VII. EVALUATING WATERSHED STORMWATER IMPROVEMENTS

The assessment of existing conditions in the Sausal Creek watershed demonstrated that changing the volume and timing of stormwater entering the creek system could reduce the negative effects of urbanization on the aquatic and riparian system.

These conditions include:

- High levels of impervious surfaces (asphalt, cement, buildings) resulting in reduced infiltration of rainfall and increased runoff volumes over a shorter period of time.
- Small increments of rainfall produce larger runoff volumes. For example, a storm event with 0.5 inches of rainfall in a 24-hour period can generate a significant level of runoff.
- Poor habitat conditions for aquatic insects in Sausal Creek but good conditions in Palo Seco Creek, a largely undeveloped tributary basin.
- Frequent runoff events (1-year frequency) are capable of scouring the creek, moving gravel and reducing the ability of the creek to support aquatic insects and aquatic habitats.
- Channel entrenchment and the lack of functional floodplain limits riparian corridors to a narrow width and removes natural regeneration and ecological successional processes.
- Numerous erosion sites from storm drain outlets and erosion in many small creeks in the upper watershed.

The watershed was reviewed for locations where stormwater could be detained or temporarily held and released slowly to reduce the volume of peak flows in Sausal Creek. Figures 110 and 111 depict the locations of a series of watershed improvements. These figures also depict seasonal or intermittent creeks and perennial creeks with one shade of blue and ephemeral or temporary creeks in a different shade of blue. Seasonal/perennial creeks appear as “blue lines” on U.S. Geologic Survey topographic maps while ephemeral creeks are not indicated with blue lines due to the very short period of flow. Ephemeral creeks are delineated using topographic contours.

PARKING LOT DETENTION

Large parking lots were reviewed in the field and measured to determine the volume of water potentially detained on the site. These sites include:

- Chabot Space & Science Center: 2 large parking lots which discharge directly into Joaquin Miller Park and have erosion at their outlets;
- Small parking area at the Metropolitan Horseman’s Association building on Skyline Boulevard
- Joaquin Miller Elementary School/Montara Middle School: large parking lots and fields. This site is constructed on fill in the channel of Cobbledick Creek and may also be appropriate for an underground water storage tank or cistern. The cistern was not included as this is the only large creek fill site with buildings on it and therefore would require considerable disturbance to install a cistern.
- Montclair shopping area parking lot: This small site is near the corner of Mountain Blvd. and Scout Rd.
- Zion Lutheran Church parking lot: This site is just off Park Blvd. near Highway 13.
- Joaquin Miller Park parking lots 1 and 2: These are near the Community Center and Native Plant Nursery.
- Fruitvale commercial areas near the intersection of Fruitvale and Coloma streets and Fruitvale and Montana streets. These four large parking lots drain directly into Sausal Creek.

