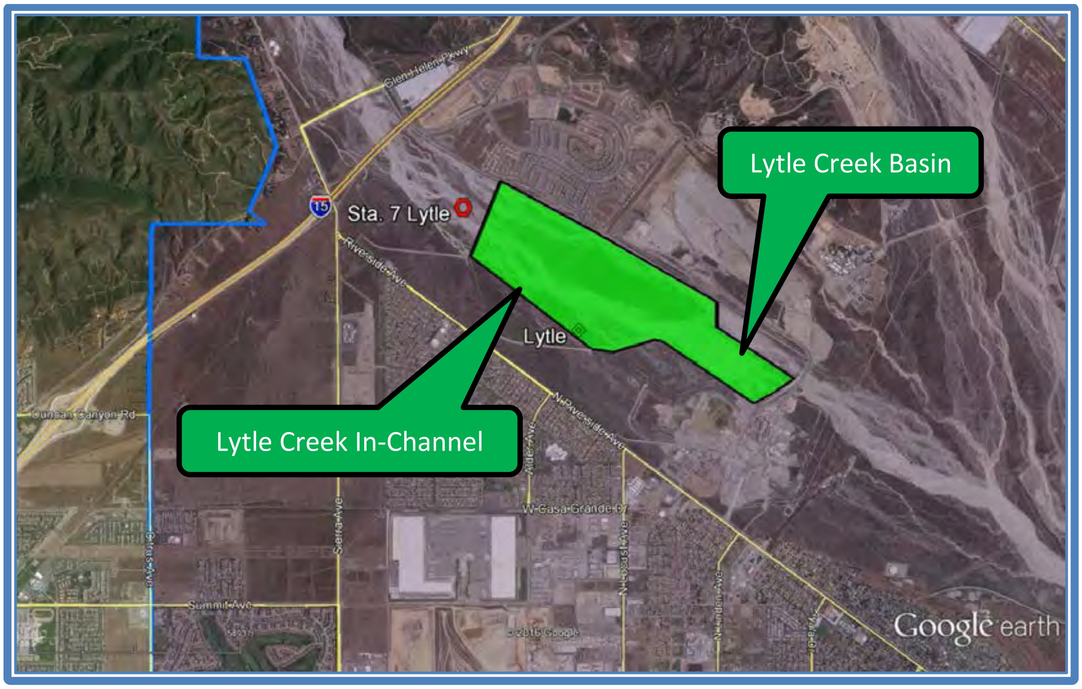

Figure 67: Lytle Creek Site (Looking South Over The Basin Area)

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Proposed Improvements

The proposed improvements at Lytle Creek for the ARP are to construct a sand diversion berm, 6 acres of in-channel recharge berms over a 60 acre site, a basin inlet structure and piping and a series of cells within the lager CEMEX basin area. The in-channel recharge area and basin cells have been developed to utilize gravity conveyance throughout the system and to maximize usage of the available area on the site.

The upstream end of the in-channel recharge area would require the construction and regular re-building of a sand diversion berm. The sand diversion berm will help to direct flows to the southern side of the existing island. The berm would be self-leveling during high flows to maintain the full flood control capacity of the creek. The basin inlet would be cooperatively designed and constructed with CEMEX's isolation berm planned for the basin area. A series of inner berms would be constructed within the basin area to terrace the site, create storage volume and maximizing the wetted area of the cells.

The in-channel recharge berms will be approximately 6 feet high and will help spread storm flows over the 60 acre site. The cell berms within the basin area will be approximately 15 feet high with slightly increased heights on the downstream slopes to terrace the basins to match the slope of the site. The maximum operating level within the basin will be approximately 12-14 feet deep for a total wetted area of 48 acres and a storage volume of 460 af. In order to avoid DSOD jurisdiction no single basin will have a berm height more than 25 feet in height or a storage capacity greater than 50 acre feet.

The area above the CEMEX isolation berm will act as the forebay for the diversion structure. The forebay area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in Lytle Creek. The wetted area above the isolation berm is approximately 19 acres in size with a volume capacity of approximately 223 af.

A series of model iterations were performed to help determine a target design flow rate of 500 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 4,023 af/yr) would be realized by constructing the Lytle Creek Project.

The proposed improvements for the ARP at the Lytle Creek site include the construction of 6 acres of in-channel recharge basins, construction of a 1,400' long by 8' tall sand diversion berm, construction of a 500 cfs diversion/inlet structure, construction of 14 basin cells (48 acres total wetted area) and transfer/overflow structures. Each of the basin cells should include remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in Lytle Creek and at the diversion site and

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flow meters in the diversion structure to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

Figure 68: Lytle Creek Basin Conceptual Design (Plan View)

Figure 69: Lytle Creek Basin Conceptual Design (Isometric View)

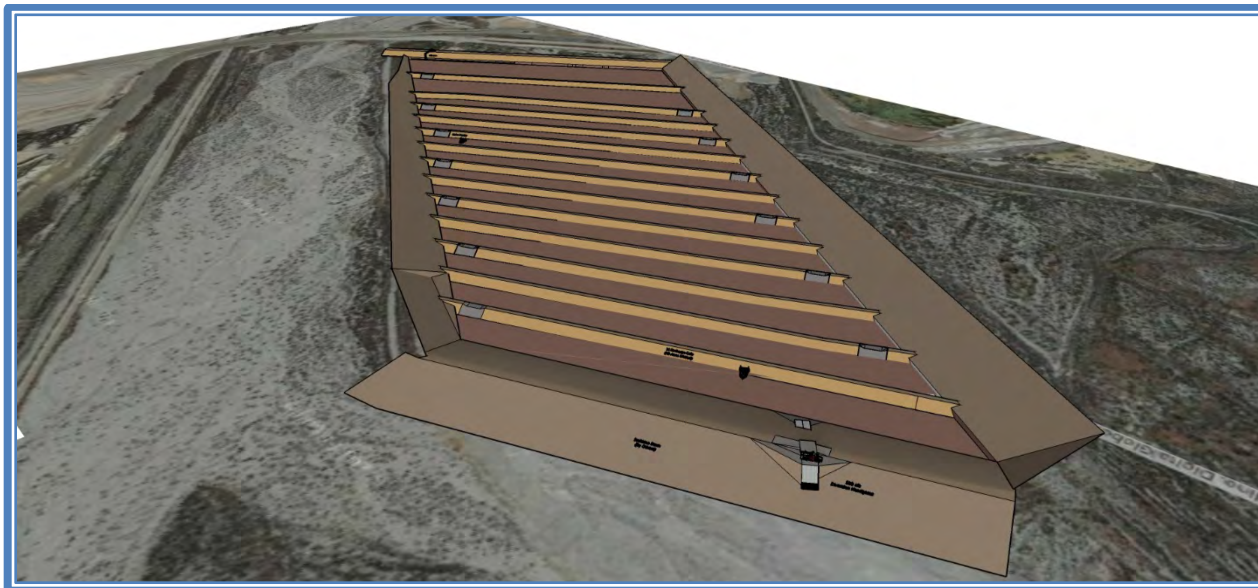

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Figure 70: Lytle Creek Basin Conceptual Design (Diversion View)

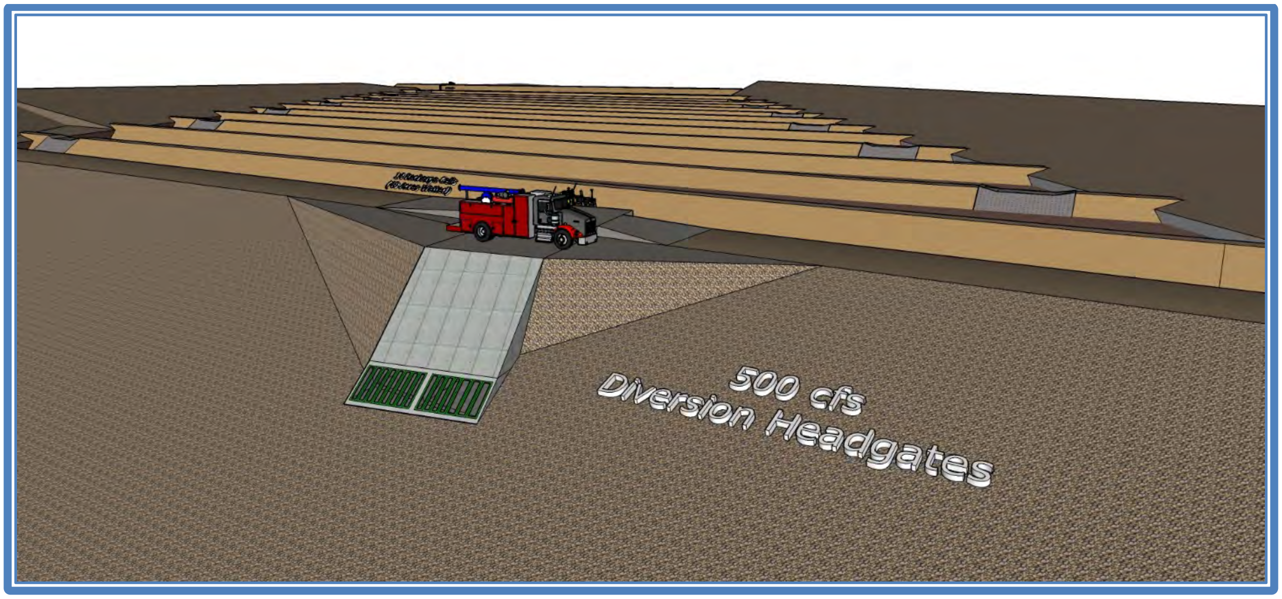
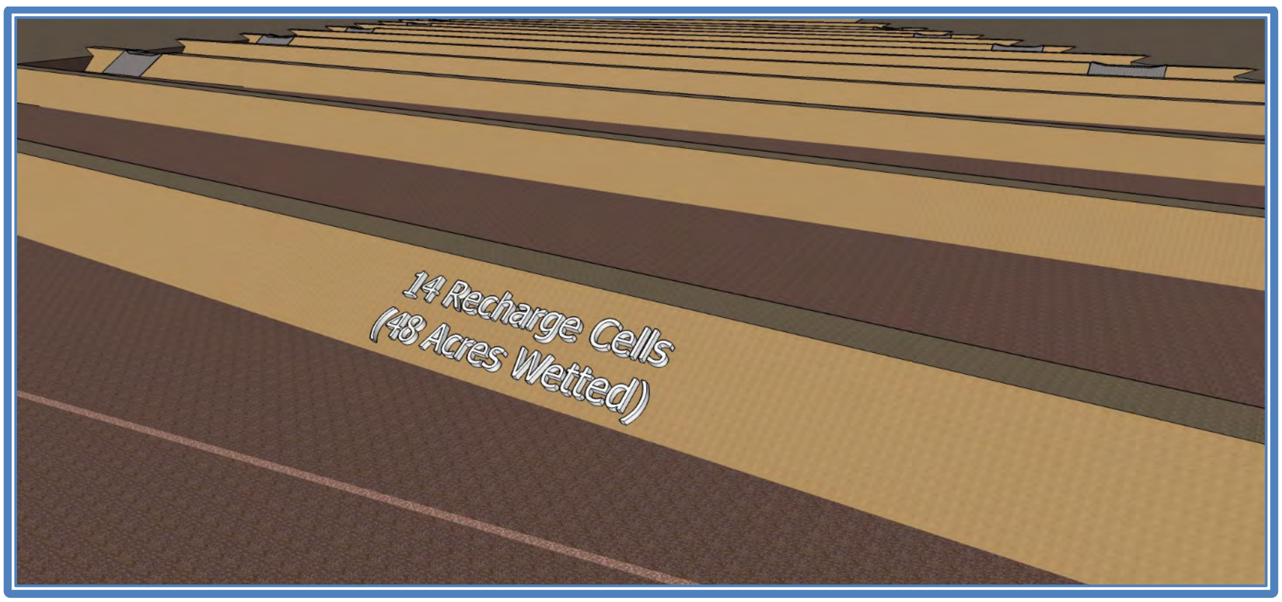


Figure 71: Lytle Creek Basin Conceptual Design (Recharge Cell View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Lytle Creek Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 30. The forebay area above the sand

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diversion berm was also included in the model to better capture the full benefit of the project.

A fundamental assumption of the model is that each time there is a high flow event that washes out the sand diversion berm, the diversion flows are reduced until such time that the berm can be reconstructed. On average the berm will need to be reconstructed 1 to 2 times per year. The available flows at the Lytle Creek site used in the groundwater recharge operations model were from flow station 7.

Please note that only 1 example of a Lytle Creek Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 73 and Figure 74 to illustrate how the infiltration rates might decay in the Lytle Creek Basins.

Table 30: Lytle Creek Model Assumptions

Lytle Creek flow hydrograph	See Figure 72
Basin area and volume	Area = 67 acres, Volume = 682 af
Forebay area and volume	Area = 6.0 acres, Volume = 24.1 af
Initial infiltration rates	2.2 ft/day
Infiltration rate decay parameters	See Figure 74 (using Figure 73 flow series)
Diversion flow capacity	500 cfs
Diversion berm washout flow rate	2,500 cfs
Diversion flow rate without berm	500 cfs

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Figure 72: Lytle Creek Flows

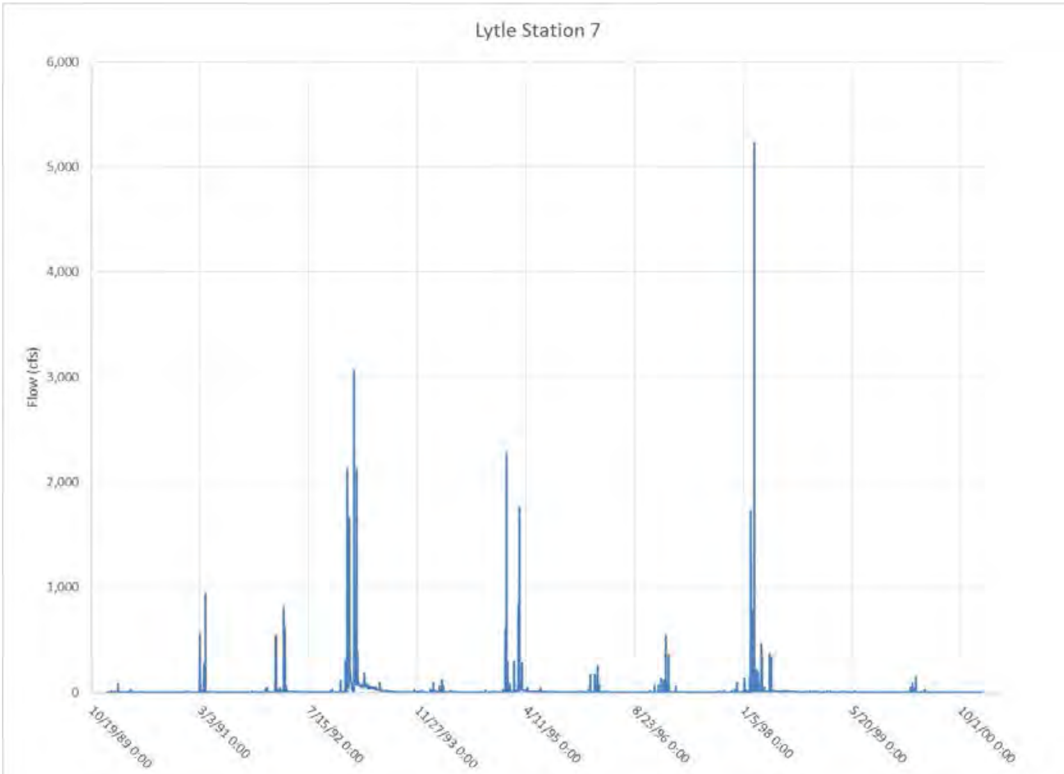


Figure 73: Lytle Creek Optimization Flow Series

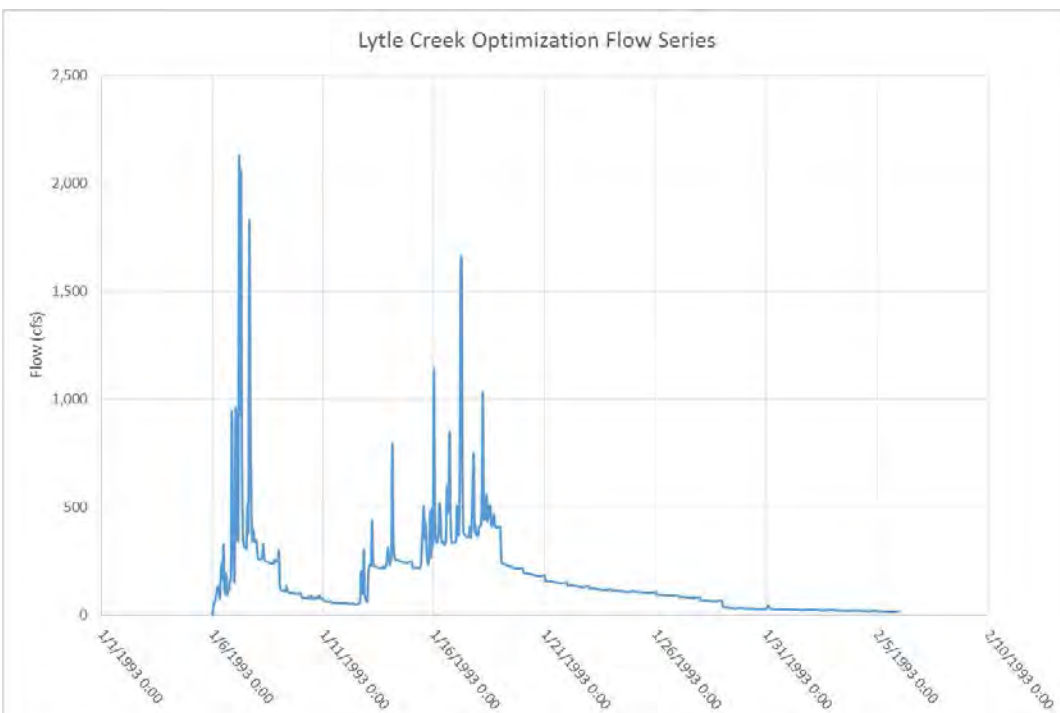
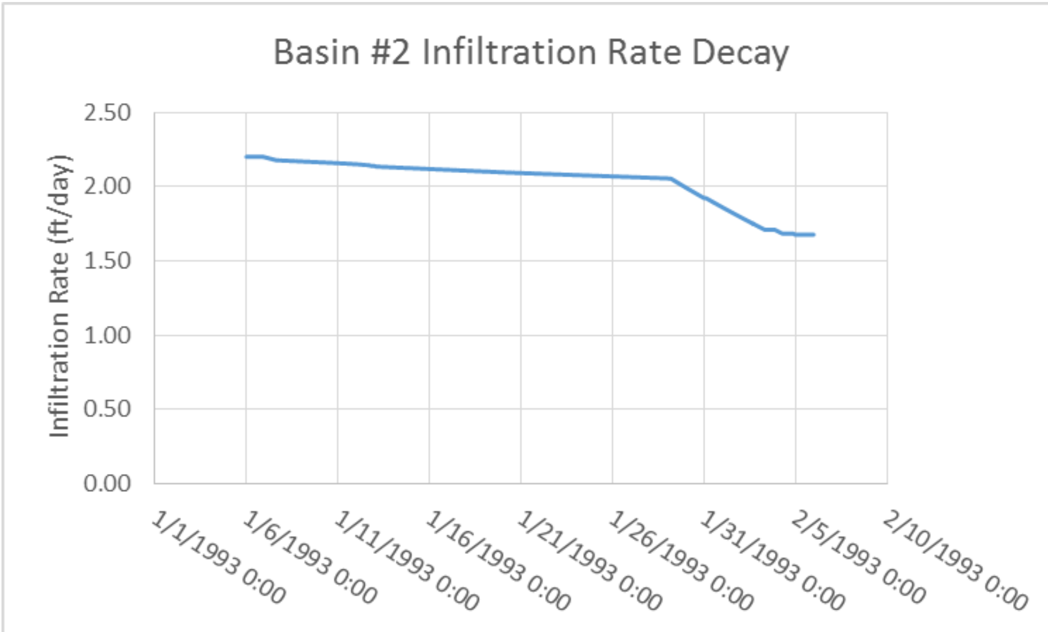


Figure 74: Lytle Creek Basin Infiltration Rate Decay



In order to determine the optimum basin inlet flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the basin inlet flow rate capacity. All model parameters were held constant except for the inlet size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 72 as the inflow for the optimization flow series for the inlet (Figure 73).

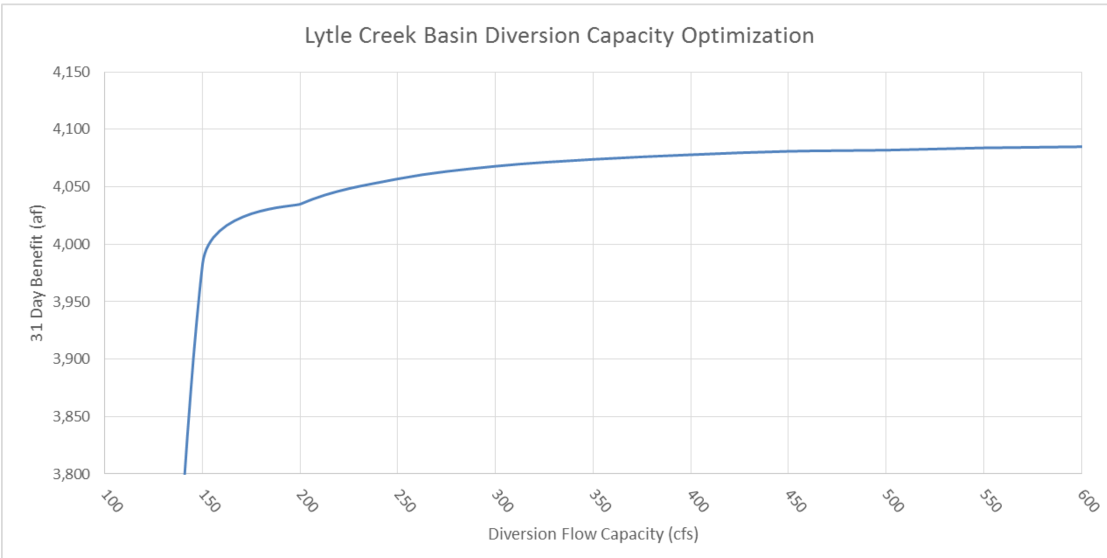
The inlet flow capacity was increased in 50 cfs increments from 50 cfs up to 1,000 cfs. The total benefit for the 31 day flow series given each inlet flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 75).

Approximately 6,100 af of water is bypassed around the system at a 600 cfs diversion flow rate capacity, this is because the basins fill rapidly given the very high flow rates in the flow series selected and then only requires a diversion flow rate equivalent to the infiltration rate of the basins.

The project benefit starts to plateau at a diversion flow rate of approximately 400 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 500 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events. In order to achieve a greater benefit, additional basin volume is required.

The above analysis limits the basin cells sizes to heights and volumes less than DSOD jurisdictional sizes. Another potential project alternative would be to construct the basin cells much larger than what is prosed here, thereby increasing the storage volume significantly. Increasing the cell sizes would also allow fewer cells to be constructed and fewer transfer structures and drain tubes to be constructed within the basin area. The primary negative consequence of increasing the cell size would be that the cells may require DSOD oversite and regulation.

Figure 75: Lytle Creek Diversion Optimization Results



The 11 year flow series was modeled using the 500 cfs inlet capacity to predict the total amount of storm water captured and recharged during the model period. The final Lytle Creek Project model results can be seen in Table 31.

Table 31: Lytle Creek 11 Year Model Results

Total Available Flow (af)	59,065
Total Flow Captured & Recharged (af)	44,256
Total Flow Bypassed (af)	14,809
Annual Average Flow Captured & Recharged (af)	4,023

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and to adjust the inlet gates to avoid overfilling the basin cells. Operators may find it beneficial to occasionally and purposely breach the sand diversion berm to encourage the natural transport of sediment downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay, in-channel recharge and basin areas. Regular re-grading of the sand diversion berm and in-channel recharge areas will be require in order to maximize the spreading of storm flows. Regular maintenance will also be required on the flow control gates, meters, level sensors and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 1 cleaning per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Lytle Creek Basin Project is presented in Table 32.