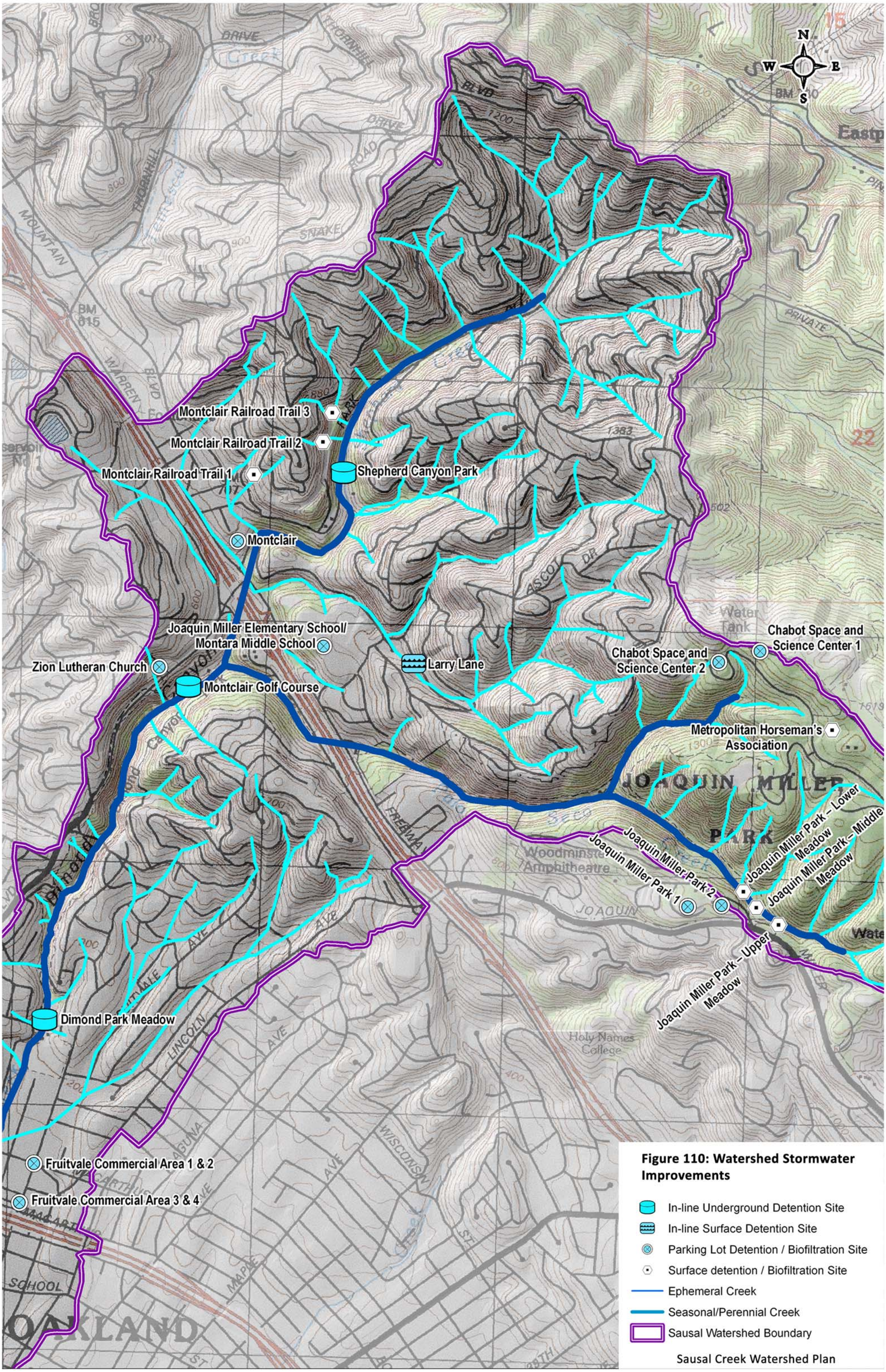


Figure 110: Watershed Stormwater Improvements

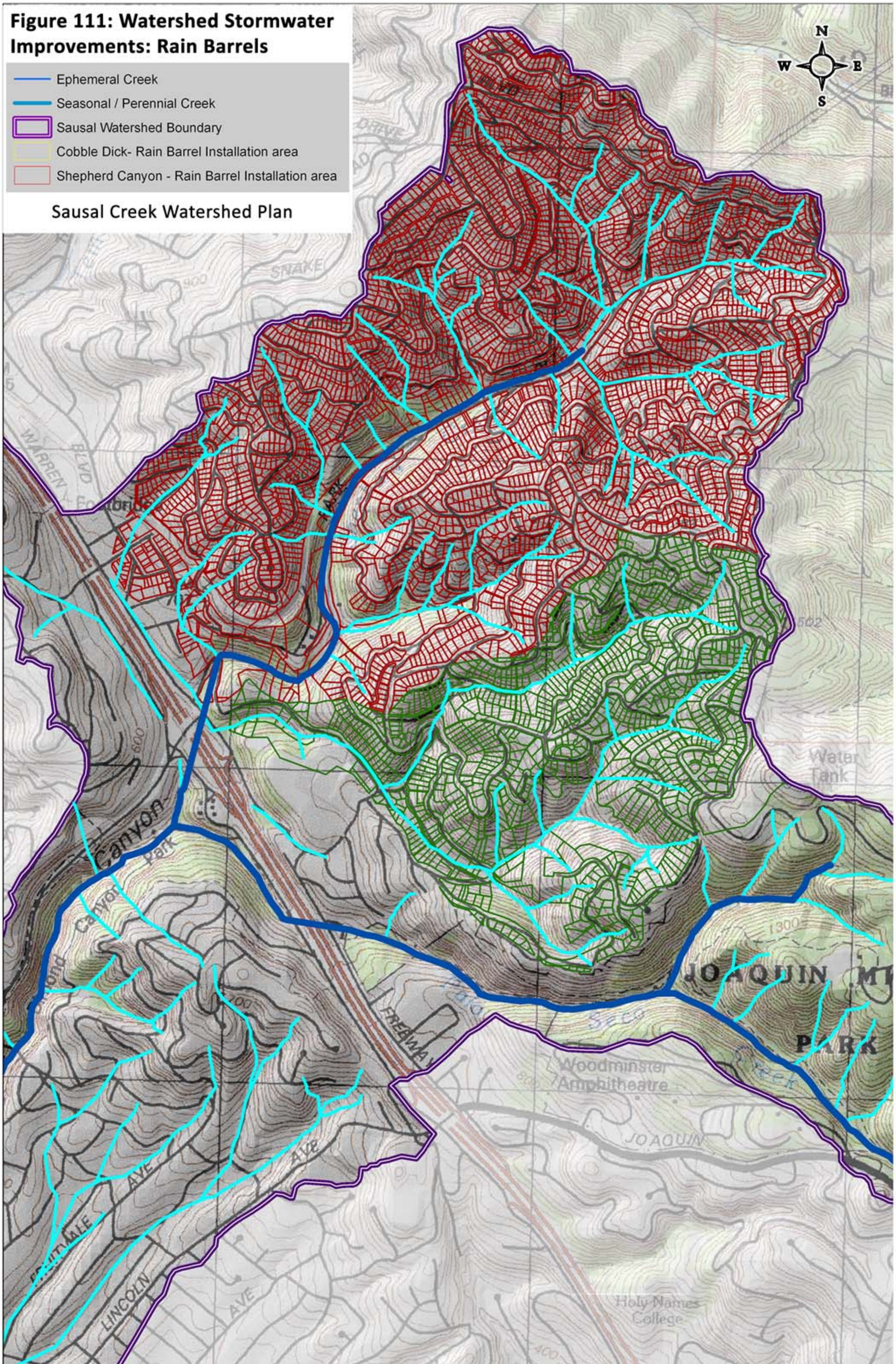


Figure 111: Watershed Stormwater Improvements: Rain Barrels

UNDERGROUND CISTERN DETENTION

Three large creek channels that have been filled with dirt and culverts installed for the creek—Shepherd Canyon Park, Montclair Golf Course, and the Dimond Park field—were reviewed for installation of a water storage tank or cistern in place of a portion of the fill. The creek would pass through the cistern where water would be detained for a while (Figure 112).

Park Detention/Recreation Areas

The meadow areas in Joaquin Miller Park were analyzed as detention basins enclosed by berms that would hold water for a short period after rainstorms but be dry most of the time. This multipurpose use of this meadow allows both environmental and recreational use.

Basins on Creeks

Along the Montclair Railroad Trail, which follows the original railroad grade, there are three small basins. These basins are ephemeral creek swales which have been dammed by the railroad berm. Currently, none of them have an outlet and one swale shows signs of having overflowed and eroded the hillside below the trail. Each basin could be engineered to temporarily hold water, but also have a facility to release flows and avoid overflows. These basins could also serve as sediment basins for adjacent erosion; however, annual maintenance would be required for the detention function to work.

The Cobbledick Creek tributary bordering Larry Lane has a sediment/water detention basin with a standpipe (Figure 57). This site needs to be maintained by clearing accumulated sediment from the basin but could serve as a detention facility.

Rain Barrels

Another option is dispersed stormwater detention facilities using rain barrels installed at each house in the Shepherd and Cobbledick Creek sub-basins. Each barrel would be able to catch 75 gallons of runoff from the roof of a single home (Figure 113). Water is released from the barrel slowly or can be used in gardens.

Biofiltration

An additional water quality benefit can be gained through the installation of biofiltration facilities in the parking lots (Figure 114). Parking lots concentrate oil and grease residues, a persistent pollutant in urban stormwater. With the use of biofiltration facilities, stormwater runs off the parking lot and into biofiltration units before entering the storm drain. Each biofiltration facility has a surface mulch layer which catches particles. Shredded hardwood, pine bark, tree chips, or coarse peat moss are typical mulch materials. Leaf or grass compost is not recommended. Stormwater is directed into the biofiltration facility through a curb cut in the parking lot. Floatable trash is caught on the surface of the device. As the stormwater filters through the mulch layer, trash and particulates are caught. Beneath the mulch are rapid infiltration layers of coarse sand and gravel. It is important to limit clay and silt in this layer to less than five percent of the total volume. At the base is an underdrain which takes the

Figure 112: Water cistern is placed underground to hold stormwater runoff temporarily to reduce downstream effects.

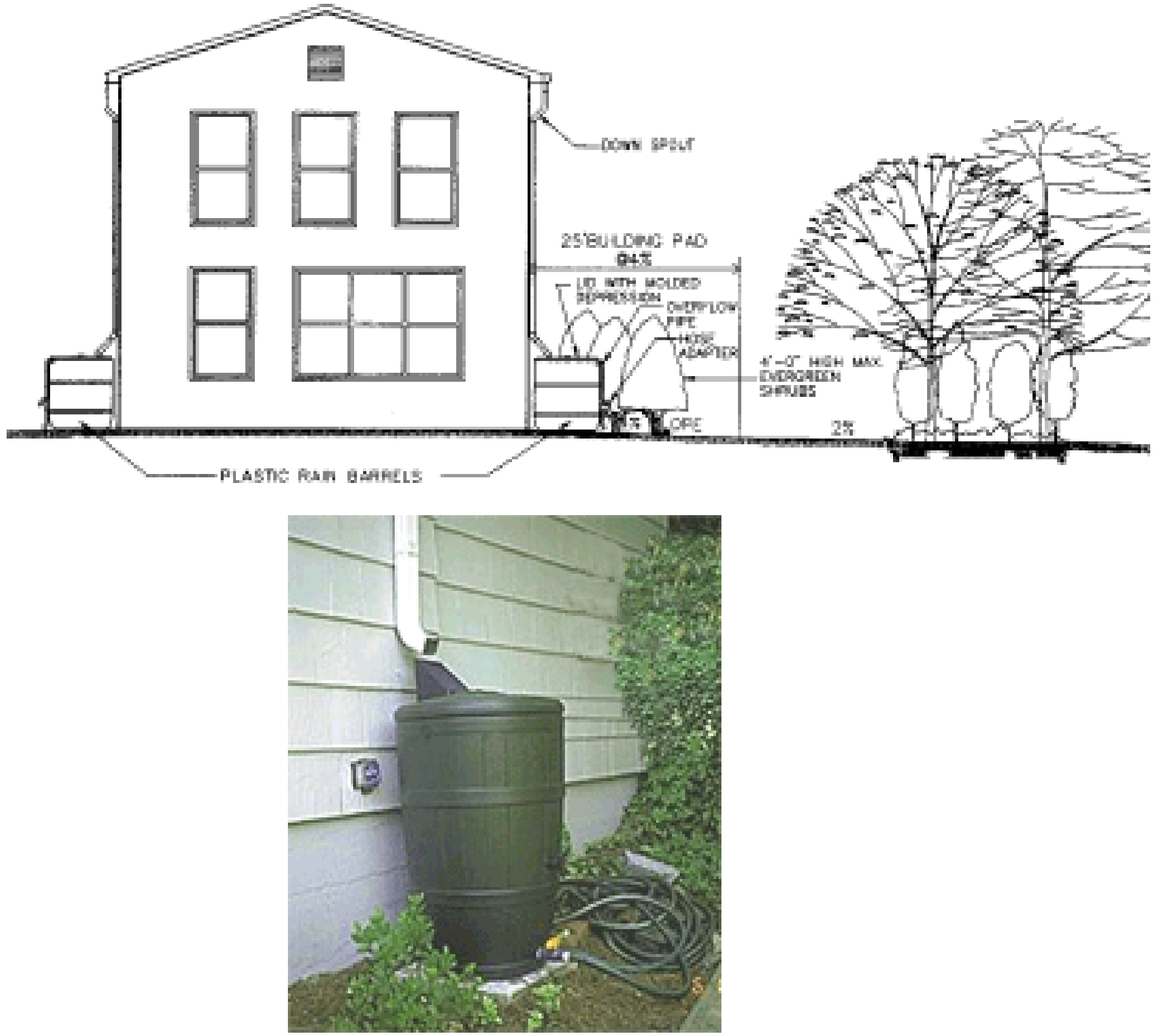


Figure 113: Rain barrels are used in many locations to collect runoff from roof areas for use in garden watering.