Table 32: Lytle Creek Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	7,255	660

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 33: Lytle Creek Basin Cost Estimate

Capital Costs			Lytle Creek Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 75,000	$ 75,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 85,000	$ 85,000
4	Survey	L.S.	1	$ 65,000	$ 65,000
5	Construction Water	L.S.	1	$ 95,000	$ 95,000
6	Temporary De-Watering	L.S.	1	$ 40,000	$ 40,000
7	Traffic Control	L.S.	1	$ 25,000	$ 25,000
8	Clearing & Grubbing	AC	60	$ 1,500	$ 90,000
9	On-Site Grading	Yd^3	490,000	$ 5	$ 2,450,000
10	Material Export	Yd^3	50,000	$ 12	$ 600,000
11	Finish Grading	AC	120	$ 300	$ 36,000
12	Access Roads	AC	3	$ 90,000	$ 270,000
13	Diversion Berm Grading	L.F.	1,400	$ 250	$ 350,000
14	Diversion Berm Surface Bypass Structure	L.S.	-	$ 350,000	$ -
15	Downstream Grade Stabilizer	L.F.	-	$ 500	$ -
16	Diversion Structure	L.S.	1	$ 2,250,000	$ 2,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,750,000	$ 1,750,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	72,000	$ 12	$ 864,000
20	Diversion Piping (7'x7' RCB)	L.F.	350	$ 1,300	$ 455,000
21	Transfer Piping (72-inch dia. RCP)	L.F.	-	$ 800	$ -
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	150	$ 450	$ 67,500
23	InterBasin Low Level Transfers	L.S.	-	$ 45,000	$ -
24	Laydown Pad	L.S.	1	$ 75,000	$ 75,000
25	Basin Outlet Structure	L.S.	1	$ 65,000	$ 65,000
26	Surface Transfer Structure (Weir)	L.S.	-	$ 850,000	$ -
27	Outlet Energy Dissipaters	L.S.	2	$ 50,000	$ 100,000
28	Diversion Sluice Gate	L.S.	2	$ 75,000	$ 150,000
29	48" Valves	L.S.	-	$ 45,000	$ -
30	42" Valve	L.S.	-	$ 40,000	$ -
31	Catwalks	L.S.	-	$ 45,000	$ -
32	Equipment Electrical	L.S.	1	$ 100,000	$ 100,000
33	Flow Control Gate Electrical	L.S.	1	$ 250,000	$ 250,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 175,000	$ 175,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	2	$ 25,000	$ 50,000
38	Low Flow Meter	L.S.	-	$ 20,000	$ -
39	Level Sensor	L.S.	4	$ 10,000	$ 40,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Chain Link)	L.F.	8,000	$ 45	$ 360,000
43	Mitigation	AC	5.0	$ 25,000	$ 125,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 626,625
48	Material Testing	%	0.5%		$ 62,663
49	Contingency	%	10%		$ 1,253,250
	Total Capital Costs				$ 14,685,038
	Annual Debt Service (5% @ 30 years)		0.06505		$ 955,262

Annual O&M Costs			Lytle Creek Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Diversion Berm & Bypass	L.S.	3	$ 15,000	$ 45,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	30	$ 1,000	$ 30,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 522,500	$ 5,225
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 10,000	$ 10,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 25,000	$ 25,000
8	Basin Cleanings	Yd^3	6,722	$ 2	$ 13,444
9	Material Export	Yd^3	6,722	$ 12	$ 80,667
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 249,336

Project Benefit Summary			Lytle Creek Basin		
	Total Annual Project Cost	$			$ 1,204,598
	Average Annual Benefit	AF/YR			4,023
	Average Annual Recharge Unit Cost	$/AF			$ 299

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Cable Creek (Station 8)

Existing Conditions

The Cable Creek site is located within Cable Creek and is bordered by Frontage Road and the 215 Freeway along the south-west edge of the site. The proposed diversion would be located approximately 2.0 miles south-east of the 210 Freeway/15 Freeway Interchange in the City of San Bernardino (Figure 76). The proposed diversion and basins would be situated immediately south of Cable Creek low flow channel over a 90 acre area. The entirety of the site is positioned within Cable Creek and the creek's overflow/overbank areas.

There is a generally un-maintained sand berm directly north of the basin site which helps to collect and focus flows in the creek to the north side of the site. The proposed diversion point would be located at the constriction caused by the existing sand berm. Water flows in the unimproved Cable Creek from north-west to south-east form the diversion point for approximately 4,300 feet before transitioning to a trapezoidal channel with rip rap slopes.

Overall the Cable Creek site has an elevation differential of approximately 30 feet over the 1,600 foot site (1.88%). The basin area is approximately 6 feet higher than the adjacent low flow channel of Cable Creek.

Figure 76: Cable Creek Overview

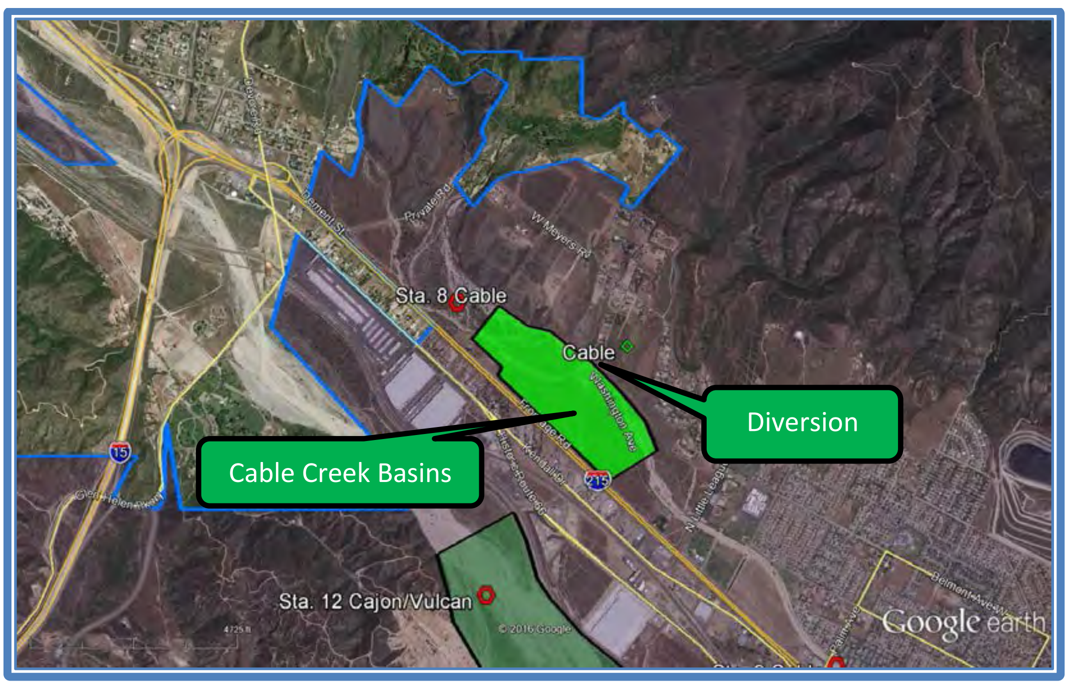

Figure 77: Cable Creek Site (Looking North Over the Basin Site)

Proposed Improvements

The proposed improvements at Cable Creek for the ARP are to construct a 245’ long by 6’ diameter inflatable rubber dam diversion, 3 recharge basins for a total wetted area of 37.9 acres, a 500 cfs capacity basin inlet structure and piping, 2 surface transfer structures and 8 basin drain tubes. The diversion, recharge basins and drain tubes have been developed to utilize a gravity conveyance system and to maximize usage of the available area on the site while maintaining adequate flood control capacity in Cable Creek. The north-east edge of the new basins will act as a levee to isolate uncontrolled high flows from the basin system. An inflatable rubber dam was selected for this site due to the frequent and high flow rates predicted to occur at the diversion site. Inflatable rubber dam diversions provide the ability to quickly transition operations from water conservation mode to flood control mode, and vice versa.

In general, the perimeter basin berms will be approximately 10 feet in height. The divider berms between the basins will be also be approximately 10 feet high with slightly increased heights on the downstream slopes to terrace the basins to match the slope of the site. The maximum operating level within the basin will be approximately 8-9 feet deep for a total wetted area of 37.9 acres and a storage volume of 281 af. In order to avoid DSOD jurisdiction each basin will be bisected with an internal berm to create a series of cells within the 3 basins so no single basin will have a berm height more than 25 feet in height or a storage capacity greater than 50 acre feet.

Each of the basins should include remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in Cable Creek at the diversion site and flow meters in the diversion structure to help facilitate operations.

The area above the rubber dam diversion will act as the forebay for the diversion structure. While the dam is inflated the forebay area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in Cable Creek. The wetted area above the rubber dam (while the dam is inflated) is approximately 2.9 acres in size with a volume capacity of approximately 8.6 af.

A series of model iterations were performed to help determine a target design flow rate of 500 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 2,978 af/yr) would be realized by constructing the Cable Creek Basin Project.

The following figures provide conceptual design views of the proposed improvements.

Figure 78: Cable Creek Basin Conceptual Design (Plan View)

Figure 79: Cable Creek Basin Conceptual Design (Diversion View)

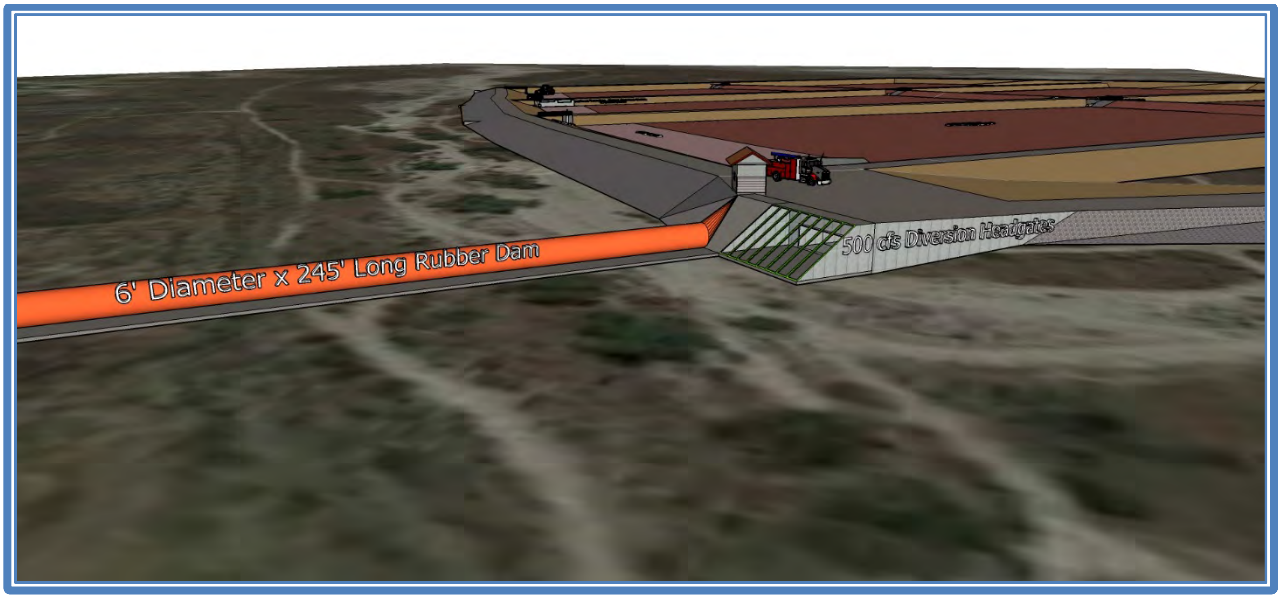

Figure 80: Cable Creek Basin Conceptual Design (Transfer Structure View)

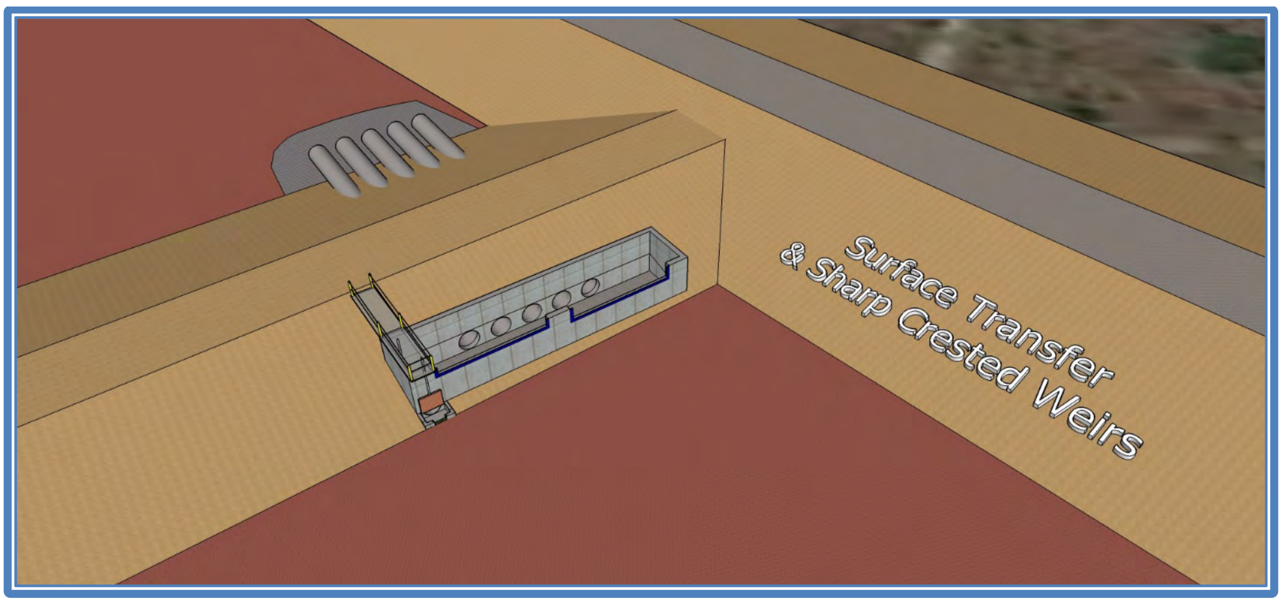

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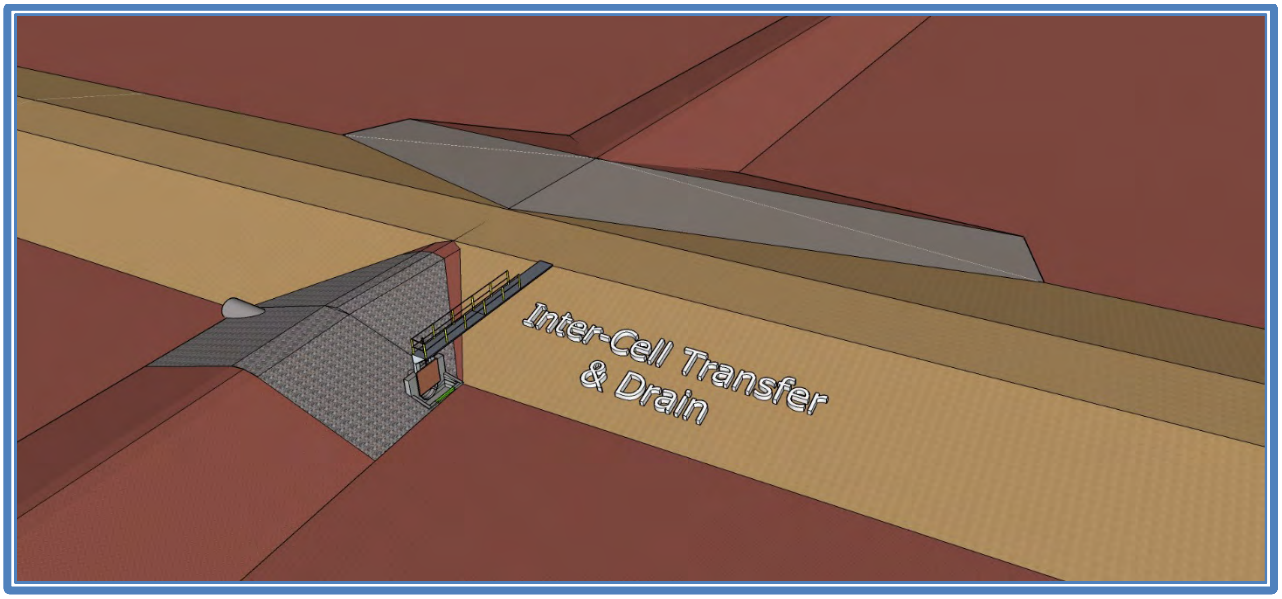
Figure 81: Cable Creek Basin Conceptual Design (Inter-Cell Transfer View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Cable Creek Basin Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 34. The forebay area above the inflatable rubber dam diversion was also included in the model to better capture the full benefit of the project.

A fundamental assumption of the model is that the diversion inlet will be kept relatively clean and free of vegetation and debris buildup. The available flows at the Cable Creek site used in the groundwater recharge operations model were from flow station 8.

Please note that only 1 example of a Cable Creek Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 83 and Figure 84 to illustrate how the infiltration rates might decay in the Cable Creek Basins.

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Table 34: Cable Creek Model Assumptions

Cable Creek flow hydrograph	See Figure 82
Basin area and volume	Area = 37.9 acres, Volume = 281 af
Forebay area and volume	Area = 2.9 acres, Volume = 8.6 af
Initial infiltration rates	2.2 ft/day
Infiltration rate decay parameters	See Figure 84 (using Figure 83 flow series)
Diversion flow capacity	500 cfs
Dam deflation set point	1,000 cfs
Diversion flow rate with dam deflated	25 cfs

Figure 82: Cable Creek Flows

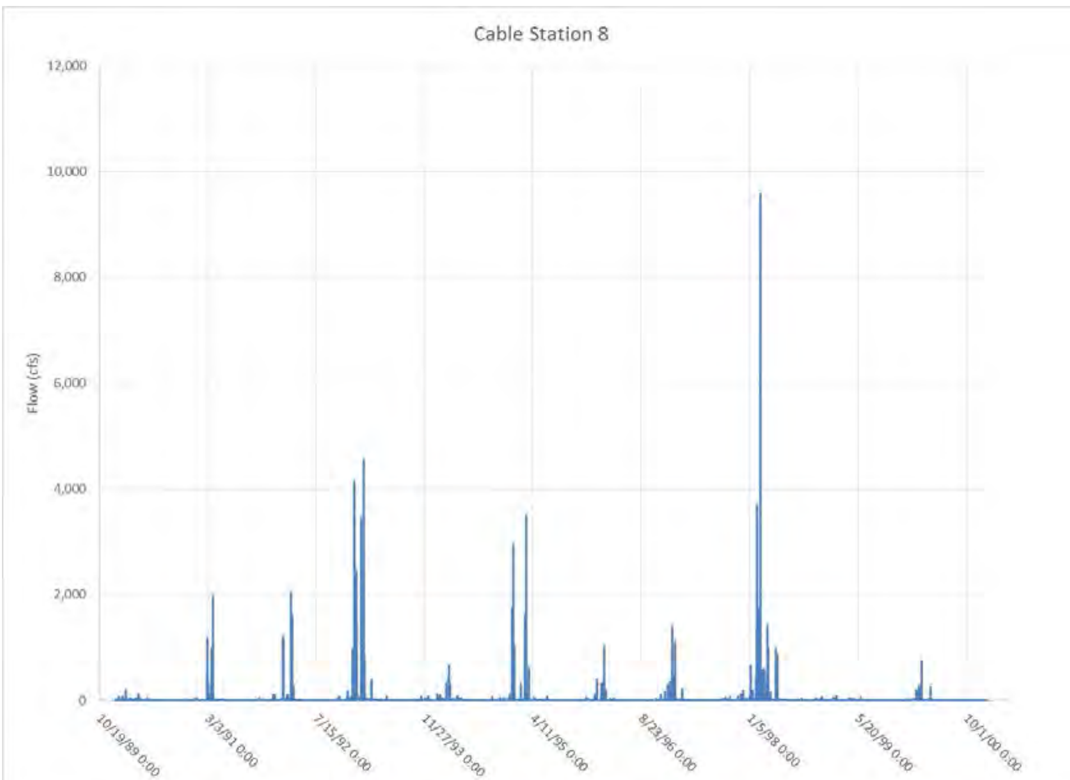

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Figure 83: Cable Creek Optimization Flow Series

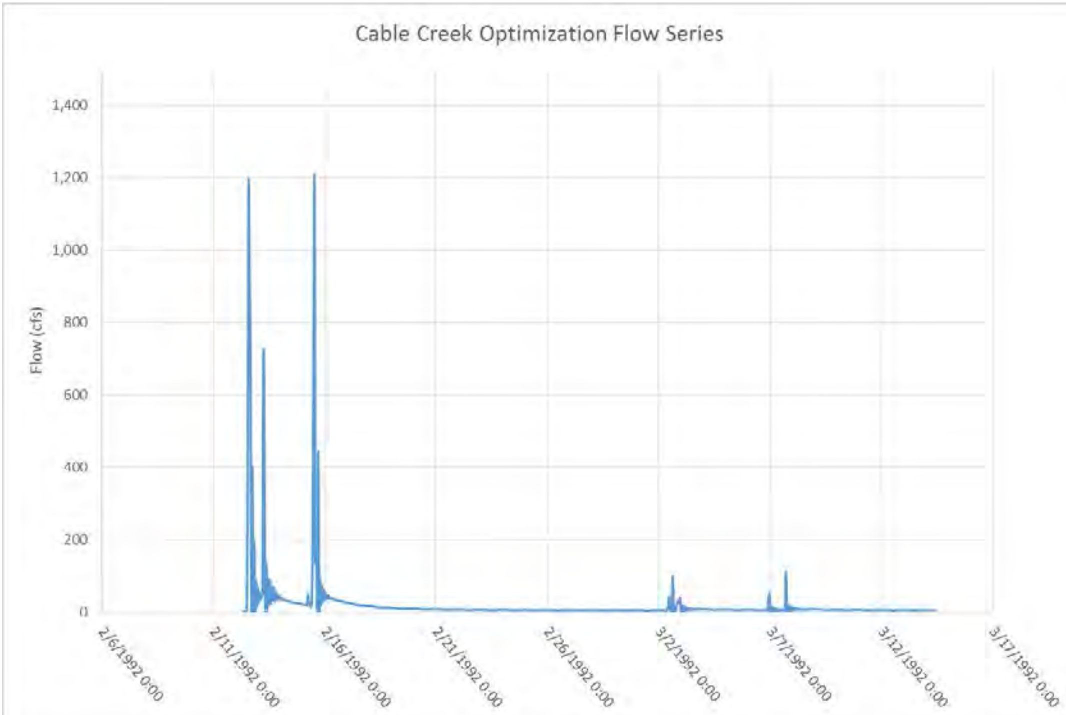
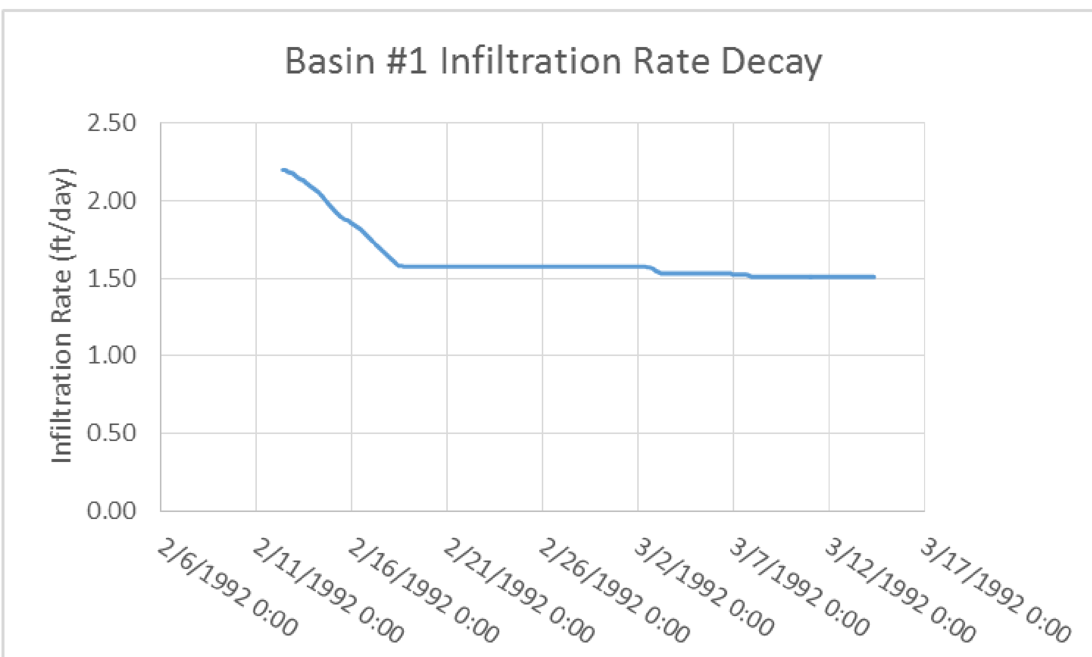


Figure 84: Cable Creek Basin Infiltration Rate Decay



In order to determine the optimum diversion flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the diversion size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 82 as the inflow for the optimization flow series for the diversion (Figure 83).

The diversion flow capacity was increased in 50 cfs increments from 50 cfs up to 800 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 85).

Approximately 285 af of water is bypassed around the system at a 800 cfs diversion flow rate capacity, this is because the basins fill rapidly given the very high flow rates in the flow series selected and then only requires a diversion flow rate equivalent to the infiltration rate of the basins.

The project benefit starts to plateau at a diversion flow rate of approximately 450 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 500 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events. In order to achieve a greater benefit, additional basin volume is required.

The above analysis limits the basin cells sizes to heights and volumes less than DSOD jurisdictional sizes. Another potential project alternative would be to construct the basin cells larger and increase the storage volume. The primary negative consequence of increasing the cell size would be that the cells may require DSOD oversite and regulation.

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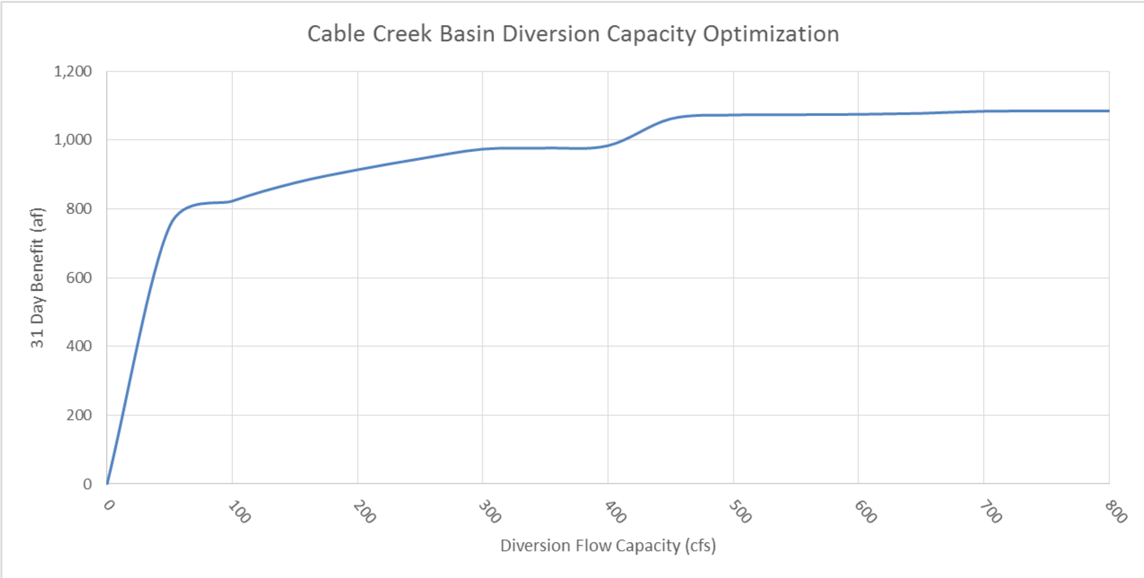
Figure 85: Cable Creek Diversion Optimization Results



The 11 year flow series was modeled using the 500 cfs inlet capacity to predict the total amount of storm water captured and recharged during the model period. The final Cable Creek Project model results can be seen in Table 35.

Table 35: Cable Creek 11 Year Model Results

Total Available Flow (af)	56,367
Total Flow Captured & Recharged (af)	32,760
Total Flow Bypassed (af)	23,607
Annual Average Flow Captured & Recharged (af)	2,978

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the rubber dam operates properly. During periods of especially high sedimentation or debris buildup in the forebay area operators may find it beneficial to purposely deflate the rubber dam for short periods of time to encourage the natural transport of the materials downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates, meters, level sensors and rubber dam mechanical and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Cable Creek Basin Project is presented in Table 36.

Table 36: Cable Creek Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	2,895	263

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 37: Cable Creek Basin Cost Estimate

Capital Costs			Cable Creek Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 75,000	$ 75,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 100,000	$ 100,000
4	Survey	L.S.	1	$ 65,000	$ 65,000
5	Construction Water	L.S.	1	$ 95,000	$ 95,000
6	Temporary De-Watering	L.S.	1	$ 50,000	$ 50,000
7	Traffic Control	L.S.	1	$ 60,000	$ 60,000
8	Clearing & Grubbing	AC	60	$ 1,500	$ 90,000
9	On-Site Grading	Yd^3	250,000	$ 5	$ 1,250,000
10	Material Export	Yd^3	50,000	$ 12	$ 600,000
11	Finish Grading	AC	60	$ 300	$ 18,000
12	Access Roads	AC	7	$ 90,000	$ 630,000
13	Dam Foundation	L.F.	300	$ 12,000	$ 3,600,000
14	Rubber Dam & Equipment	L.S.	1	$ 2,500,000	$ 2,500,000
15	Dam Downstream Grade Stabilizer	L.F.	300	$ 500	$ 150,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	68,000	$ 12	$ 816,000
20	Diversion Piping (84-inch dia. RCP)	L.F.	450	$ 950	$ 427,500
21	Transfer Piping (48-inch dia. RCP)	L.F.	880	$ 500	$ 440,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	500	$ 450	$ 225,000
23	InterCell Transfers & Drains	L.S.	3	$ 250,000	$ 750,000
24	Low Flow Channels	L.S.	1	$ 50,000	$ 50,000
25	Basin Outlet Structure	L.S.	3	$ 65,000	$ 195,000
26	Surface Transfer Structure (Weir)	L.S.	2	$ 850,000	$ 1,700,000
27	Outlet Energy Dissipaters	L.S.	6	$ 50,000	$ 300,000
28	Diversion Sluice Gate	L.S.	3	$ 60,000	$ 180,000
29	48" Valves	L.S.	6	$ 45,000	$ 270,000
30	42" Valve	L.S.	3	$ 40,000	$ 120,000
31	Catwalks	L.S.	7	$ 45,000	$ 315,000
32	Dam & Equipment Electrical	L.S.	1	$ 100,000	$ 100,000
33	Flow Control Gate Electrical	L.S.	1	$ 500,000	$ 500,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	3	$ 25,000	$ 75,000
38	Low Flow Meter	L.S.	3	$ 20,000	$ 60,000
39	Level Sensor	L.S.	6	$ 10,000	$ 60,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	8,000	$ 100	$ 800,000
43	Mitigation	AC	3.0	$ 25,000	$ 75,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 1,054,575
48	Material Testing	%	0.5%		$ 105,458
49	Contingency	%	10%		$ 2,109,150
	Total Capital Costs				$ 24,520,683
	Annual Debt Service (5% @ 30 years)		0.06505		$ 1,595,070

Annual O&M Costs			Cable Creek Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Rubber Dam	L.S.	1	$ 30,000	$ 30,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	30	$ 1,000	$ 30,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 1,092,500	$ 10,925
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 25,000	$ 25,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 45,000	$ 45,000
8	Basin Cleanings	Yd^3	10,218	$ 2	$ 20,436
9	Material Export	Yd^3	13,218	$ 12	$ 158,613
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 359,974

Project Benefit Summary			Cable Creek Basin		
	Total Annual Project Cost	$			$ 1,955,044
	Average Annual Benefit	AF/YR			2,978
	Average Annual Recharge Unit Cost	$/AF			$ 656

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Devil Canyon Basins (Station 10)

Existing Conditions

The Devil Canyon site is located along Devil Creek and is bordered by Devils Canyon Road to the east and Campus Parkway to the south-east. The Devil Canyon Spreading Grounds are an existing SBCFCD facility (System # 2-302-2A) located approximately 3.4 miles north-west of the 210 Freeway/215 Freeway interchange in the City of San Bernardino (Figure 86). The existing basins attenuate storm flows from Devil Creek and the overall site covers an area approximately 275 acres in size.

Water flows to the Devil Canyon Spreading Grounds from the north and is either bypassed around the basins, or, during very high flow events, water spills uncontrolled into the basins and is routed through the basins at 3 diversion points. The diversion point proposed to be improved can be seen in Figure 87. Flows that enter the basin are discharged at the southern corner of the site into Devil Creek Diversion Channel. The southernmost levee and the outlet channel were constructed by the USACE.

There are 3 primary basins within the west side of the Devil Canyon Spreading Grounds system which provide an opportunity to increase storm water capture and groundwater recharge. The basins are interconnected by a series of unimproved surface transfer structures and low-level drain tubes. The approximate volume available for storm water capture and groundwater recharge is 242 af across 35.9 wetted acres. Overall the Devil Canyon Site has an elevation differential of approximately 150 feet over the 4,000 foot site (3.75% grade).

Figure 86: Devil Canyon Overview

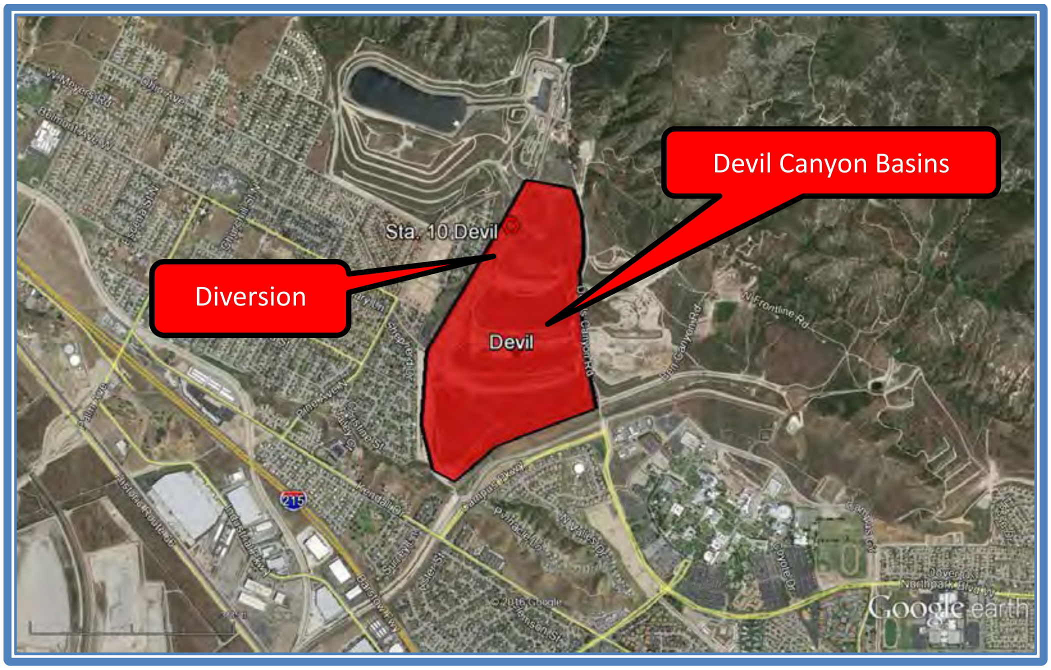

Figure 87: Devil Canyon Site (Looking North-West Over the Proposed Diversion Site)

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Proposed Improvements

The proposed improvements at Devil Canyon Basins for the ARP are to construct an inflatable armored dam (Obermeyer Spillway Gate) diversion across Devil Creek to increase the diversion flow rate capacity and divert low flows that would otherwise pass by the basins. Two new recharge cells (13.3 acres total) will be constructed below the existing SBCFCD Basin 1 and above the USACE levee. Additionally, the existing inter-basin surface transfer structures and low-level outlets/drains will be refurbished and/or replaced as a part of the project.

A new operational plan would need to be developed with SBCFCD in order realize the project benefit at Devil Canyon Basins. In general, higher flows would be diverted into the basins more frequently, and the basins would be operated at higher WSEs for longer durations to allow captured storm water to be infiltrated into the basins.

The existing basins will be cleaned to remove deposits of silt and clay. The average operating level within the basins will range between 7-10 feet for a total wetted area of 35.9 acres and a total storage volume of 242 af. The groundwater recharge acreages and volumes proposed here are conservative and may be expanded in the future after successfully demonstrating that there are no impacts to the flood control function of the basins. There will be no groundwater recharge operations directly against the USACE levees.

Based on field observations and preliminary hydraulic analysis it is estimated that the existing diversion capacity could be as high as 500 cfs with the proper hydraulic conditions. In order to create adequate hydraulic head to convey 500 cfs into the basins a new armored spillway gate will be needed. A series of model iterations were performed to help determine what diversion flow rate would be optimum to fully utilize the basins. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 3,631 af/yr) would be realized by constructing the proposed improvements and re-operating the Devil Canyon Basins.

The proposed physical improvements for the ARP at the Devil Canyon Basins include the construction of a 250’ long by 8’ tall spillway gate, refurbishment of 3 inter-basin surface transfer structures and 5 low-level outlets/drains. Each of the basins should include the construction of remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in Devil Creek at the diversion site and flow meters in the diversion structure to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

Figure 88: Devil Canyon Basins Conceptual Design (Plan View)

Figure 89: Devil Canyon Basins Conceptual Design (Diversion View)

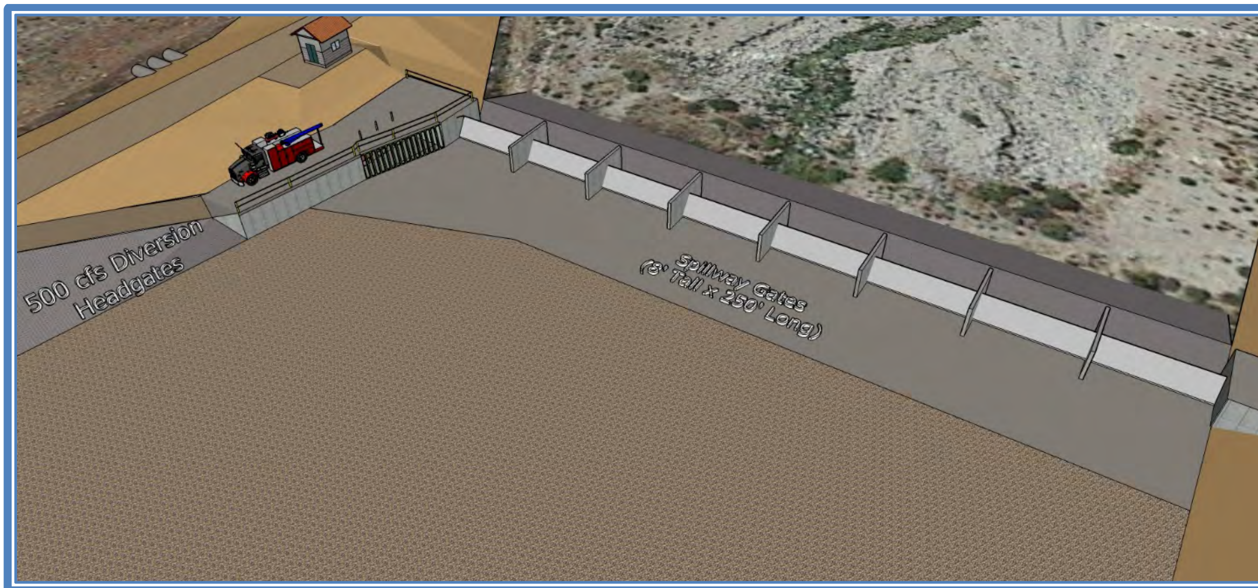

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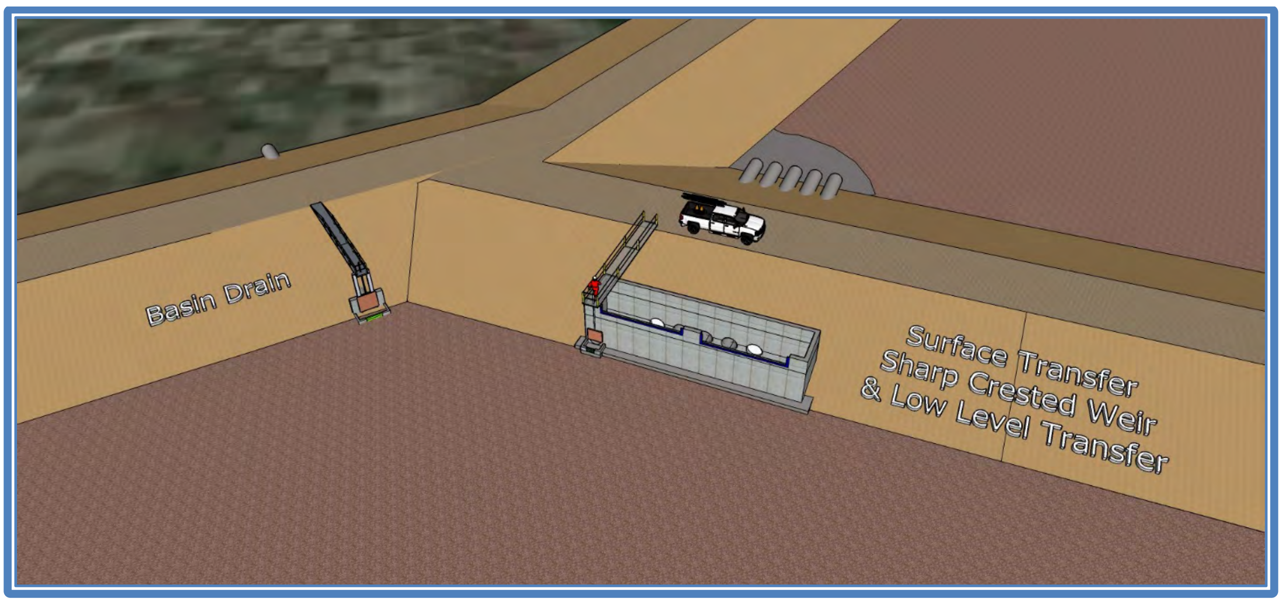
Figure 90: Devil Canyon Basins Conceptual Design (Basin Isometric View)

Figure 91: Devil Canyon Basins Conceptual Design (Surface Transfer View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Devil Canyon Basins Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 38. The forebay area above

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the spillway gate diversion (although very small when compared to the basin system) was also included in the model to better capture the full benefit of the project.

The available flows at the Devil Canyon Basins used in the groundwater recharge operations model were from flow station 10. The 500 cfs diversion assumption is slightly greater then what is required for the areas and volumes analyzed here, however, utilizing additional storage volume at a later date will require the higher diversion rates assumed in the model. Also, if the basins perform at a higher level than expected, then the increased diversion flow rate capacity will be required.

Please note that only 1 example of a Devil Canyon Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 53 and Figure 54 to illustrate how the infiltration rates may decay in the Devil Canyon Basins.

Table 38: Devil Canyon Basins Model Assumptions

Devil Canyon Basins flow hydrograph	See Figure 92
Basin area and volume	Area = 35.9 acres, Volume = 242 af
Forebay area and volume	Area = 0.7 acres, Volume = 2.75 af
Initial infiltration rates	2.4 ft/day
Infiltration rate decay parameters	See Figure 94 (using Figure 93 flow series)
Diversion flow capacity	500 cfs
Dam deflation set point	750 cfs
Diversion flow rate with dam deflated	5 cfs

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Figure 92: Devil Canyon Basin Flows

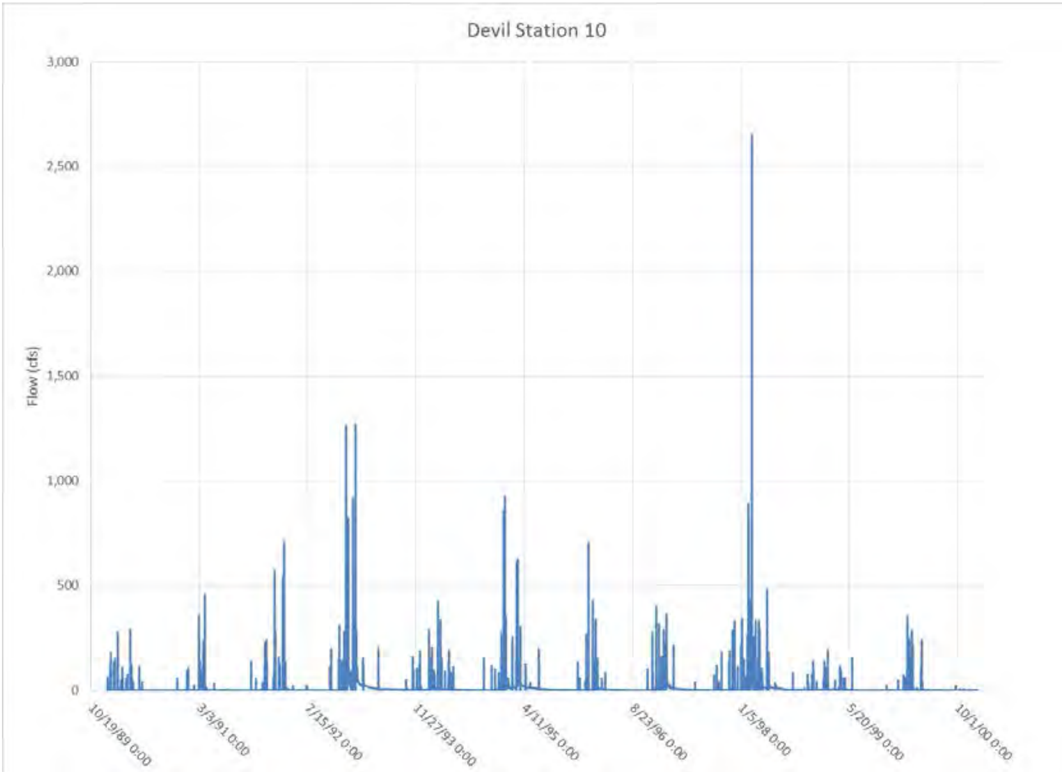

Figure 93: Devil Canyon Basins Optimization Flow Series

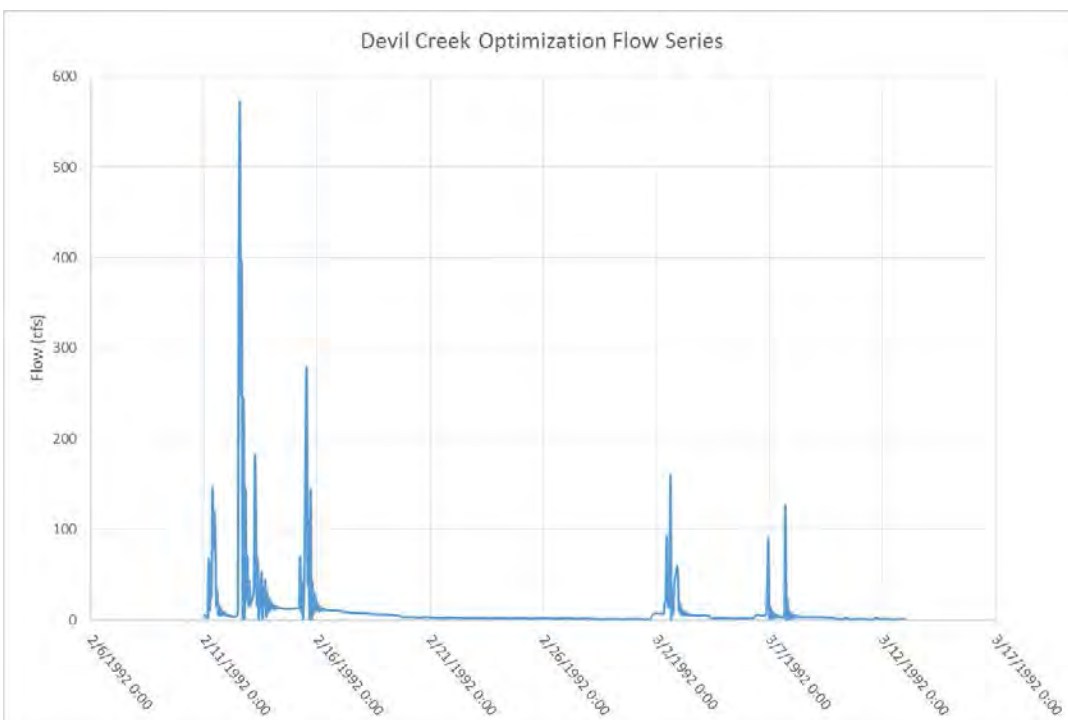

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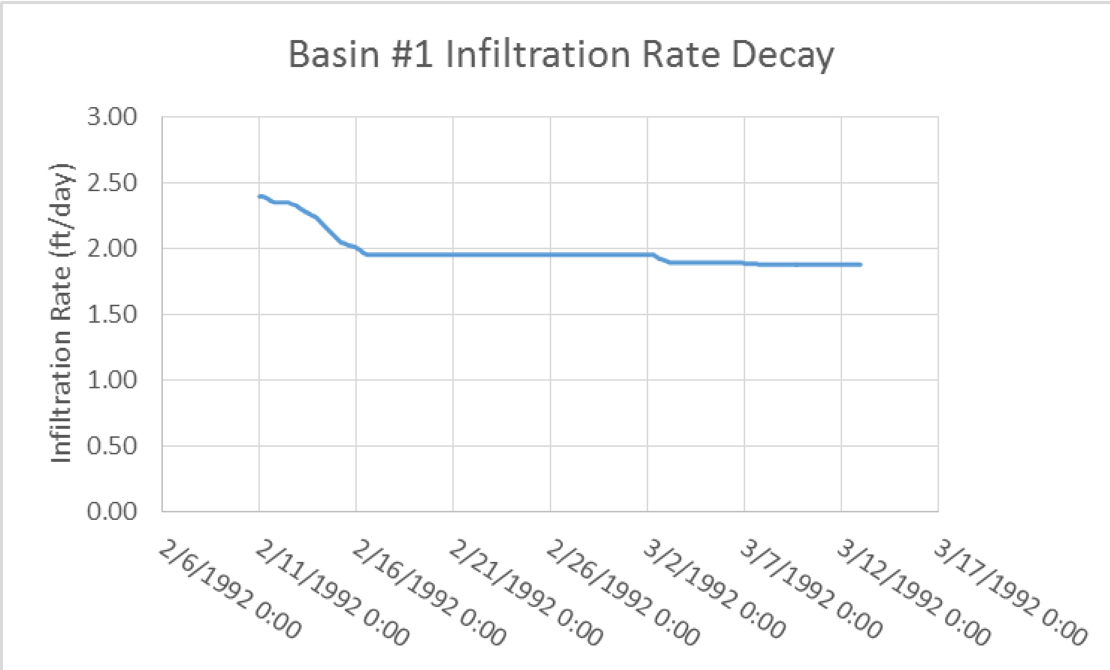
Figure 94: Devil Canyon Basin Infiltration Rate Decay



In order to determine the optimum diversion flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the inlet size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 92 as the inflow for the optimization flow series for the diversion (Figure 93).

The diversion flow capacity was increased in 50 cfs increments from 50 cfs up to 700 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 95).

Approximately 6 af of water is bypassed around the system with a 500 cfs diversion flow rate capacity.

The project benefit plateaus at a diversion flow rate of approximately 400 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 500 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events. As higher operating levels are approved the ability to divert higher flows will already be in place. Also, the cost to construct the diversion for 500 verses 400 cfs will be relatively small

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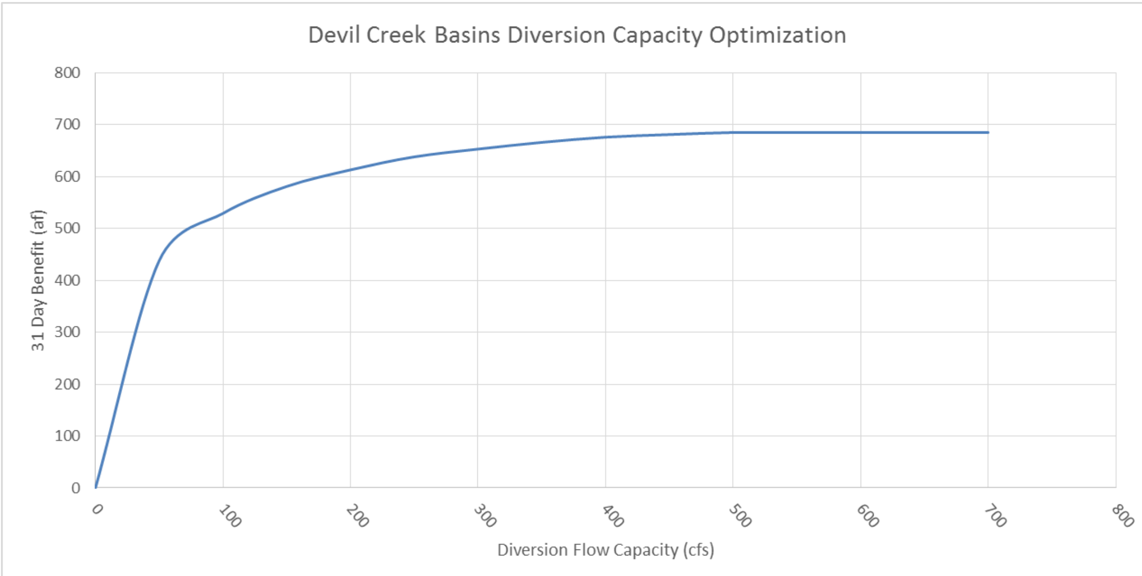
given that the diversion conveyances will likely be an open channel system and require relatively low capital cost to achieve the extra 100 cfs of flow capacity.

Figure 95: Devil Canyon Basins Diversion Optimization Results



The 11 year flow series was modeled using the 500 cfs diversion capacity to predict the total amount of storm water captured and recharged during the model period. The final Devil Canyon Basins Project model results can be seen in Table 39.

Table 39: Devil Canyon Basins 11 Year Model Results

Total Available Flow (af)	52,308
Total Flow Captured & Recharged (af)	39,937
Total Flow Bypassed (af)	12,371
Annual Average Flow Captured & Recharged (af)	3,631

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the spillway gate operate properly. During periods of especially high sedimentation, vegetation or debris buildup in the forebay area operators may find it beneficial to purposely drop the spillway gate for short periods of time to encourage the natural bypass of the materials around the basins.

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Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates, meters, level sensors and spillway gate mechanical and control systems. An armored spillway gate will be required in order to withstand the large rocks and cobles transported across it in high flow events. The gate will require regular maintenance and re-coating to repair surficial damage caused by the bedload transported across it. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 1 cleaning per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Devil Canyon Basins Project is presented in Table 40.

Table 40: Devil Canyon Basins Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	1,748	159

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 41: Devil Canyon Basins Cost Estimate

Capital Costs			Devil Canyon Basins		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 85,000	$ 85,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 65,000	$ 65,000
4	Survey	L.S.	1	$ 35,000	$ 35,000
5	Construction Water	L.S.	1	$ 55,000	$ 55,000
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	1	$ 25,000	$ 25,000
8	Clearing & Grubbing	AC	17	$ 1,500	$ 25,500
9	On-Site Grading	Yd^3	225,000	$ 5	$ 1,125,000
10	Material Export	Yd^3	500	$ 12	$ 6,000
11	Finish Grading	AC	17	$ 300	$ 5,100
12	Access Roads	AC	4.5	$ 90,000	$ 405,000
13	Spillway Gate Foundation	L.F.	250	$ 12,000	$ 3,000,000
14	Spillway Gate & Equipment	L.S.	8	$ 350,000	$ 2,800,000
15	Spillway Downstream Grade Stabilizer	L.F.	250	$ 500	$ 125,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	20,000	$ 12	$ 240,000
20	Diversion Piping (60-inch dia. RCP)	L.F.	400	$ 500	$ 200,000
21	Transfer Piping (42-inch dia. RCP)	L.F.	3,050	$ 450	$ 1,372,500
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	500	$ 450	$ 225,000
23	InterCell Transfers & Drains	L.S.	4	$ 250,000	$ 1,000,000
24	Overflow Spillway Rehab	L.S.	3	$ 250,000	$ 750,000
25	Basin Outlet Structure	L.S.	5	$ 65,000	$ 325,000
26	Surface Transfer Structure (Weir)	L.S.	2	$ 850,000	$ 1,700,000
27	Outlet Energy Dissipaters	L.S.	5	$ 50,000	$ 250,000
28	Surface Transfer Rehab	L.S.	3	$ 125,000	$ 375,000
29	60" Valves	L.S.	3	$ 45,000	$ 135,000
30	42" Valves	L.S.	8	$ 40,000	$ 320,000
31	Catwalks	L.S.	8	$ 45,000	$ 360,000
32	Spillway Gate & Equipment Electrical	L.S.	1	$ 150,000	$ 150,000
33	Flow Control Gate Electrical	L.S.	1	$ 500,000	$ 500,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	1	$ 25,000	$ 25,000
38	Low Flow Meter	L.S.	5	$ 20,000	$ 100,000
39	Level Sensor	L.S.	7	$ 10,000	$ 70,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	-	$ 100	$ -
43	Mitigation	AC	10.0	$ 25,000	$ 250,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 1,014,455
48	Material Testing	%	0.5%		$ 101,446
49	Contingency	%	10%		$ 2,028,910
	Total Capital Costs				$ 23,768,911
	Annual Debt Service (5% @ 30 years)		0.06505		$ 1,546,168

Annual O&M Costs			Devil Canyon Basins		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Spillway Gate	L.S.	4	$ 30,000	$ 120,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	30	$ 1,000	$ 30,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 1,797,500	$ 17,975
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 15,000	$ 15,000
8	Basin Cleanings	Yd^3	6,722	$ 2	$ 13,444
9	Material Export	Yd^3	7,222	$ 12	$ 86,667
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 358,086

Project Benefit Summary			Devil Canyon Basins		
	Total Annual Project Cost	$			$ 1,904,254
	Average Annual Benefit	AF/YR			3,631
	Average Annual Recharge Unit Cost	$/AF			$ 524

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Cajon Creek (Station 11)

Existing Conditions

The Cajon Creek site is located within Cajon Creek and is bordered by railroad tracks along the south-west edge of the site and Cajon Blvd. along the north-east edge of the site. The proposed diversion would be located approximately 5,000 feet north-west of the 215 Freeway/15 Freeway Interchange in the City of San Bernardino (Figure 96). The proposed diversion and basins would be situated immediately south of the Cajon Creek low flow channel over an area approximately 110 acres in size. The entirety of the site is positioned within Cajon Creek and the creek's overflow/overbank areas.

The proposed diversion point would be located across the entire creek width at the upstream end of the basin site. Water flows in Cajon Creek from north-west to south-east for approximately 3,400 feet past the proposed basin site.

Overall the Cajon Creek site has an elevation differential of approximately 55 feet over the 3,400 foot site (1.62%). The basin area is approximately 10 feet higher than the adjacent low flow channel of Cajon Creek.

Figure 96: Cajon Creek Overview

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Figure 97: Cajon Creek Site (Looking South Over the Basin Site)

Proposed Improvements

The proposed improvements at Cajon Creek for the ARP are to construct a 915' long by 6' high sand berm diversion, a surface transfer bypass structure, 4 recharge basins for a total wetted area of 18.3 acres, a 500 cfs capacity basin inlet structure and piping, 3 surface transfer structures and 4 basin drain tubes. The diversion, recharge basins and drain tubes have been developed to utilize a gravity conveyance system and to maximize usage of the available area on the site while maintaining adequate flood control capacity in Cajon Creek. The north-east edge of the new basins will act as a levee to isolate uncontrolled high flows from the basin system. A sand berm diversion was selected for this site due to the large width of Cajon Creek at the diversion location.

In general, the perimeter basin berms will be approximately 10 feet in height. The divider berms between the basins will be also be approximately 10 feet high with slightly increased heights on the downstream slopes to terrace the basins to match the slope of the site. The maximum operating level within the basin will be approximately 8 feet deep for a total wetted area of 18.3 acres and a storage volume of 129.4 af. In order to avoid DSOD jurisdiction, no single basin will have a berm more than 25 feet in height or a storage capacity greater than 50 acre feet.

A focused geotechnical investigation and analysis during final design will likely be required along the south-west side of the basins to insure no negative impacts to the railroad tracks.

Each of the basins should include remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in Cajon Creek at the diversion site and flow meters in the diversion structure to help facilitate operations.

The area above the sand berm diversion will act as the forebay for the diversion structure. While in operation, the forebay area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in Cajon Creek. The wetted area above the sand berm diversion is approximately 3.4 acres in size with a volume capacity of approximately 10.3 af.

A series of model iterations were performed to help determine a target design flow rate of 500 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 1,230 af/yr) would be realized by constructing the Cajon Creek Basin Project.

The following figures provide conceptual design views of the proposed improvements.

Figure 98: Cajon Creek Basin Conceptual Design (Plan View)

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Figure 99: Cajon Creek Basin Conceptual Design (Diversion View)

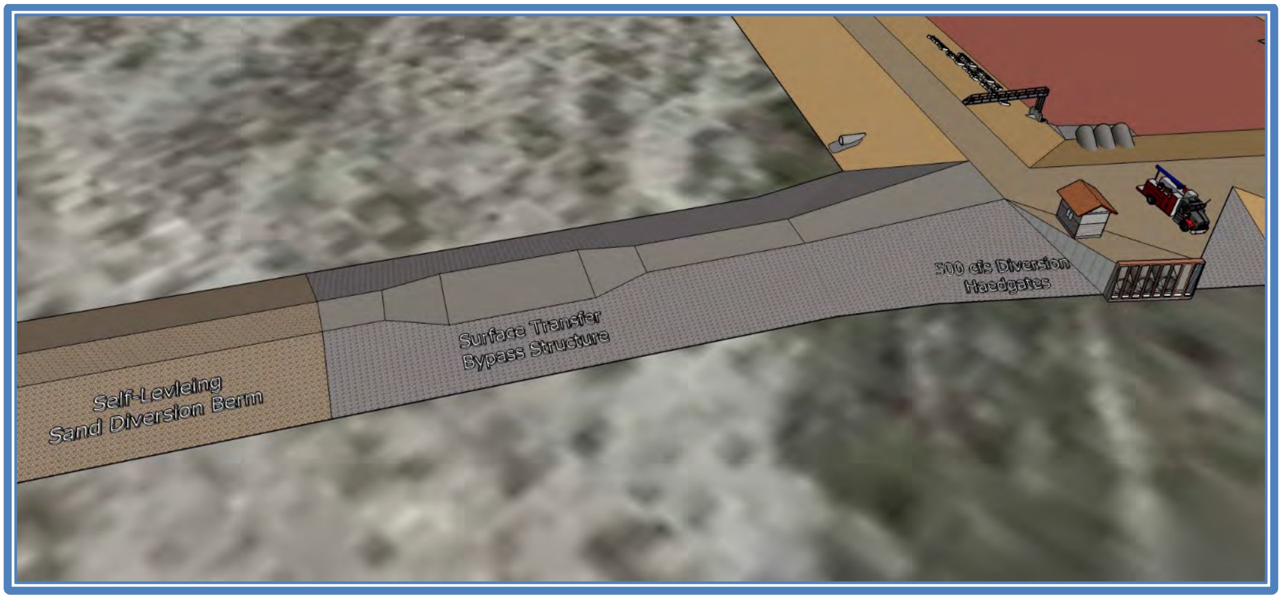

Figure 100: Cajon Creek Basin Conceptual Design (Transfer View)

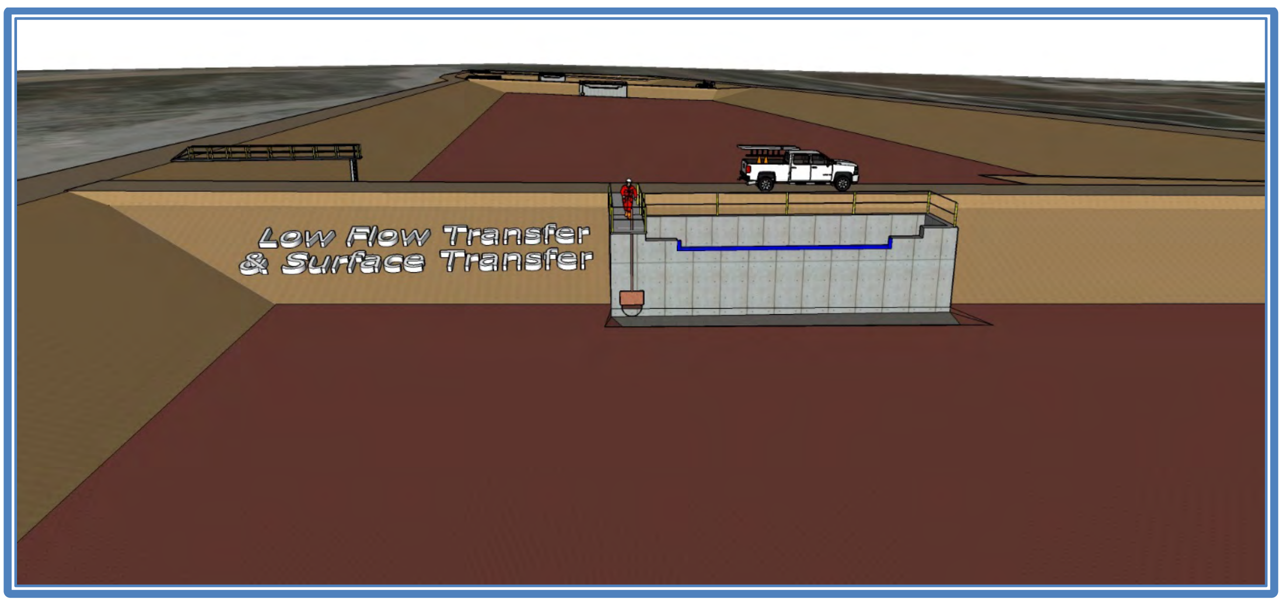

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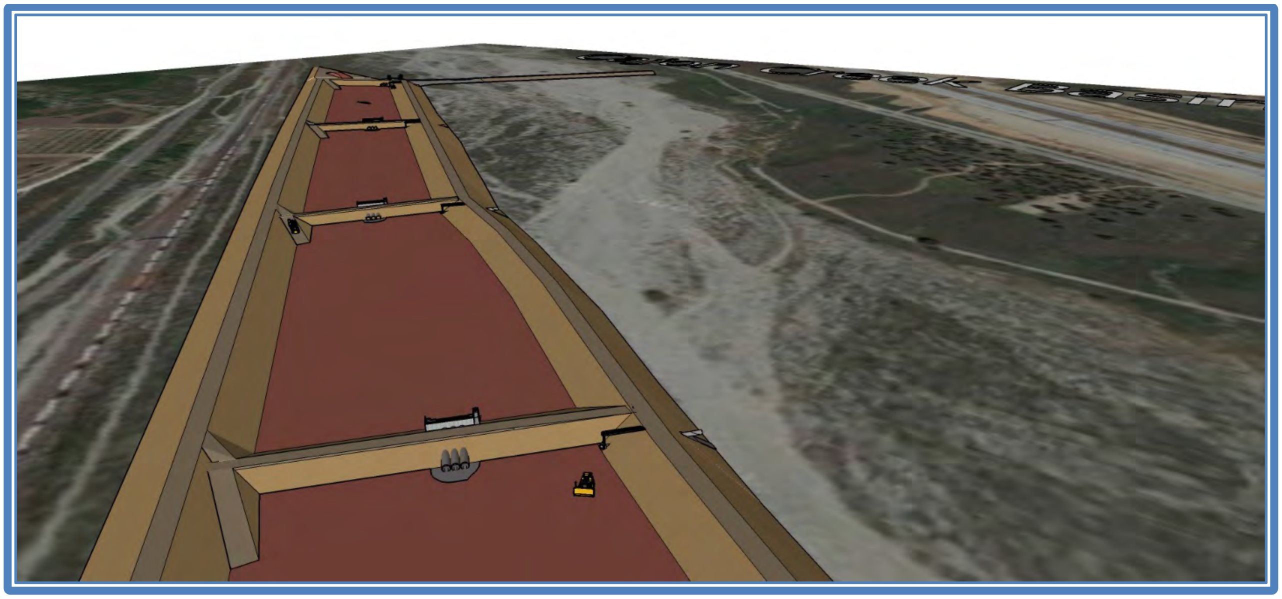
Figure 101: Cajon Creek Basin Conceptual Design (Looking Upstream)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Cajon Creek Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 42. The forebay area above the sand berm diversion was also included in the model to better capture the full benefit of the project.

A fundamental assumption of the model is that each time there is a high flow event that washes out the sand diversion berm, the diversion flows are reduced until such time that the berm can be reconstructed. On average the berm will need to be reconstructed 1 to 2 times per year. The available flows at the Cajon Creek site used in the groundwater recharge operations model were from flow station 11.

Please note that only 1 example of a Cajon Creek Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 103 and Figure 104 to illustrate how the infiltration rates might decay in the Cajon Creek Basins.

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Table 42: Cajon Creek Model Assumptions

Cajon Creek flow hydrograph	See Figure 102
Basin area and volume	Area = 18.3 acres, Volume = 129 af
Forebay area and volume	Area = 3.4 acres, Volume = 10.3 af
Initial infiltration rates	3.5 ft/day
Infiltration rate decay parameters	See Figure 104 (using Figure 103 flow series)
Diversion flow capacity	500 cfs
Diversion berm washout flow rate	1,500 cfs
Diversion flow rate without berm	5 cfs

Figure 102: Cajon Creek Flows

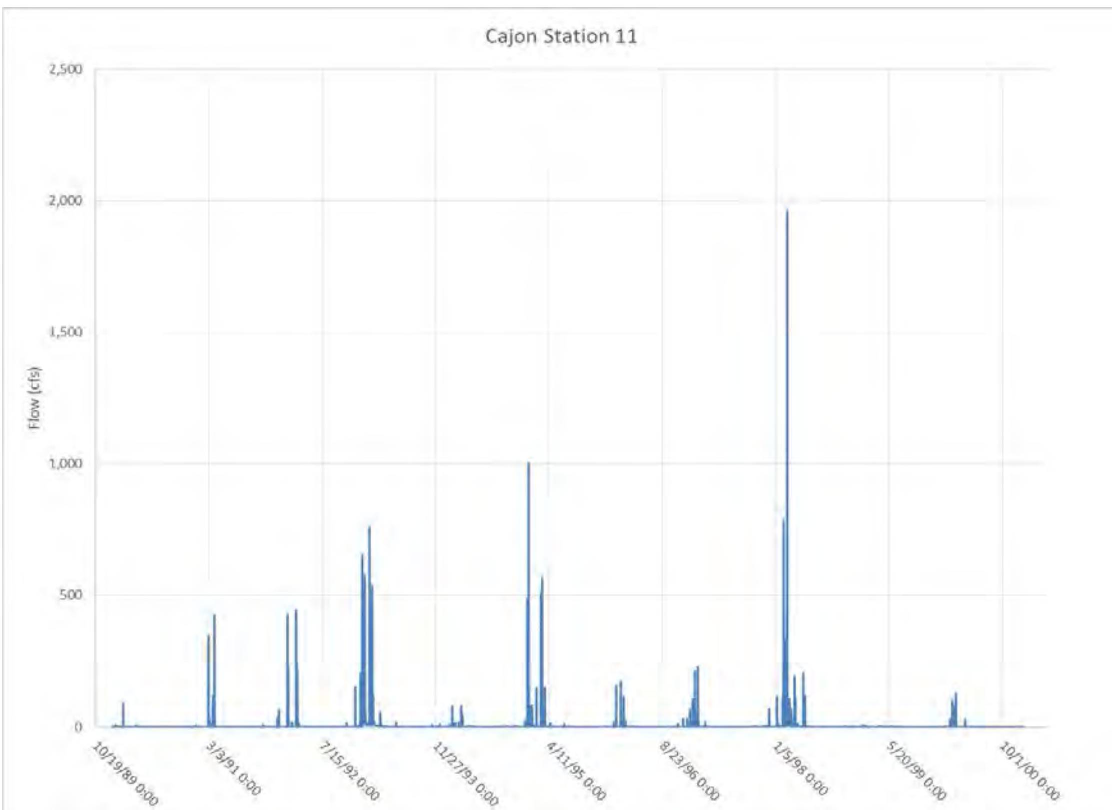

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Figure 103: Cajon Creek Optimization Flow Series

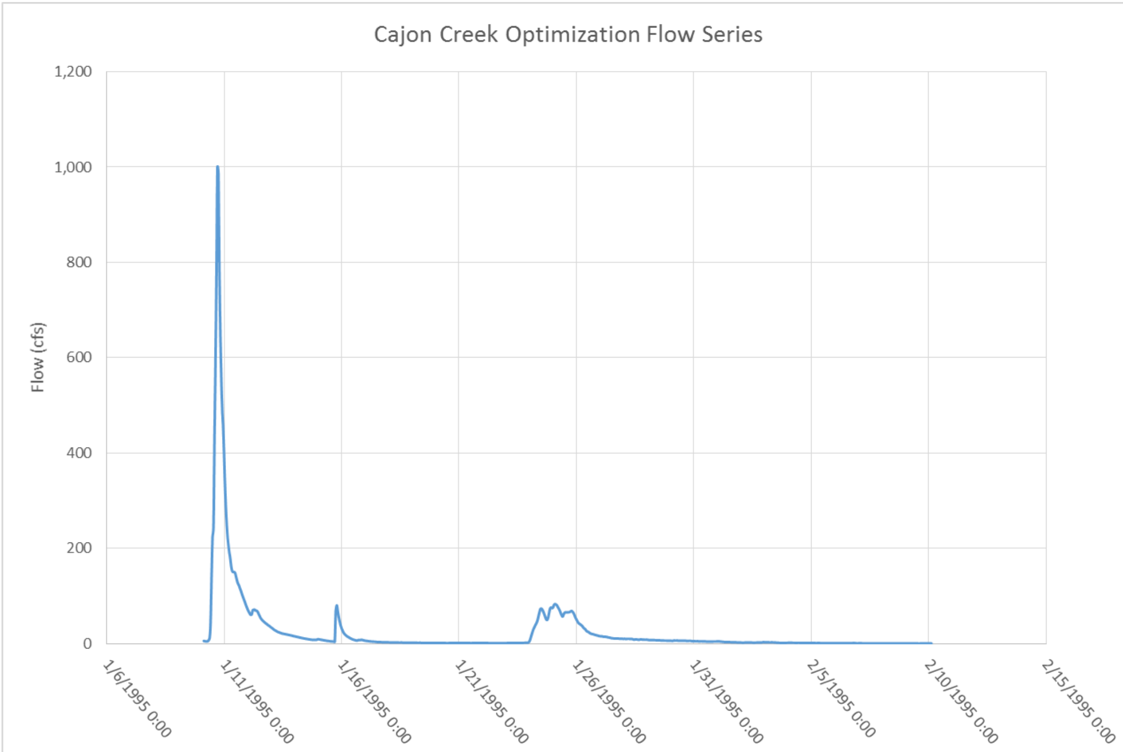
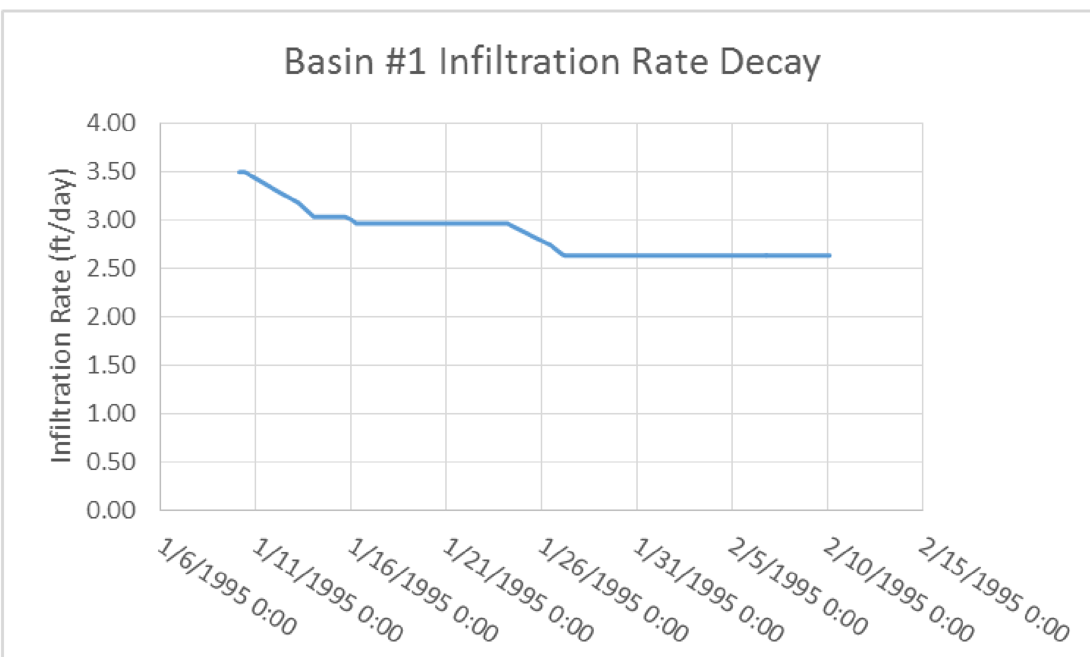


Figure 104: Cajon Creek Basin Infiltration Rate Decay



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In order to determine the optimum basin inlet flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the basin diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the diversion size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 102 as the inflow for the optimization flow series for the diversion (Figure 103).

The diversion flow capacity was increased in 50 cfs increments from 50 cfs up to 700 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 105).

Approximately 740 af of water is bypassed around the system at a 700 cfs diversion flow rate capacity, this is because the basins fill rapidly given the very high flow rates in the flow series selected and then only requires a diversion flow rate equivalent to the infiltration rate of the basins.

The project benefit plateaus at a diversion flow rate of approximately 350 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 500 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events. In order to achieve a greater benefit, additional basin volume is required.

The above analysis limits the basin sizes to heights and volumes less than DSOD jurisdictional sizes. Another potential project alternative would be to construct the basins larger and increase the storage volume. The primary negative consequence of increasing the basin size would be that the basins may require DSOD oversite and regulation.

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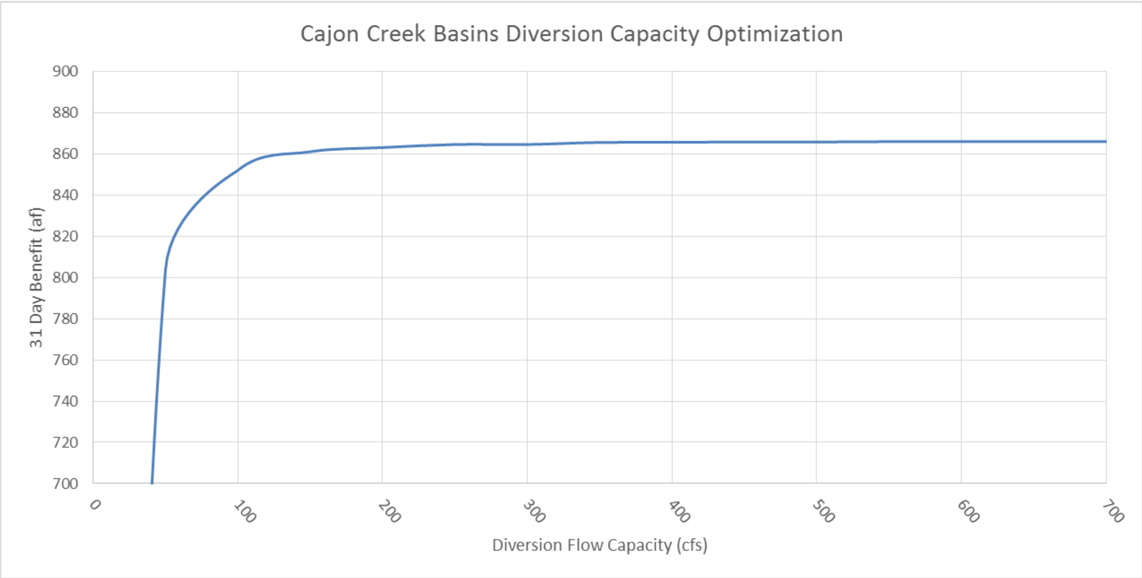
Figure 105: Cajon Creek Diversion Optimization Results



The 11 year flow series was modeled using the 500 cfs inlet capacity to predict the total amount of storm water captured and recharged during the model period. The final Cajon Creek Project model results can be seen in Table 43.

Table 43: Cajon Creek 11 Year Model Results

Total Available Flow (af)	25,586
Total Flow Captured & Recharged (af)	13,533
Total Flow Bypassed (af)	12,053
Annual Average Flow Captured & Recharged (af)	1,230

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and to adjust the inlet gates to avoid overfilling the basins. Operators may find it beneficial to occasionally and purposely breach the sand diversion berm to encourage the natural transport of sediment downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular regrading of the sand diversion berm and forebay area will be require in order to maximize the spreading of storm flows and maintain diversion rates. Regular maintenance will also be required on the flow control gates, surface transfer structures, meters, level sensors and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been

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assumed that the basins will require 1 cleaning per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Cajon Creek Basin Project is presented in Table 44.

Table 44: Cajon Creek Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	941	86

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 45: Cajon Creek Basin Cost Estimate

Capital Costs			Cajon Creek Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 75,000	$ 75,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 85,000	$ 85,000
4	Survey	L.S.	1	$ 65,000	$ 65,000
5	Construction Water	L.S.	1	$ 75,000	$ 75,000
6	Temporary De-Watering	L.S.	1	$ 40,000	$ 40,000
7	Traffic Control	L.S.	1	$ 35,000	$ 35,000
8	Clearing & Grubbing	AC	25	$ 1,500	$ 37,500
9	On-Site Grading	Yd^3	185,000	$ 5	$ 925,000
10	Material Export	Yd^3	50,000	$ 12	$ 600,000
11	Finish Grading	AC	25	$ 300	$ 7,500
12	Access Roads	AC	5	$ 90,000	$ 450,000
13	Diversion Berm Grading	L.F.	915	$ 250	$ 228,750
14	Diversion Berm Surface Bypass Structure	L.S.	1	$ 350,000	$ 350,000
15	Downstream Grade Stabilizer	L.F.	250	$ 500	$ 125,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	20,300	$ 12	$ 243,600
20	Diversion Piping (84-inch dia. RCP)	L.F.	350	$ 950	$ 332,500
21	Transfer Piping (72-inch dia. RCP)	L.F.	630	$ 800	$ 504,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	400	$ 450	$ 180,000
23	InterBasin Low Level Transfers	L.S.	3	$ 45,000	$ 135,000
24	Laydown Pad	L.S.	1	$ 75,000	$ 75,000
25	Basin Outlet Structure	L.S.	4	$ 65,000	$ 260,000
26	Surface Transfer Structure (Weir)	L.S.	3	$ 850,000	$ 2,550,000
27	Outlet Energy Dissipaters	L.S.	4	$ 50,000	$ 200,000
28	Diversion Sluice Gate	L.S.	3	$ 60,000	$ 180,000
29	48" Valves	L.S.	3	$ 45,000	$ 135,000
30	42" Valve	L.S.	4	$ 40,000	$ 160,000
31	Catwalks	L.S.	4	$ 45,000	$ 180,000
32	Equipment Electrical	L.S.	1	$ 100,000	$ 100,000
33	Flow Control Gate Electrical	L.S.	1	$ 400,000	$ 400,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	3	$ 25,000	$ 75,000
38	Low Flow Meter	L.S.	3	$ 20,000	$ 60,000
39	Level Sensor	L.S.	4	$ 10,000	$ 40,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Chain Link)	L.F.	8,500	$ 45	$ 382,500
43	Mitigation	AC	3.0	$ 25,000	$ 75,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 685,818
48	Material Testing	%	0.5%		$ 68,582
49	Contingency	%	10%		$ 1,371,635
	Total Capital Costs				$ 16,002,384
	Annual Debt Service (5% @ 30 years)		0.06505		$ 1,040,955

Annual O&M Costs			Cajon Creek Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Diversion Berm & Bypass	L.S.	1	$ 15,000	$ 15,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	30	$ 1,000	$ 30,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 1,016,500	$ 10,165
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 20,000	$ 20,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 45,000	$ 45,000
8	Basin Cleanings	Yd^3	2,460	$ 2	$ 4,921
9	Material Export	Yd^3	4,460	$ 12	$ 53,524
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 218,610

Project Benefit Summary			Cajon Creek Basin		
	Total Annual Project Cost	$			$ 1,259,565
	Average Annual Benefit	AF/YR			1,230
	Average Annual Recharge Unit Cost	$/AF			$ 1,024

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Cajon Creek/Vulcan 1 (Station 12)

Existing Conditions

The Cajon Creek/Vulcan 1 site is located adjacent to Cajon Creek and is bordered by Cajon Creek along the west edge of the site and crosses Institution Road along the north end of the site. The proposed diversion would be located immediately upstream of Institution Road near the east end of Institution Road and approximately 4,700 feet south-west of the 215 Freeway/Palm Avenue crossing in the City of San Bernardino (Figure 106). The proposed diversion would be situated parallel to, and immediately north of, Institution Road. Vulcan 1 Basin is an existing aggregate mining pit with a top area measuring approximately 83 acres and a total depth of approximately 115 feet. Overall the Cajon Creek/Vulcan 1 site has an elevation differential of approximately 171 feet from the diversion location to the bottom of the existing Vulcan 1 Basin.

Water flows in Cajon Creek from north-west to south-east past the proposed project site. The existing Institution Road alignment rests at-grade and crosses Cajon Creek. The proposed sand berm diversion would cross the entire width of Cajon Creek and provide protection for Institution Road during low flows (< 500 cfs). Flows greater than 500 cfs would continue to flow across the road as is the current condition.

Figure 106: Cajon Creek/Vulcan 1 Overview

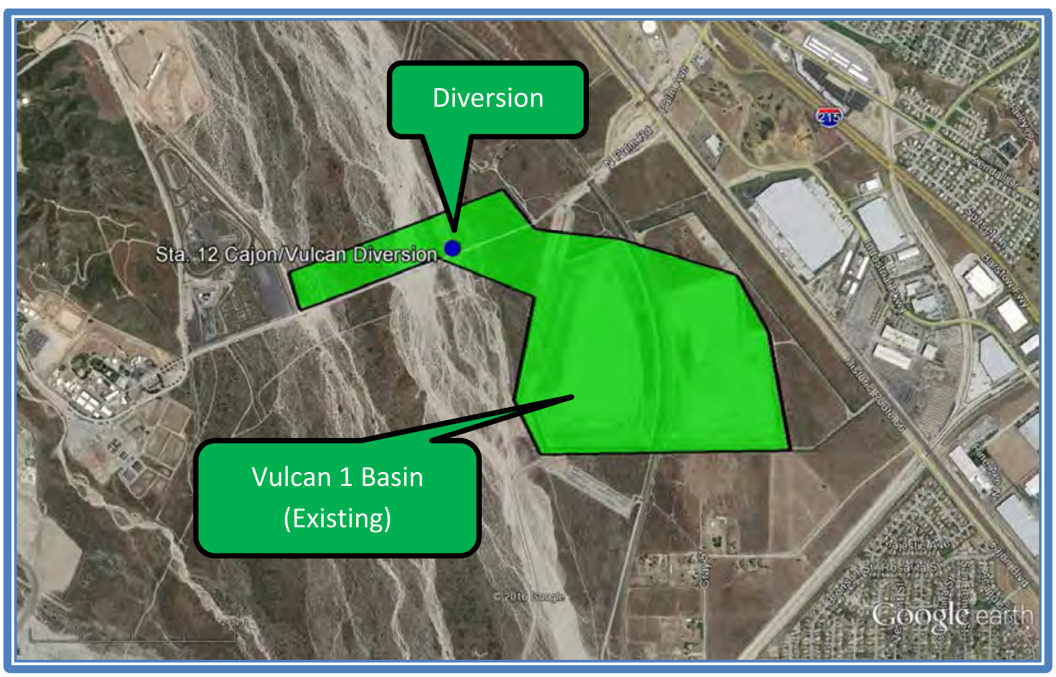

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Figure 107: Cajon Creek/Vulcan 1 Site (Existing Vulcan 1 Basin)

Proposed Improvements

The proposed improvements at Cajon Creek/Vulcan 1 site for the ARP are to construct a 3,000’ long by 12’ high sand berm diversion, a surface transfer bypass structure and a 500 cfs capacity diversion inlet structure and piping. The diversion has been developed to utilize a gravity conveyance system while maintaining adequate flood control capacity in Cajon Creek. A sand berm diversion was selected for this site due to the large width of Cajon Creek at the diversion location.

The sand berm diversion will provide a means to collect the storm water flows and focus them into the diversion inlet structure. Once in the structure, the flows will be conveyed via pipeline underneath Institution Road and into the existing Vulcan 1 Basin. The surface transfer bypass structure will provide a means to send flows across the diversion berm without a berm was-out. Once flows in Cajon Creek reach a pre-determined flow rate a section (or multiple sections) of the diversion berm will be designed to was-out a self-level, thereby preserving the flood control capacity of the creek.

A focused geotechnical investigation and analysis during final design will be required in order to design the diversion berm and properly specify material. Material with the proper gradation will be required to control the breaching and leveling of the diversion berm during significant storm events.

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The area above the sand berm diversion will act as the forebay for the diversion structure. While in operation, the forebay area will pool water and increase the wetted area thereby increasing the groundwater recharge yield in Cajon Creek. The wetted area above the sand berm diversion is approximately 6.0 acres in size with a volume capacity of approximately 24.1 af.

A series of model iterations were performed to help determine a target design flow rate of 500 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 1,446 af/yr) would be realized by constructing the Cajon Creek/Vulcan 1 Basin Project.

Flows that enter the diversion will be delivered to the existing Vulcan 1 Basin via a 500 cfs pipeline. An energy dissipating structure will be required in Vulcan 1 Basin along with remote level sensing equipment. The basin may require a cleaning or over-excavation prior to use as a groundwater recharge basin.

The following figures provide conceptual design views of the proposed improvements.

Figure 108: Cajon Creek/Vulcan 1 Basin Conceptual Design (Plan View)

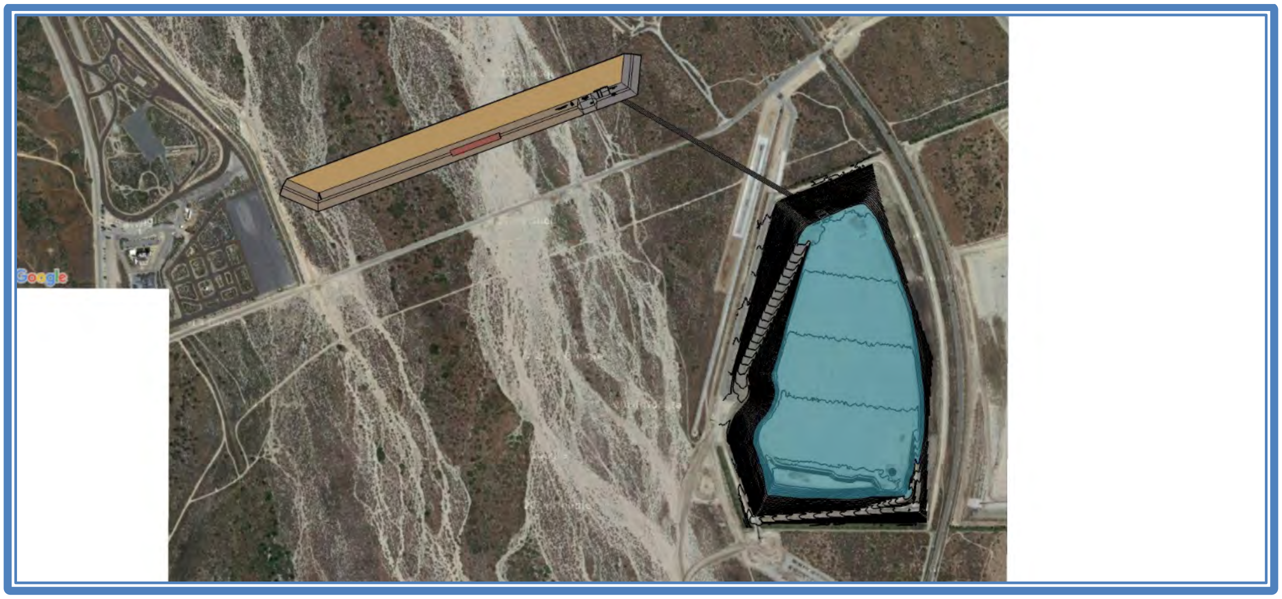

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Figure 109: Cajon Creek/Vulcan 1 Basin Conceptual Design (Diversion View)

Figure 110: Cajon Creek/Vulcan 1 Basin Conceptual Design (Diversion Berm View)

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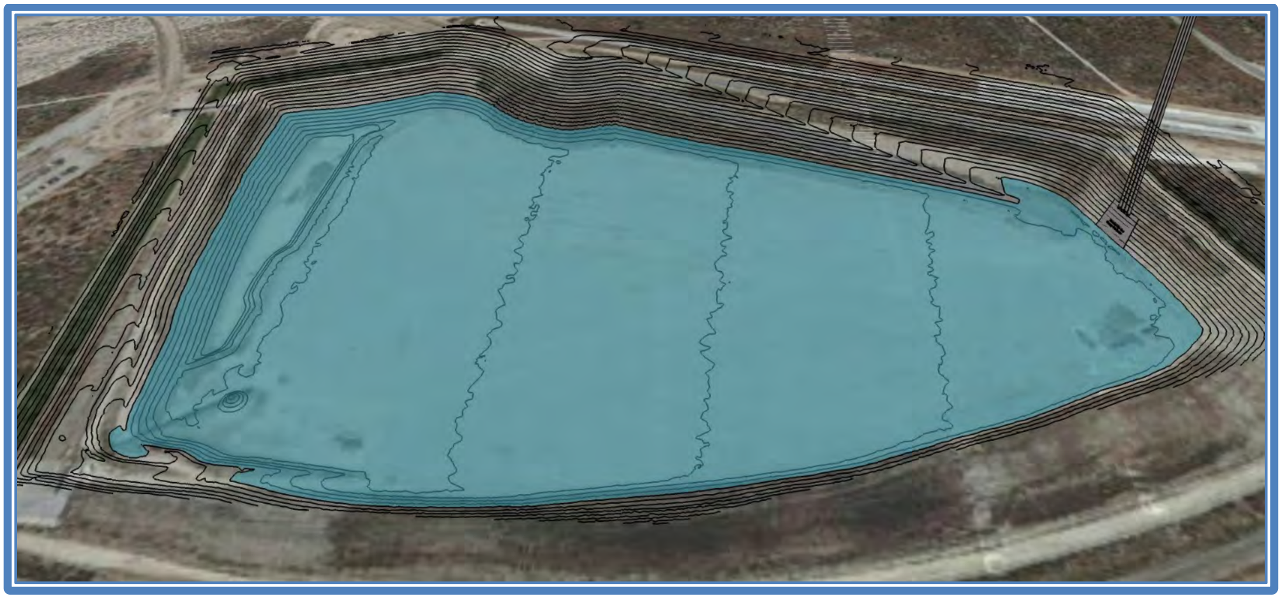
Figure 111: Cajon Creek/Vulcan 1 Basin Conceptual Design (Basin View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Cajon Creek/Vulcan 1 Basin Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 46. The forebay area above the sand berm diversion was also included in the model to better capture the full benefit of the project.

A fundamental assumption of the model is that each time there is a high flow event that washes out the sand diversion berm, the diversion flows are reduced until such time that the berm can be reconstructed. On average the berm will need to be reconstructed 3 to 4 times per year. The available flows at the Cajon Creek/Vulcan 1 site used in the groundwater recharge operations model were from flow station 12.

Please note that only 1 example of a Cajon Creek/Vulcan 1 Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 113 and Figure 114 to illustrate how the infiltration rates might decay in the Vulcan 1 Basin.

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Table 46: Cajon Creek/Vulcan 1 Basin Model Assumptions

Cajon Creek/Vulcan 1 flow hydrograph	See Figure 112
Basin area and volume	Area = 70.0 acres, Volume = 3,618 af
Forebay area and volume	Area = 6.0 acres, Volume = 24.1 af
Initial infiltration rates	2.5 ft/day
Infiltration rate decay parameters	See Figure 114 (using Figure 113 flow series)
Diversion flow capacity	500 cfs
Diversion berm washout flow rate	1,500 cfs
Diversion flow rate without berm	10 cfs

Figure 112: Cajon Creek/Vulcan 1 Flows

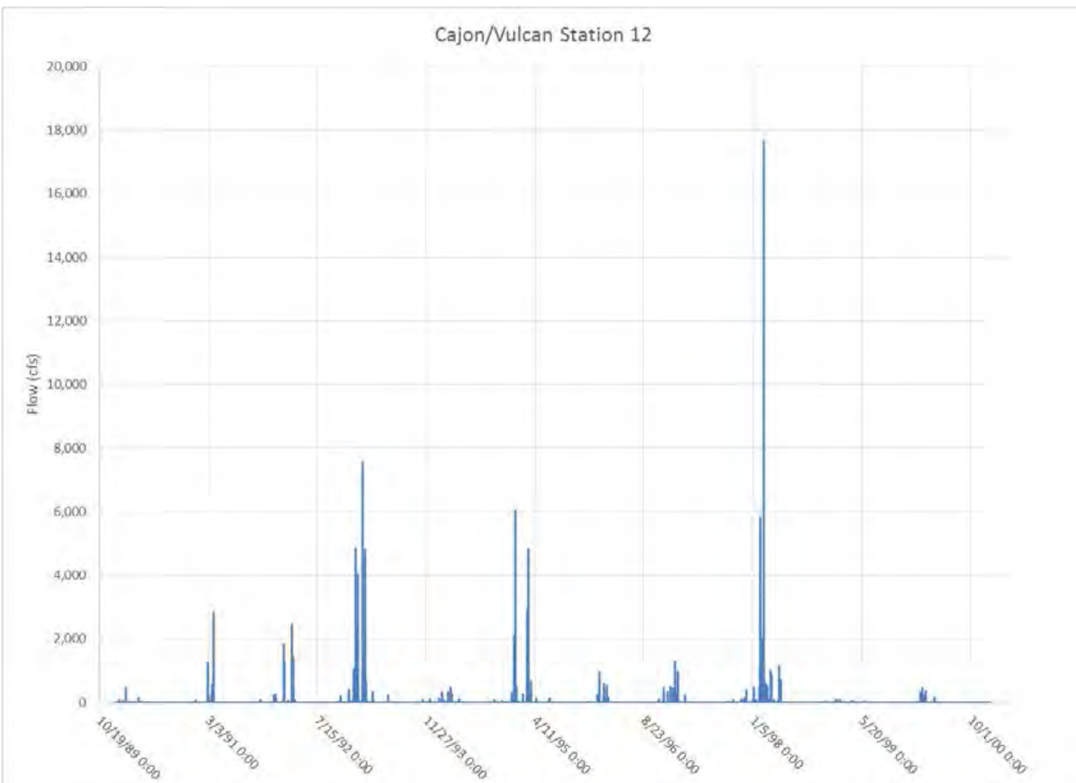

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Figure 113: Cajon Creek/Vulcan 1 Basin Optimization Flow Series

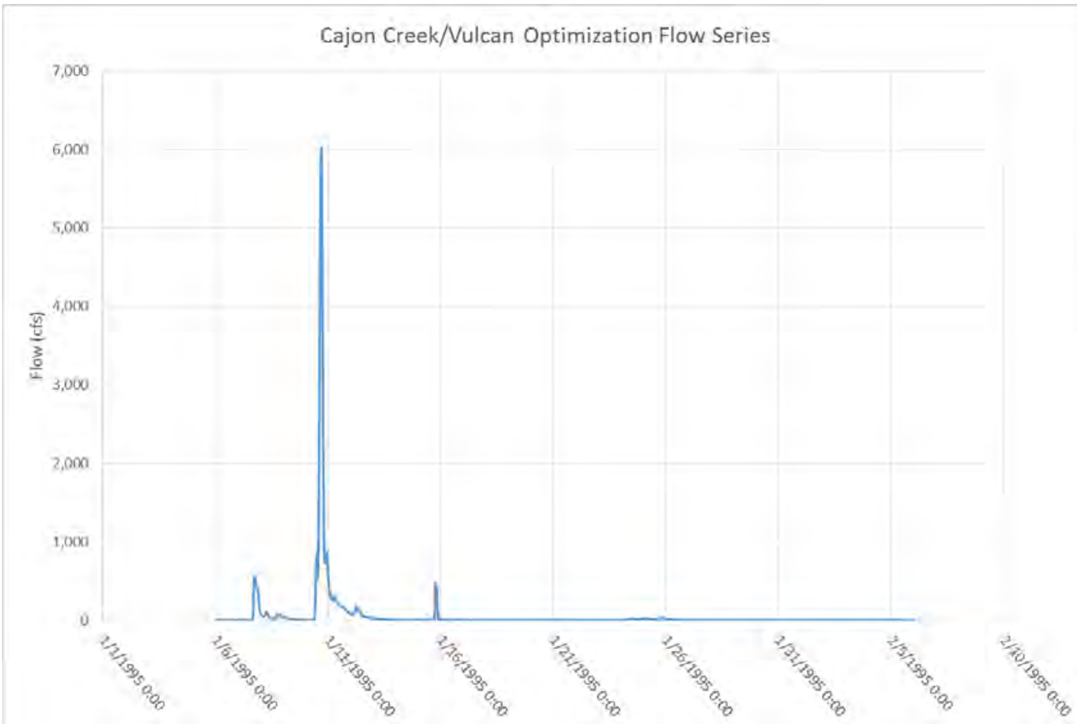
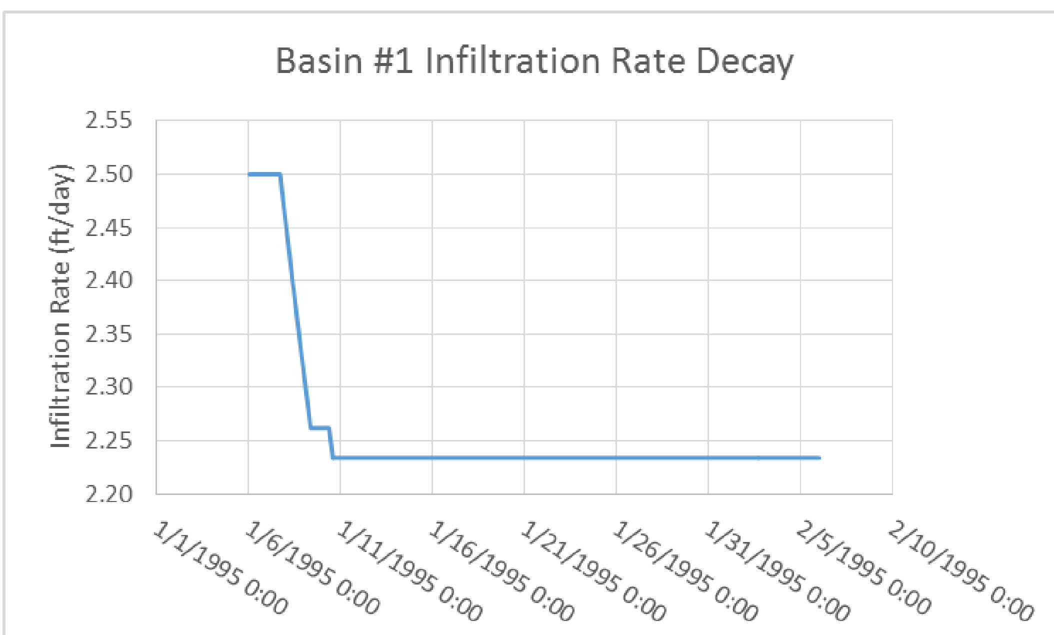


Figure 114: Cajon Creek/Vulcan 1 Basin Infiltration Rate Decay

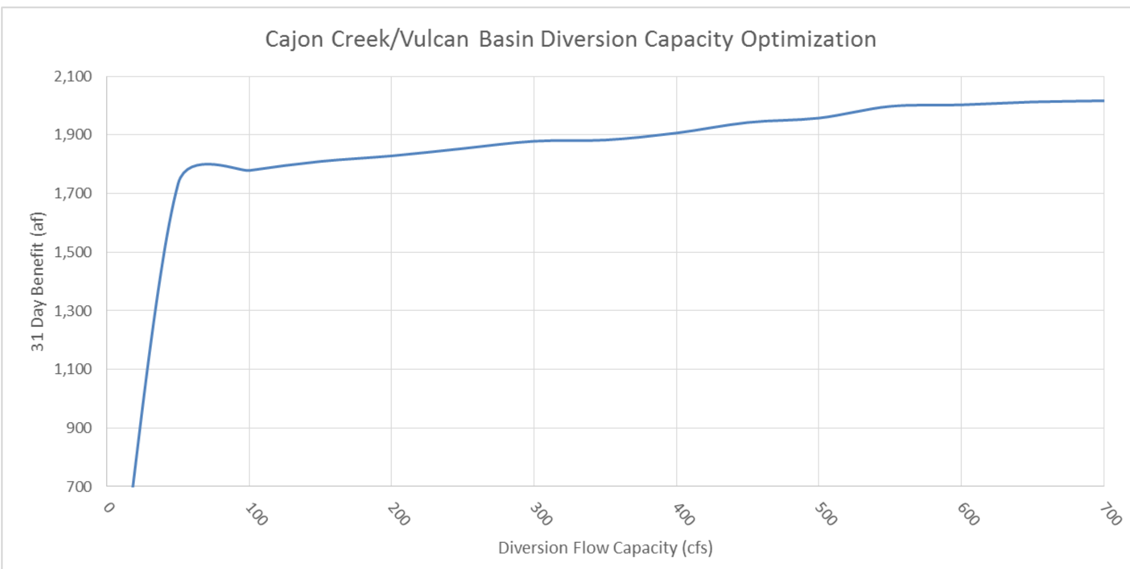


In order to determine the optimum basin inlet flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the basin diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the diversion size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 112 as the inflow for the optimization flow series for the diversion (Figure 113).

The diversion flow capacity was increased in 50 cfs increments from 50 cfs up to 700 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 115).

The project benefit plateaus at a diversion flow rate of approximately 550 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 500 cfs be carried forward.

Figure 115: Cajon Creek/Vulcan 1 Diversion Optimization Results



The 11 year flow series was modeled using the 500 cfs inlet capacity to predict the total amount of storm water captured and recharged during the model period. The final Cajon Creek/Vulcan 1 Basin Project model results can be seen in Table 43.

Table 47: Cajon Creek/Vulcan 1 Basin 11 Year Model Results

Total Available Flow (af)	58,502
Total Flow Captured & Recharged (af)	15,902
Total Flow Bypassed (af)	42,600
Annual Average Flow Captured & Recharged (af)	1,446

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Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site occasionally during storm events to insure that the diversion inlet remains free of vegetation and debris and to adjust the inlet gates to avoid overfilling the basins. Operators may find it beneficial to occasionally and purposely breach the sand diversion berm to encourage the natural transport of sediment downstream.

The overall operating depth of Vulcan 1 Basin may need to be limited to avoid excessive seepage laterally into the basin located to the east. For the purpose of this analysis it was assumed that 90' of the total 115' of basin depth was used as the maximum operating level in the basin.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular regrading of the sand diversion berm and forebay area will be require in order to maximize the spreading of storm flows and maintain diversion rates. Regular maintenance will also be required on the flow control gates, surface transfer structures, meters, level sensors and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Cajon Creek/Vulcan 1 Basin Project is presented in Table 48.

Table 48: Cajon Creek/Vulcan 1 Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	2,565	233

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20

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to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 49: Cajon Creek-Vulcan 1 Basin Cost Estimate

Capital Costs			Cajon Creek/Vulcan 1 Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 65,000	$ 65,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 100,000	$ 100,000
4	Survey	L.S.	1	$ 65,000	$ 65,000
5	Construction Water	L.S.	1	$ 45,000	$ 45,000
6	Temporary De-Watering	L.S.	1	$ 50,000	$ 50,000
7	Traffic Control	L.S.	1	$ 60,000	$ 60,000
8	Clearing & Grubbing	AC	50	$ 1,500	$ 75,000
9	On-Site Grading	Yd^3	140,000	$ 5	$ 700,000
10	Material Export	Yd^3	5,000	$ 12	$ 60,000
11	Finish Grading	AC	50	$ 300	$ 15,000
12	Access Roads	AC	1	$ 90,000	$ 90,000
13	Diversion Berm Grading	L.F.	1,500	$ 250	$ 375,000
14	Diversion Berm Surface Bypass Structure	L.S.	1	$ 350,000	$ 350,000
15	Downstream Grade Stabilizer	L.F.	250	$ 500	$ 125,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	78,800	$ 12	$ 945,600
20	Diversion Piping (60-inch dia. RCP)	L.F.	7,000	$ 700	$ 4,900,000
21	Diversion Piping Road Crossing (60-inch d	L.F.	500	$ 900	$ 450,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	260	$ 450	$ 117,000
23	High Flow Berm Breach Zone	L.S.	1	$ 35,000	$ 35,000
24	Forebay Area Grading	L.S.	1	$ 10,000	$ 10,000
25	Vulcan 1 Basin Regrading	L.S.	1	$ 25,000	$ 25,000
26	Road Crossing Improvements	L.S.	1	$ 150,000	$ 150,000
27	Outlet Energy Dissipaters	L.S.	1	$ 45,000	$ 45,000
28	Diversion Sluice Gate	L.S.	4	$ 50,000	$ 200,000
29	42" Valve	L.S.	1	$ 40,000	$ 40,000
30	42" Valve	L.S.	1	$ 40,000	$ 40,000
31	Catwalks	L.S.	2	$ 45,000	$ 90,000
32	Equipment Electrical	L.S.	1	$ 100,000	$ 100,000
33	Flow Control Gate Electrical	L.S.	1	$ 150,000	$ 150,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 250,000	$ 250,000
37	Diversion Flow Meter	L.S.	4	$ 25,000	$ 100,000
38	Low Flow Meter	L.S.	1	$ 20,000	$ 20,000
39	Level Sensor	L.S.	2	$ 10,000	$ 20,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Chain Link)	L.F.	1,000	$ 45	$ 45,000
43	Mitigation	AC	5.0	$ 25,000	$ 125,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 699,130
48	Material Testing	%	0.5%		$ 69,913
49	Contingency	%	10%		$ 1,398,260
	Total Capital Costs				$ 16,359,903
	Annual Debt Service (5% @ 30 years)		0.06505		$ 1,064,212

Annual O&M Costs			Cajon Creek/Vulcan 1 Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Diversion Berm & Bypass	L.S.	1	$ 15,000	$ 15,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	5	$ 1,000	$ 5,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 5,467,000	$ 54,670
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 10,000	$ 10,000
6	Valve & Gates	L.S.	1	$ 15,000	$ 15,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 25,000	$ 25,000
8	Basin Cleanings	Yd^3	13,982	$ 2	$ 27,964
9	Material Export	Yd^3	14,982	$ 12	$ 179,787
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 357,421

Project Benefit Summary			Cajon Creek/Vulcan 1 Basin		
	Total Annual Project Cost	$			$ 1,421,633
	Average Annual Benefit	AF/YR			1,446
	Average Annual Recharge Unit Cost	$/AF			$ 983

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Vulcan 2 (Station 13)

Existing Conditions

The Vulcan 2 site is located adjacent to the Devil Creek Diversion Channel. The Devil Creek Diversion Channel borders the south-east edge of the proposed Vulcan 2 Basin. The proposed diversion would be located within the Devil Creek Diversion Channel immediately downstream Cajon Boulevard/Devil Creek Diversion Channel crossing. The basin site is south-west of Cajon Boulevard and is approximately 7,500 feet south of the 215 Freeway/Palm Avenue crossing in the City of San Bernardino (Figure 116).

The Devil Creek Diversion Channel is a concrete lined trapezoidal channel which delivers flow from the Devil Creek and Cable Creek drainage areas into Cajon Creek. The Devil Creek Diversion Channel is a SBCFCD facility (System # 2-307-1B) with oversite by the USACE. The Vulcan 2 Basin site is currently an open space area/un-improved site planned for future aggregate mining. Overall the Vulcan 2 Basin site has an elevation differential of approximately 35 feet from the diversion location to the south-west end of the basin site (0.88% grade).

Figure 116: Vulcan 2 Overview

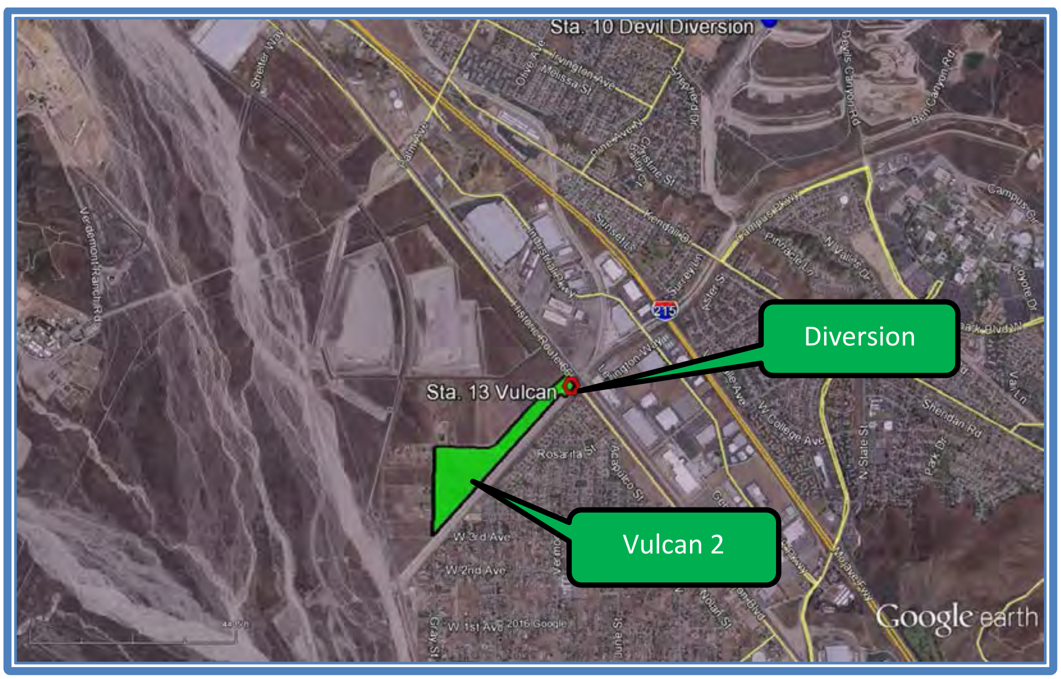

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Figure 117: Vulcan 2 Diversion Site (Looking South West)

Proposed Improvements

The proposed improvements at Vulcan 2 Basin for the ARP are to construct an 8' diameter by 75' long inflatable rubber dam diversion across Devil Creek Diversion Channel and a series of basins from Cajon Boulevard extending south-west 4,000 feet (approximately 4 basins total). The basin layout has been developed to utilize a gravity conveyance system and to maximize usage of the available area on the site. The basin invert will be slightly lower than the Devil Creek Diversion Channel invert near the diversion point and slightly higher than the channel invert at the downstream most end of the basins.

An inflatable rubber dam will be constructed in the channel diversion. An inflatable rubber dam was selected for this because the channel is trapezoidal in shape and concrete lined. Inflatable rubber dam diversions provide the ability to quickly transition operations from water conservation mode to flood control mode and vice versa.

A diversion structure and inlet piping will be constructed from the channel to the first basin. A series of surface transfer structures and basin drains will be constructed between each basin as well as from each basin directly back into the channel.

In general, the perimeter of the basin will be constructed at existing grade with low perimeter berms. The average basin depth will range between 12 to 15 feet with the

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maximum operating level within the basins at approximately 10-13 feet deep. The total wetted area of the basins will be approximately 35.2 acres with a storage volume of 383 af. The operating level of the basins will be lower than the surrounding grade and therefore will likely not be considered a DSOD jurisdictional facility. A jurisdictional determination request should be made to DSOD to confirm this assumption.

The area above the rubber dam diversion will act as the forebay for the diversion structure. While the dam is inflated the forebay area will pool water above the dam but because the channel is concrete lined there will be no increase to groundwater recharge yield in the forebay.

A series of model iterations were performed to help determine a target design flow rate of 750 cfs for the diversion capacity. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 3,441 af/yr) would be realized by constructing the Vulcan 2 Basin Project.

The proposed improvements for the ARP at the Vulcan 2 Basin site include the construction of 35.2 acres of basin, construction of a 75' long by 8' tall inflatable rubber dam, construction of a 750 cfs diversion/inlet structure, construction of 3 basin transfer and overflow structures and the construction of 8, 36-inch diameter basin drains. Each of the basins should include remote level sensing and inflow/outflow metering. The site should also be improved by adding a flow measuring station in the Devil Creek Diversion Channel at the diversion site and flow meters in the diversion structure to help facilitate operations. The following figures provide conceptual design views of the proposed improvements.

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Figure 118: Vulcan 2 Basin Conceptual Design (Plan View)

Figure 119: Vulcan 2 Basin Conceptual Design (Diversion View)

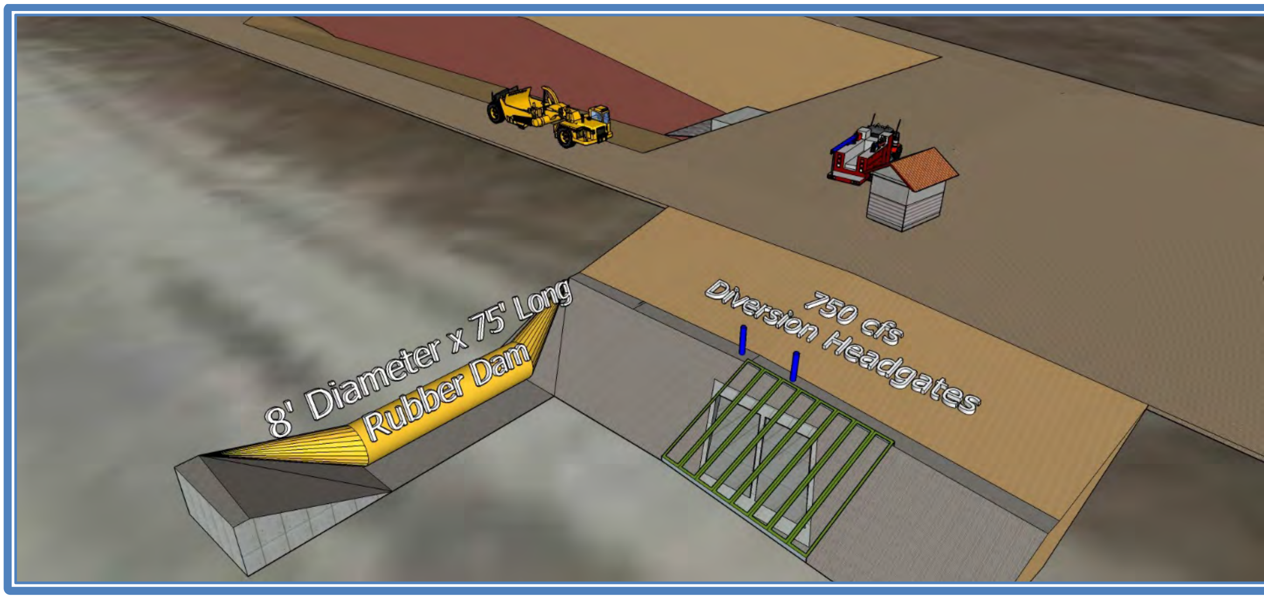

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Figure 120: Vulcan 2 Basin Conceptual Design (Transfer View)

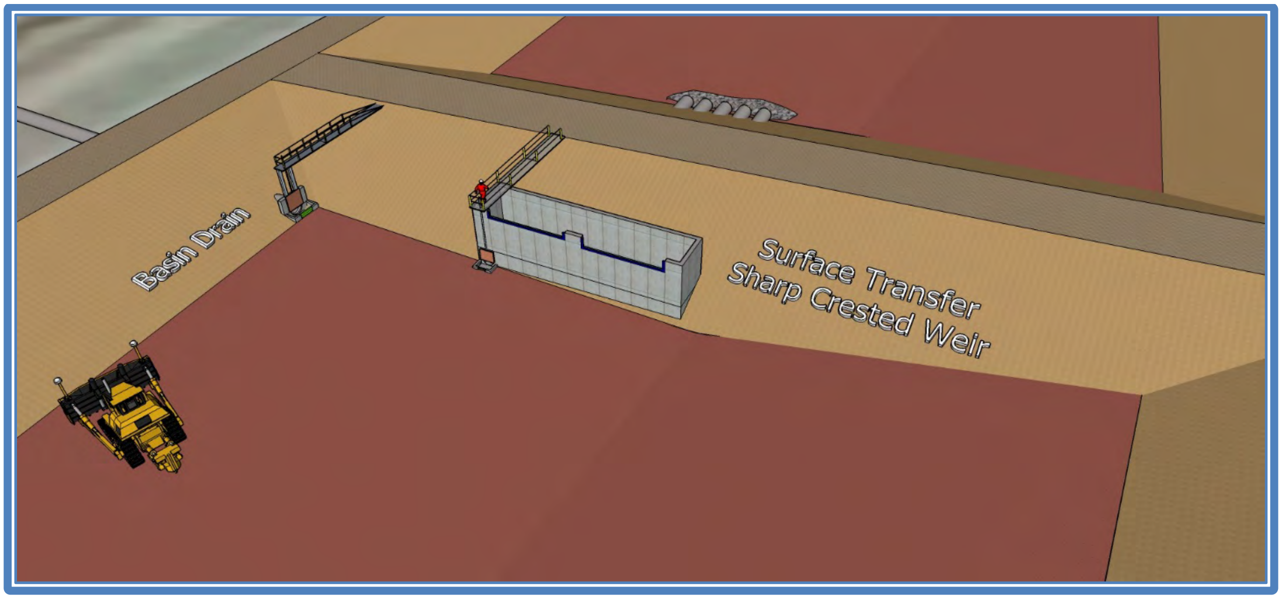
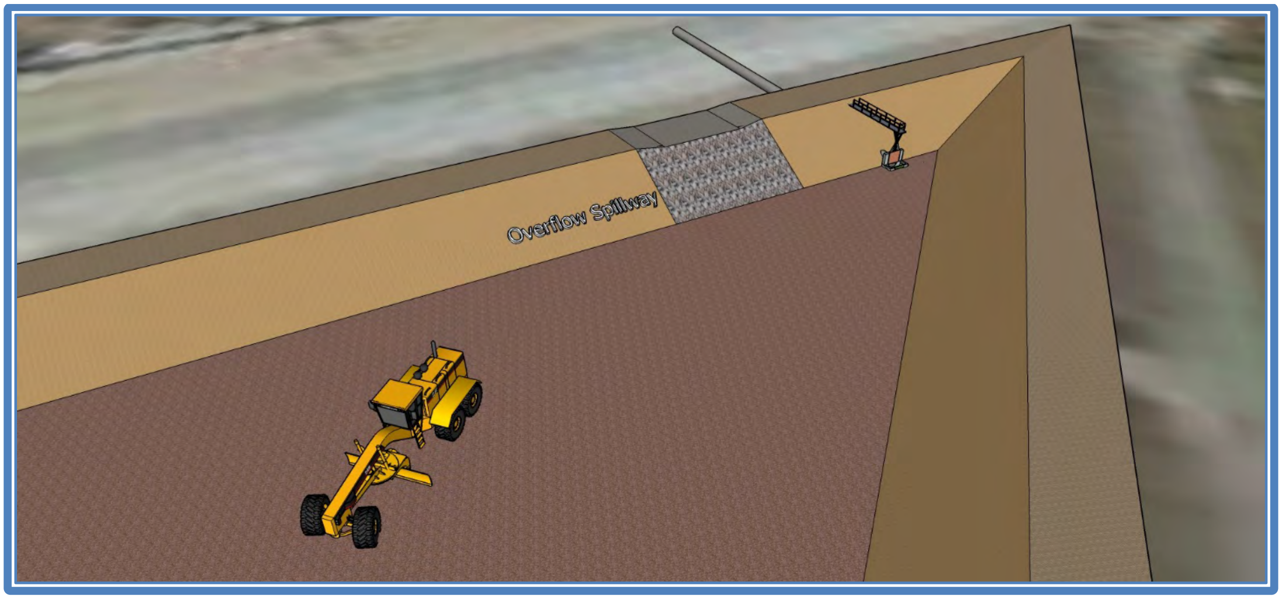


Figure 121: Vulcan 2 Basin Conceptual Design (Outlet View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Vulcan 2 Basin Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 50. The forebay area above

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the diversion was included in the model but does not provide additional infiltration capacity because the cannel is concrete lined.

A fundamental assumption of the model is that each time there is a high flow event (> 3,000 cfs) the dam would be deflated and the diversion flows reduced, until such time that flows recede and the dam can be re-inflated. The available flows at the Vulcan 2 Basin site used in the groundwater recharge operations model were from flow station 13.

Please note that only 1 example of a Vulcan 2 Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 123 and Figure 124 to illustrate how the infiltration rates might decay in the Vulcan 2 Basin.

Table 50: Vulcan 2 Basin Model Assumptions

Vulcan 2 flow hydrograph	See Figure 122
Basin area and volume	Area = 35.2 acres, Volume = 383 af
Forebay area and volume	Area = NA acres, Volume = 4.3 af
Initial infiltration rates	3.5 ft/day
Infiltration rate decay parameters	See Figure 124 (using Figure 123 flow series)
Diversion flow capacity	750 cfs
Dam deflation set point	3,000 cfs
Diversion flow rate with dam deflated	10 cfs

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Figure 122: Vulcan 2 Flows

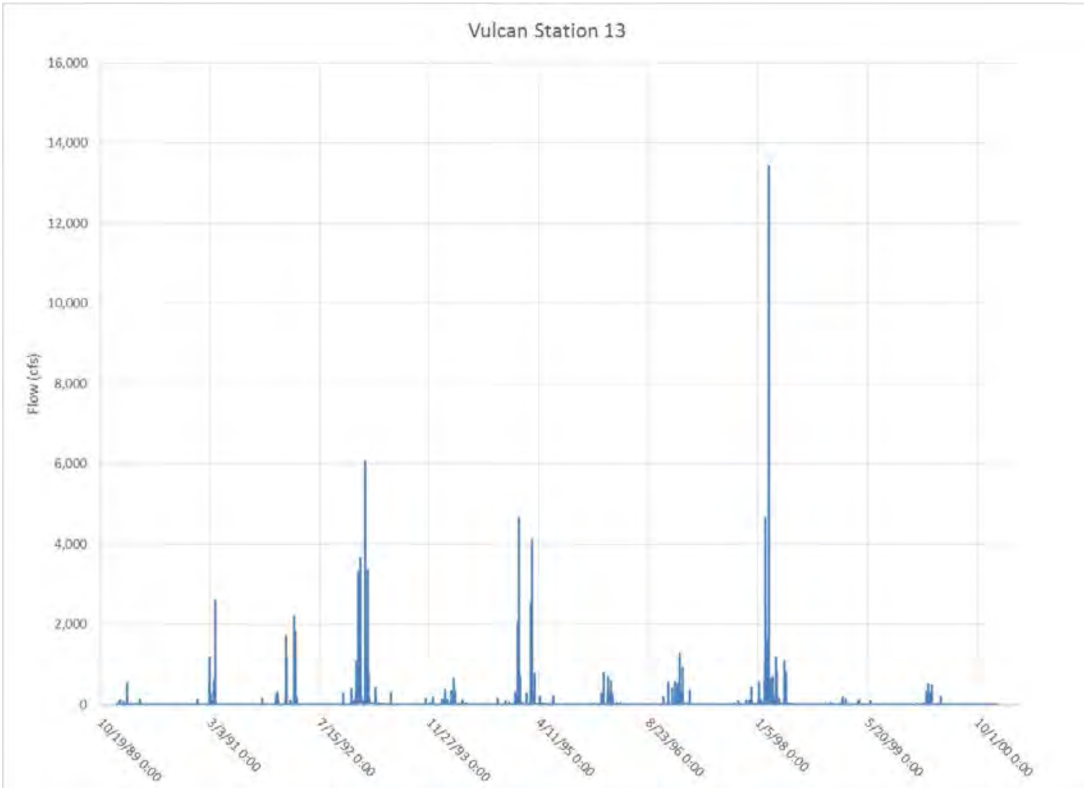

Figure 123: Vulcan 2 Basin Optimization Flow Series

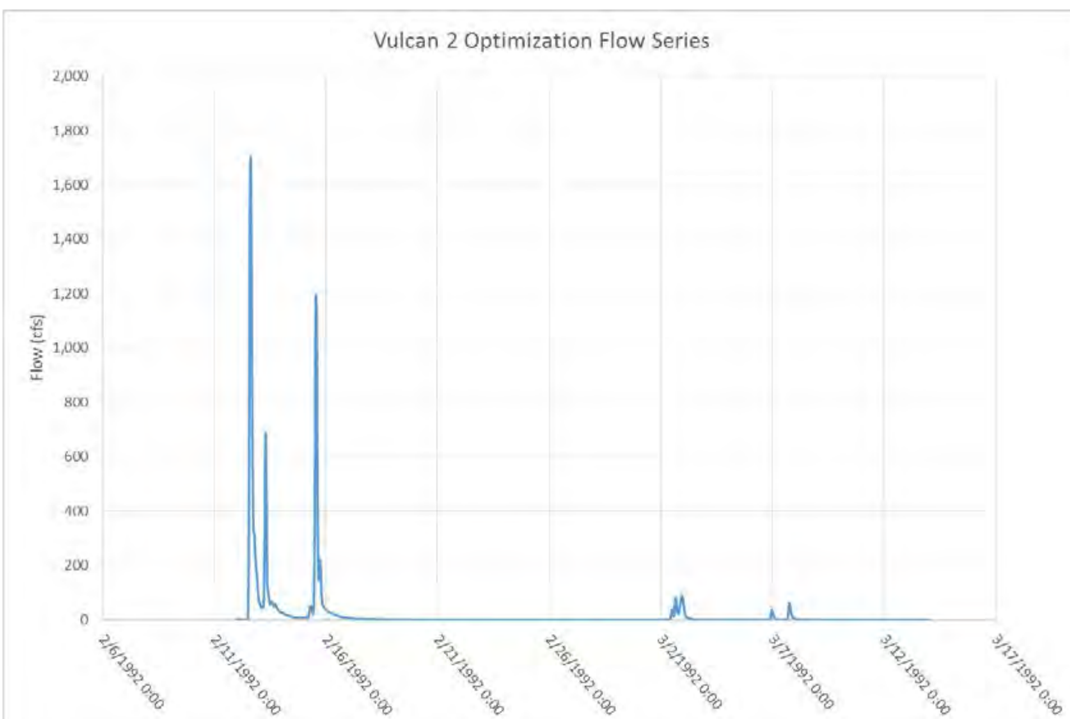

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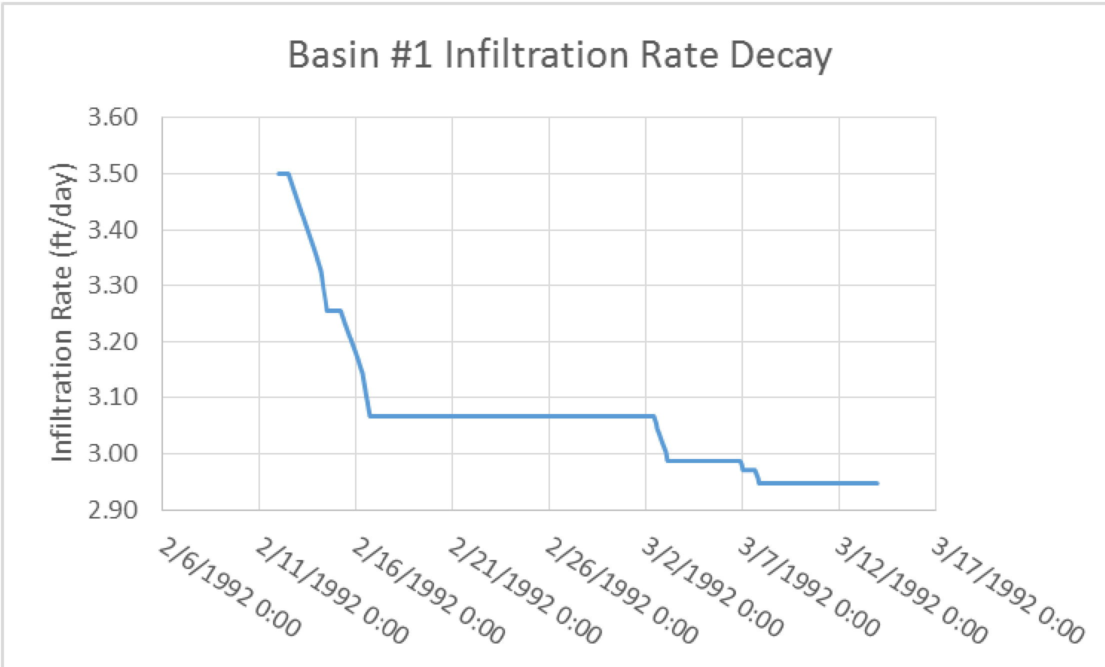
Figure 124: Vulcan 2 Basin Infiltration Rate Decay



In order to determine the optimum basin inlet flow rate capacity, a series of 31 day model runs were performed to test the sensitivity of the benefit to the basin diversion flow rate capacity. All model parameters were held constant except for the diversion size. Also, because most of the benefit from increasing the diversion size comes from higher intensity storm events, a sample storm period of 31 days was selected from the flow series in Figure 122 as the inflow for the optimization flow series for the diversion (Figure 123).

The diversion flow capacity was increased in 50 cfs increments from 50 cfs up to 1,000 cfs. The total benefit for the 31 day flow series given each diversion flow capacity was plotted in order to visualize the rate of change and determine at what point the benefit stops increasing (Figure 125).

The project benefit plateaus at a diversion flow rate of approximately 700 cfs. At this time Scheevel Engineering recommends that a diversion design flow rate of 750 cfs be carried forward in order to account for the variability in flows and to help sustain diversion rates as the diversion inlet plugs with vegetation and debris during storm events.

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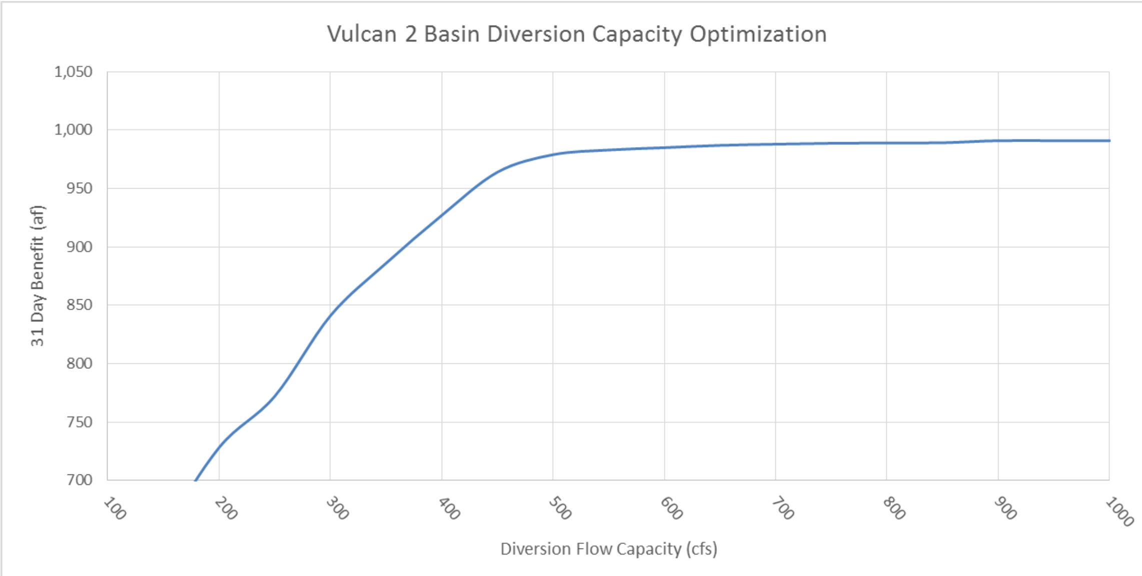
Figure 125: Vulcan 2 Diversion Optimization Results



The 11 year flow series was modeled using the 750 cfs inlet capacity to predict the total amount of storm water captured and recharged during the model period. The final Vulcan 2 Basin Project model results can be seen in Table 51.

Table 51: Vulcan 2 Basin 11 Year Model Results

Total Available Flow (af)	74,543
Total Flow Captured & Recharged (af)	37,850
Total Flow Bypassed (af)	36,693
Annual Average Flow Captured & Recharged (af)	3,441

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site regularly during storm events to insure that the diversion inlet remains free of vegetation and debris and that the rubber dam operates properly. During periods of especially high sedimentation or debris buildup in the forebay area operators may find it beneficial to purposely deflate the rubber dam for short periods of time to encourage the natural transport of the materials downstream.

Maintenance activities will include the removal of sediment, vegetation and debris from the forebay and basin areas. Regular maintenance will also be required on the flow control gates, surface transfer structures, meters, level sensors and rubber dam mechanical and control systems. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates.

The groundwater recharge model provides an estimate of the overall amount of sediment delivered to the basin. The 11 year total, and annual average, sediment loading for the Vulcan 2 Basin Project is presented in Table 52.

Table 52: Vulcan 2 Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	7,605	691

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 53: Vulcan 2 Basin Cost Estimate

Capital Costs			Vulcan 2 Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 65,000	$ 65,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 150,000	$ 150,000
4	Survey	L.S.	1	$ 65,000	$ 65,000
5	Construction Water	L.S.	1	$ 85,000	$ 85,000
6	Temporary De-Watering	L.S.	1	$ 75,000	$ 75,000
7	Traffic Control	L.S.	1	$ 60,000	$ 60,000
8	Clearing & Grubbing	AC	55	$ 1,500	$ 82,500
9	On-Site Grading	Yd^3	75,000	$ 5	$ 375,000
10	Material Export	Yd^3	920,000	$ 12	$ 11,040,000
11	Finish Grading	AC	55	$ 300	$ 16,500
12	Access Roads	AC	20	$ 90,000	$ 1,800,000
13	Dam Foundation	L.F.	75	$ 12,000	$ 900,000
14	Rubber Dam & Equipment	L.S.	1	$ 650,000	$ 650,000
15	Demolish & Haul Off	L.S.	1	$ 450,000	$ 450,000
16	Diversion Structure	L.S.	1	$ 1,250,000	$ 1,250,000
17	Trash Rack System (Automated)	L.S.	1	$ 1,500,000	$ 1,500,000
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	3,600	$ 12	$ 43,200
20	Diversion Piping (7'x 7' RCB)	L.F.	350	$ 1,300	$ 455,000
21	Transfer Piping (48-inch dia. RCP)	L.F.	1,200	$ 500	$ 600,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	450	$ 450	$ 202,500
23	InterCell Transfers & Drains	L.S.	-	$ 250,000	$ -
24	Overflow Spillway	L.S.	1	$ 250,000	$ 250,000
25	Basin Outlet Structure	L.S.	4	$ 65,000	$ 260,000
26	Surface Transfer Structure (Weir)	L.S.	3	$ 850,000	$ 2,550,000
27	Outlet Energy Dissipaters	L.S.	4	$ 50,000	$ 200,000
28	Diversion Sluice Gate	L.S.	2	$ 75,000	$ 150,000
29	48" Valve	L.S.	3	$ 45,000	$ 135,000
30	42" Valve	L.S.	4	$ 40,000	$ 160,000
31	Catwalks	L.S.	7	$ 45,000	$ 315,000
32	Equipment Electrical	L.S.	1	$ 100,000	$ 100,000
33	Flow Control Gate Electrical	L.S.	1	$ 150,000	$ 150,000
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 250,000	$ 250,000
37	Diversion Flow Meter	L.S.	2	$ 35,000	$ 70,000
38	Low Flow Meter	L.S.	3	$ 20,000	$ 60,000
39	Level Sensor	L.S.	5	$ 10,000	$ 50,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	9,600	$ 100	$ 960,000
43	Mitigation	AC	5.0	$ 25,000	$ 125,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 1,342,485
48	Material Testing	%	0.5%		$ 134,249
49	Contingency	%	10%		$ 2,684,970
	Total Capital Costs				$ 31,221,404
	Annual Debt Service (5% @ 30 years)		0.06505		$ 2,030,952

Annual O&M Costs			Vulcan 2 Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Rubber Dam	L.S.	1	$ 15,000	$ 15,000
2	Diversion Head Works	L.S.	1	$ 15,000	$ 15,000
3	Forebay Recharge Area	Day	-	$ 1,000	$ -
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 1,257,500	$ 12,575
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 10,000	$ 10,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 25,000	$ 25,000
8	Basin Cleanings	Yd^3	9,411	$ 2	$ 18,822
9	Material Export	Yd^3	9,511	$ 12	$ 114,133
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 255,531

Project Benefit Summary			Vulcan 2 Basin		
	Total Annual Project Cost	$			$ 2,286,483
	Average Annual Benefit	AF/YR			3,441
	Average Annual Recharge Unit Cost	$/AF			$ 664

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Lytle-Cajon Basin (Station 14)

Existing Conditions

The Lytle-Cajon Basin site is located within Lytle Creek Wash. The proposed in-channel recharge basin system would be located within the flow path of Lytle Creek Wash immediately downstream West Baseline Road/Lytle Creek Wash crossing. The basin site is approximately 1.9 miles south-west of the 215 Freeway/210 Freeway Interchange in the City of San Bernardino (Figure 126).

Lytle Creek Wash is a SBCFCD facility (System # 2-202-1D). Lytle Creek Wash is currently an un-improved creek with a native sand/rock bottom and side slopes. Lytle Creek Wash flows north to south and delivers flow from the upstream Lytle and Cajon Creek drainage area, downstream to Lytle-Cajon Channel. The Lytle-Cajon Basin site has an elevation differential of approximately 40 feet from West Baseline Road in the north, 5,000 feet downstream to the Lytle-Cajon Radial Gate in the south end of the site (0.80% grade).

Figure 126: Lytle-Cajon Overview

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Figure 127: Lytle-Cajon Site (In-Channel Recharge Zone)

Proposed Improvements

The proposed improvements at the Lytle-Cajon Basin Site for the ARP include constructing a series of in-channel recharge basins. The basins would increase the wetted area of Lytle Creek Wash and provide storage volume for storm water capture and recharge. There would be 8 basins constructed in series and operated as flow-through basins. The basin berms would be approximately 8 -10 feet high. The basins would be constructed of the native creek bed materials. Sections of the basin berms perpendicular to the flow would self-level during high flow events to preserve the flood control capacity of Lytle Creek Wash. Each in-channel recharge basin would have an overflow surface transfer structure and a low level drain tube.

The average operating level within the proposed basins will be approximately 6 feet for a total wetted area of 43 acres and a storage volume of 244 af. There will be no groundwater recharge operations in the zones directly adjacent to the Radial Gate or USACE levees.

The proposed project would be placed in an existing flow through system and therefore there is no diversion or inlet restriction associated with this project. There were no model iterations needed to determine an optimum diversion flow rate. Based on the analysis presented below in the modeling results it was determined that the project benefit (approx. 3,408 af/yr) would be realized by constructing the proposed improvements.

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The proposed physical improvements for the ARP at the Lytle-Cajon Basin Project include the construction of 8 in-channel recharge basins, construction of 8 new surface transfer structures and low-level outlets/drains. Each of the basins should include the construction of remote level sensing and inflow/outflow metering. The following figures provide conceptual design views of the proposed improvements.

Figure 128: Lytle-Cajon Basins Conceptual Design (Plan View)

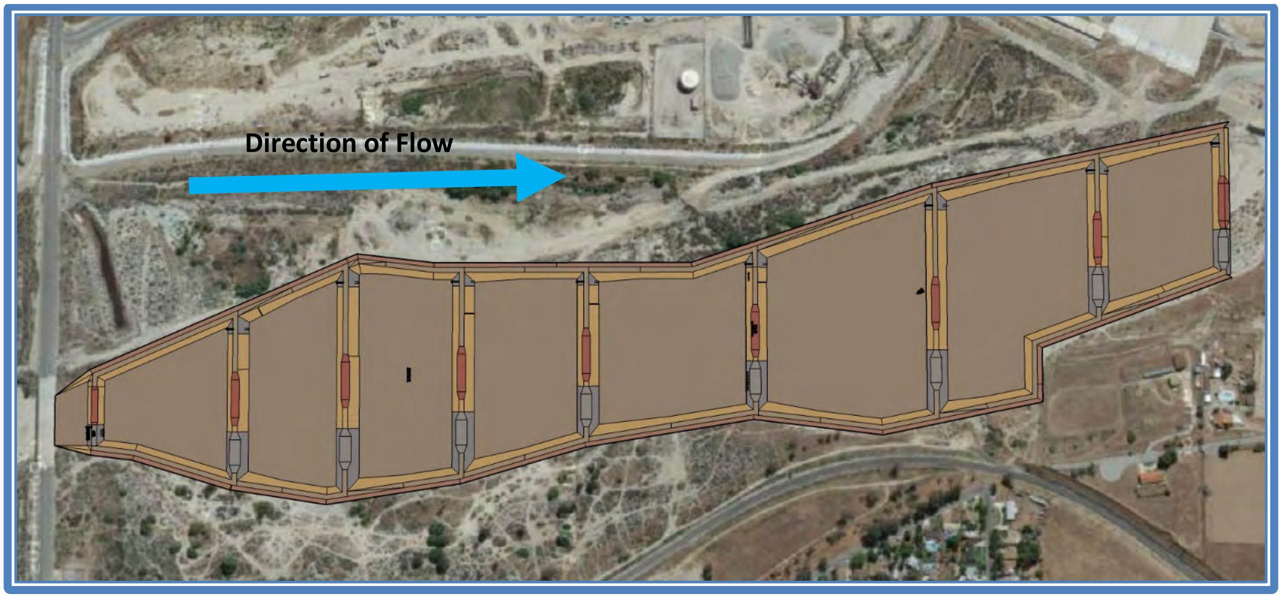

Figure 129: Lytle-Cajon Basins Conceptual Design (Basin 1 Inlet View)

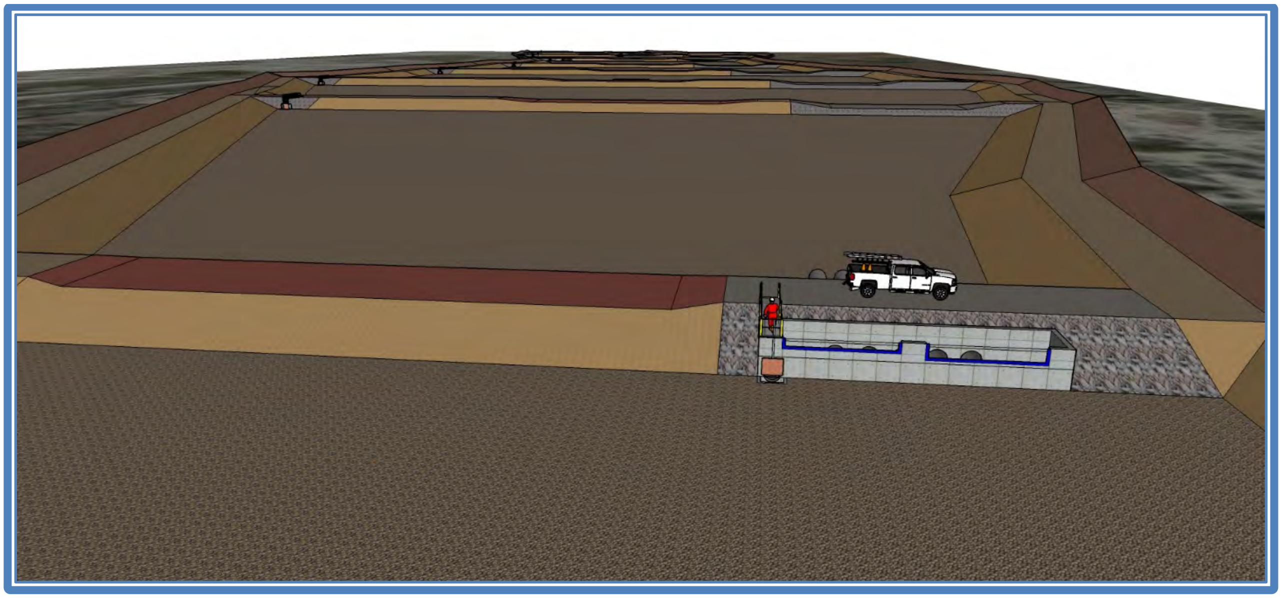

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Figure 130: Lytle-Cajon Basins Conceptual Design (Transfer View)

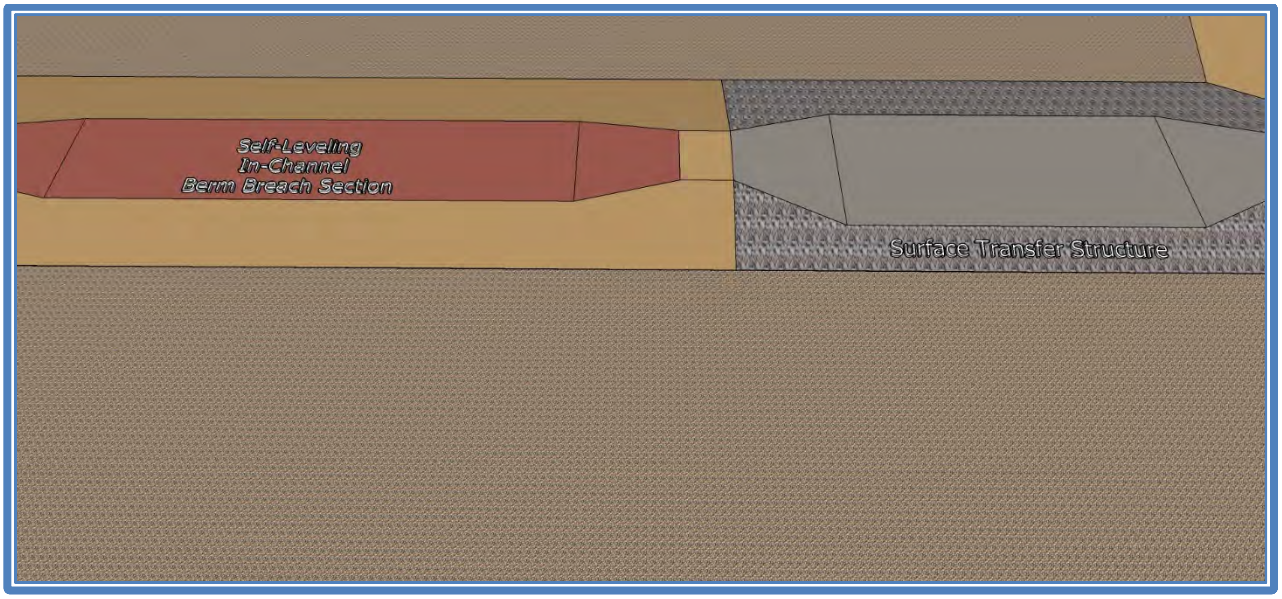
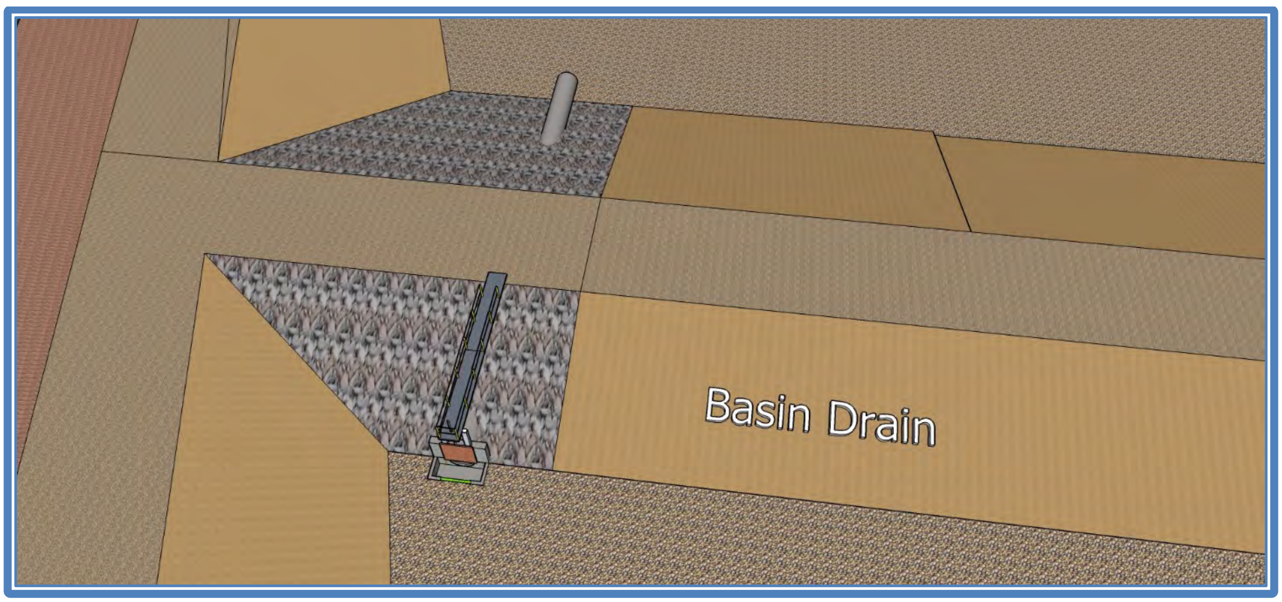


Figure 131: Lytle-Cajon Basins Conceptual Design (Basin Drain View)



Modeling Results & Design Optimization

A groundwater recharge operations model was developed to estimate the potential benefit due to the Lytle-Cajon Basin Project. The model assumptions used in the groundwater recharge operations model can be seen in Table 54.

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The available flows at the Lytle-Cajon Basin site used in the groundwater recharge operations model were from flow station 14. There was no limit set on the inflow rate from a groundwater recharge perspective because of the site's existing flow-through configuration.

Please note that only 1 example of a Lytle-Cajon Basin infiltration rate decay curve has been included in this report. The infiltration rate decay of the basins will vary with every storm event, and with the performance of each upstream basin. A sample 31 day flow series and the associated infiltration rate decay curve has been provided in Figure 133 and Figure 134 to illustrate how the infiltration rates may decay in the Lytle-Cajon Basins.

Table 54: Lytle-Cajon Basin Model Assumptions

Lytle-Cajon flow hydrograph	See Figure 132
Basin area and volume	Area = 43 acres, Volume = 244 af
Forebay area and volume	NA
Initial infiltration rates	3.2 ft/day
Infiltration rate decay parameters	See Figure 134 (using Figure 133 flow series)
Diversion flow capacity	NA
Basin berm wash-out flow rate	2,500 cfs
Diversion flow rate with dam deflated	NA

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Figure 132: Lytle-Cajon Basin Flows

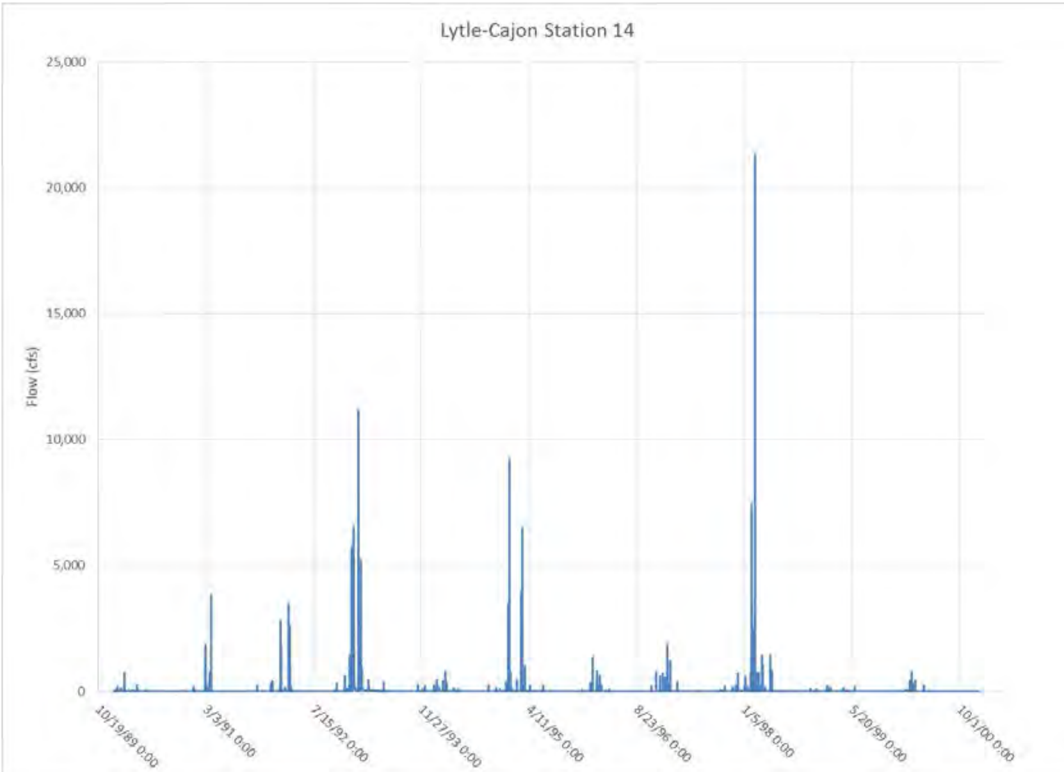

Figure 133: Lytle-Cajon Basin Infiltration Rate Decay Flow Series

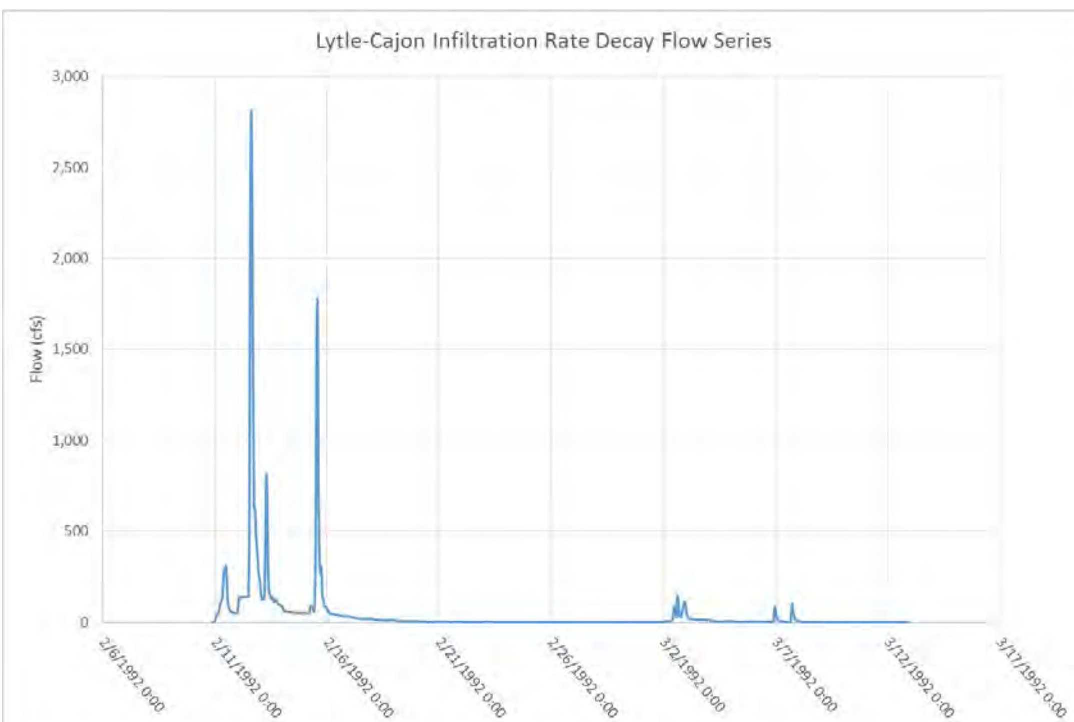

Figure 134: Lytle-Cajon Basin Infiltration Rate Decay

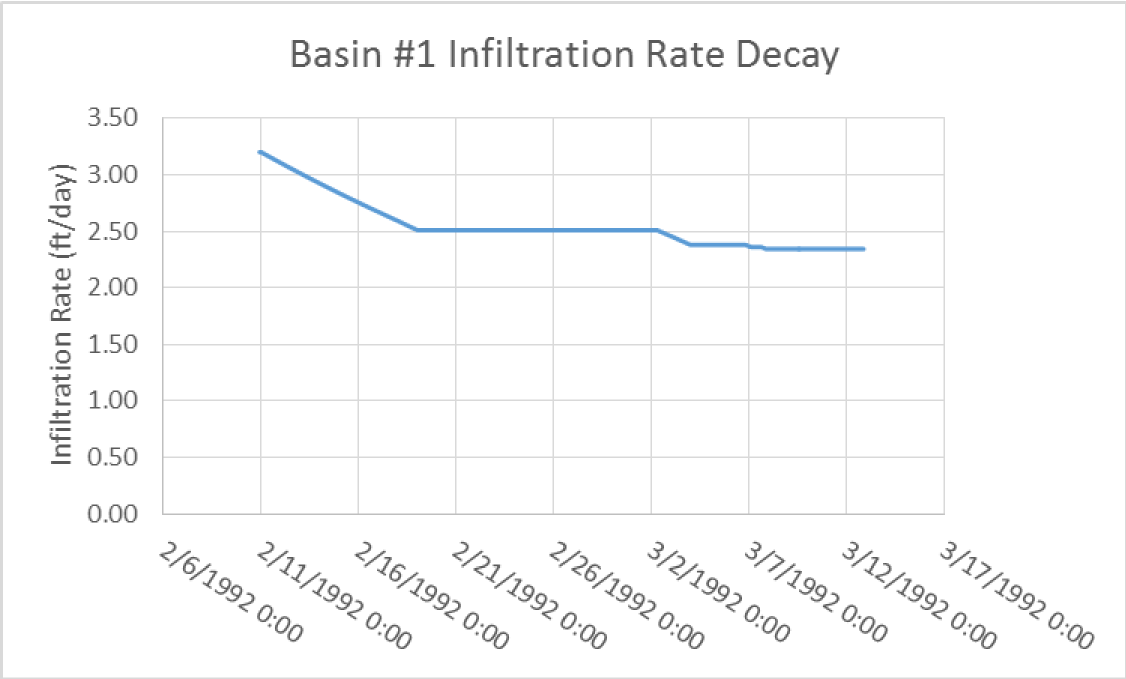

Figure 135: Lytle-Cajon Basin Diversion Optimization Results

NA

The 11 year flow series was modeled to predict the total amount of storm water captured and recharged during the model period. The final Lytle-Cajon Basin Project model results can be seen in Table 55.

Table 55: Lytle-Cajon Basin 11 Year Model Results

Total Available Flow (af)	108,401
Total Flow Captured & Recharged (af)	37,485
Total Flow Bypassed (af)	70,916
Annual Average Flow Captured & Recharged (af)	3,408

Operation & Maintenance

Operation of the proposed project will require operations personnel to visit the site occasionally during storm events to operate the drain tubes in advance of significant storm events.

Maintenance activities will include the removal of sediment, vegetation and debris from the basin areas. Regular maintenance will also be required on the low-level flow control gates, meters and basin level sensors. Based on infiltration rate decay trends observed in the groundwater recharge model it has been assumed that the basins will require 2 cleanings per year (on average) to sustain reasonable infiltration rates. The basin berms will also need to be rebuilt after they have been washed out due to high flow events. On average the berms will need to be re-built 1 time per year.

The groundwater recharge model provides an estimate of the overall amount of sediment that will deposit in the basins. The 11 year total, and annual average, sediment loading for the Twin Creek Spreading Grounds Project is presented in Table 56.

Table 56: Lytle-Cajon Basin Sedimentation Rates

	11 Year Total Sedimentation (cubic yards)	Annual Average Sedimentation (cubic yards)
Proposed Project	8,674	789

Cost Estimate

The following cost estimate includes design features that will maximize storm water capture and minimize the amount of time operators will need to be onsite. Project features have also been included that will allow for accurate performance monitoring and remote control of some system features. In order to equitably compare each project evaluated in this report, similar design features which provide comparable levels of service have been included in each conceptual design. Designing and constructing several projects at one time will provide additional economy for some project features such as permitting, SCADA, Strat-Up and Testing, and some material costs that can be purchased at reduced costs in bulk quantities. The total capital costs presented below may be reduced by %20 to %30 if some design features are omitted from the project. It should be noted that as design features are omitted there will be an increase in annual O&M costs and an increase to operations personnel level of effort to realize the project benefit.

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Table 57: Lytle-Cajon Basin Cost Estimate

Capital Costs			Lytle-Cajon Basin		
Bid Item #	Bid Item Description	Unit	Qty.	Unit Price	Total
1	Mobilization/Demobilization	L.S.	1	$ 200,000	$ 200,000
2	SWPPP	L.S.	1	$ 85,000	$ 85,000
3	Sheeting/Shoring/Bracing	L.S.	1	$ 25,000	$ 25,000
4	Survey	L.S.	1	$ 55,000	$ 55,000
5	Construction Water	L.S.	1	$ 110,000	$ 110,000
6	Temporary De-Watering	L.S.	1	$ 10,000	$ 10,000
7	Traffic Control	L.S.	1	$ 15,000	$ 15,000
8	Clearing & Grubbing	AC	92	$ 1,500	$ 138,000
9	On-Site Grading	Yd^3	375,000	$ 5	$ 1,875,000
10	Material Export	Yd^3	5,000	$ 12	$ 60,000
11	Finish Grading	AC	92	$ 300	$ 27,600
12	Access Roads	AC	5.5	$ 90,000	$ 495,000
13	Spillway Gate Foundation	L.F.	-	$ 12,000	$ -
14	Spillway Gate & Equipment	L.S.	-	$ 350,000	$ -
15	Spillway Downstream Grade Stabilizer	L.F.	-	$ 500	$ -
16	Diversion Structure	L.S.	-	$ 1,250,000	$ -
17	Trash Rack System (Automated)	L.S.	-	$ 1,500,000	$ -
18	Control Building	L.S.	1	$ 350,000	$ 350,000
19	Rip Rap Slopes	S.F.	105,000	$ 12	$ 1,260,000
20	Diversion Piping (60-inch dia. RCP)	L.F.	-	$ 500	$ -
21	Transfer Piping (42-inch dia. RCP)	L.F.	300	$ 450	$ 135,000
22	Basin Drain Piping (42-inch dia. RCP)	L.F.	680	$ 450	$ 306,000
23	InterCell Transfers & Drains	L.S.	-	$ 250,000	$ -
24	Overflow Spillway Rehab	L.S.	-	$ 250,000	$ -
25	Basin Outlet Structure	L.S.	8	$ 65,000	$ 520,000
26	Surface Transfer Structure (Weir)	L.S.	1	$ 850,000	$ 850,000
27	Outlet Energy Dissipaters	L.S.	9	$ 50,000	$ 450,000
28	Surface Transfer Rehab	L.S.	-	$ 125,000	$ -
29	60" Valves	L.S.	-	$ 45,000	$ -
30	42" Valves	L.S.	9	$ 40,000	$ 360,000
31	Catwalks	L.S.	9	$ 45,000	$ 405,000
32	Spillway Gate & Equipment Electrical	L.S.	-	$ 150,000	$ -
33	Flow Control Gate Electrical	L.S.	-	$ 500,000	$ -
34	Main Electrical To Site	L.S.	1	$ 450,000	$ 450,000
35	Creek Flow Meter	L.S.	1	$ 75,000	$ 75,000
36	SCADA	L.S.	1	$ 350,000	$ 350,000
37	Diversion Flow Meter	L.S.	-	$ 25,000	$ -
38	Low Flow Meter	L.S.	-	$ 20,000	$ -
39	Level Sensor	L.S.	9	$ 10,000	$ 90,000
40	Monitoring Well	L.S.	2	$ 75,000	$ 150,000
41	Start-Up & Testing	L.S.	1	$ 100,000	$ 100,000
42	Perimeter Fencing (Architectural)	L.F.	-	$ 100	$ -
43	Mitigation	AC	10.0	$ 25,000	$ 250,000
44	Property Acquisition	AC	-	$ 100,000	$ -
45	Permitting	L.S.	1	$ 85,000	$ 85,000
46	Utility Fees & Relocating Costs	L.S.	-	$ 500,000	$ -
47	Construction Management	%	5%		$ 447,330
48	Material Testing	%	0.5%		$ 44,733
49	Contingency	%	10%		$ 894,660
	Total Capital Costs				$ 10,668,323
	Annual Debt Service (5% @ 30 years)		0.06505		$ 693,974

Annual O&M Costs			Lytle-Cajon Basin		
	O&M Item Description	Unit	Qty.	Unit Price	Total
1	Spillway Gate	L.S.	-	$ 30,000	$ -
2	Diversion Head Works	L.S.	-	$ 15,000	$ -
3	Recharge Area	Day	30	$ 5,000	$ 150,000
4	Pipelines (1% of Const. Cost)	%	1.0%	$ 441,000	$ 4,410
5	Flowmeters, Level Sensors & SCADA	L.S.	1	$ 15,000	$ 15,000
6	Valve & Gates	L.S.	1	$ 35,000	$ 35,000
7	Fences, Access Roads & Control Building	L.S.	1	$ 15,000	$ 15,000
8	Basin Cleanings	Yd^3	26,889	$ 2	$ 53,778
9	Material Export	Yd^3	27,389	$ 12	$ 328,667
10	Electrical	L.S.	1	$ 10,000	$ 10,000
	Total Annual O&M Cost	$			$ 611,854

Project Benefit Summary			Lytle-Cajon Basin		
	Total Annual Project Cost	$			$ 1,305,829
	Average Annual Benefit	AF/YR			3,408
	Average Annual Recharge Unit Cost	$/AF			$ 383

Project Summary Table

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Table 58: Project Summary

Station Number	Project Site	Total Flow Available 11 Year (Acre-Feet)	Total New Flow Captured & Recharged 11 Year (Acre-Feet)	Average Annual Benefit (Acre-Feet)	Capital Cost	Annual Capital Cost (5%@30Years)	Annual O&M Cost	Total Annual Cost	Recharge Unit Cost ($/AF)
1	Mill Creek North 110 cfs	171,558	2,156	196	$ 2,237,002	$ 145,517	$ 68,750	$ 214,267	$ 1,093
1	Mill Creek North 210 cfs	171,558	9,752	887	$ 2,595,052	$ 168,808	$ 69,000	$ 237,808	$ 268
2	Plunge Creek 1	123,078	27,286	2,481	$ 10,900,345	$ 709,067	$ 180,537	$ 889,604	$ 359
2	Plunge Creek 2	95,792	11,555	1,050	$ 12,808,867	$ 833,217	$ 190,930	$ 1,024,146	$ 975
3	City Creek	87,424	57,713	5,247	$ 32,823,285	$ 2,135,155	$ 424,220	$ 2,559,374	$ 488
5	Waterman	34,192	18,421	1,675	$ 10,207,218	$ 663,980	$ 277,312	$ 941,292	$ 562
6	Twin Creek	77,698	44,956	4,087	$ 16,677,990	$ 1,084,903	$ 487,744	$ 1,572,648	$ 385
7	Lytle Creek	59,065	44,256	4,023	$ 14,685,038	$ 955,262	$ 249,336	$ 1,204,598	$ 299
8	Cable Creek	56,367	32,760	2,978	$ 24,520,683	$ 1,595,070	$ 359,974	$ 1,955,044	$ 656
10	Devil Creek	52,308	39,937	3,631	$ 23,768,911	$ 1,546,168	$ 358,086	$ 1,904,254	$ 524
11	Cajon Creek	25,586	13,533	1,230	$ 16,002,384	$ 1,040,955	$ 218,610	$ 1,259,565	$ 1,024
12	Cajon-Vulcan 1	58,502	15,902	1,446	$ 16,359,903	$ 1,064,212	$ 357,421	$ 1,421,633	$ 983
13	Vulcan 2	74,543	37,850	3,441	$ 31,221,404	$ 2,030,952	$ 255,531	$ 2,286,483	$ 664
14	Lytle-Cajon Creek	108,401	37,485	3,408	$ 10,668,323	$ 693,974	$ 611,854	$ 1,305,829	$ 383

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References

Geoscience; (dated January 10, 2012); Stormwater Flow and Capture Analysis - Active Recharge Project for the Tributaries of the Santa Ana River, San Bernardino Valley, California DRAFT

San Bernardino County Flood Control District; (dated October, 2014); Flood Control System Number Index and General File Codes

USGS; (dates accessed November 2015 through March 2016); Access to online flow and suspended sediment concentration data for various stations near project areas, http://waterdata.usgs.gov

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