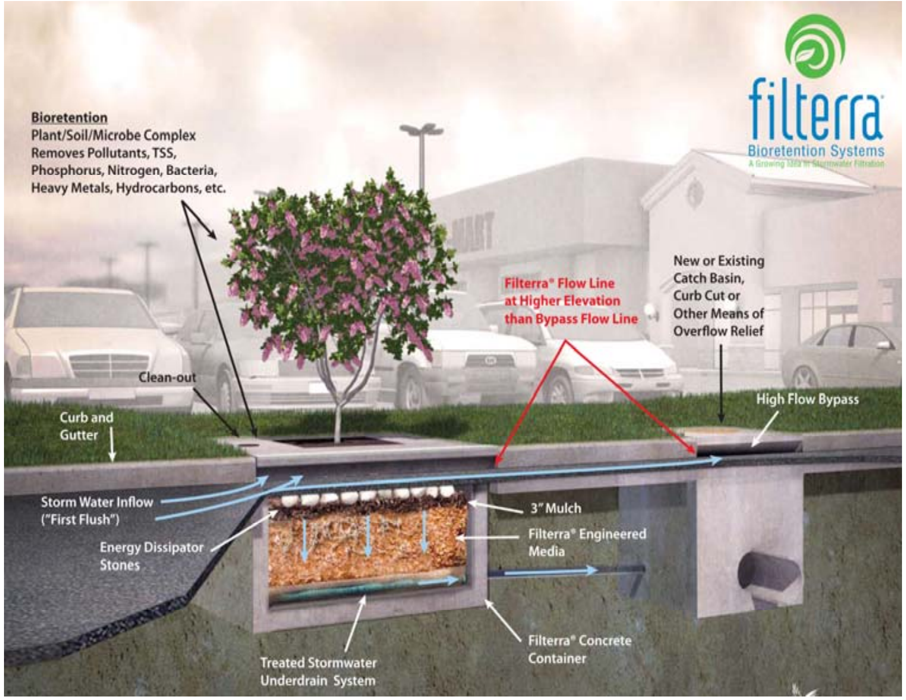


Figure 114: Biofiltration units for parking lots

filtered water to the storm drain system. It is also possible to infiltrate the filtered water if soil types and groundwater levels are appropriate. Each facility has plants, trees, shrubs, and low-growing herbs or rushes which are part of the filtration system. As nutrients such as nitrate fertilizers are filtered out, the plant roots uptake these materials. There needs to be a large number of these small facilities distributed over the drainage in order to have an impact on pollutant levels.

In addition to parking lots there are a number of roads with large turnouts where biofiltration facilities can be installed (Figure 115). Skyline Blvd. in the Sausal Creek watershed has a number of pullouts on the in-sloping side of the roadway where a storm drain inlet is located. A biofiltration unit can be installed around the inlet to reduce pollutants in the stormwater. Park Blvd. along Dimond Canyon also has a number of pullouts which could support biofiltration facilities. Leimert Ave. may also have adequate areas for biofiltration. There are numerous other locations where on-street parking could be changed to accommodate biofiltration facilities where storm drain inlets occur. The runoff from freeways also could be treated by installing biofiltration facilities. Downstream of I-580 in the intensely urbanized area of the watershed, biofiltration units can be installed along streets and sidewalks.

In other cities, the installation of biofiltration facilities has been done to beautify residential and commercial areas. The neighborhoods bordering Fruitvale Ave. just above and below Interstate 580 are relatively flat and have wide enough streets and sidewalks for biofiltration facilities. There are numerous other areas where biofiltration can be installed in the watershed and should be considered. The narrow width of many streets in the upper watershed may limit installation in these areas. Figures 116-119 show examples of biofiltration facilities from Seattle and Portland.

The San Francisco Bay Regional Water Quality Control Board recommends a minimum five inch per hour infiltration rate for these facilities and a minimum of 18 inches of media for filtration. The biofilters can accommodate a certain volume of runoff during rainstorms. When runoff volumes are high, a percentage of the stormwater flow bypasses the filters and directly enters the storm drain system. Most biofiltration facilities also have cleanout/observation wells.

Other Measures

Additional practices could be incorporated into the Sausal Creek watershed to reduce runoff. One is the use of porous pavement (Figure 120). Residential driveways, commercial and industrial area landscaping, walkways, and even parking lots can use paving stones set over base rock and sand which provide for infiltration of stormwater instead of runoff. Porous pavement can be incorporated into landscaping using biofiltration measures and rain gardens but is limited in use on steep slopes. Rain gardens can be built at the outlets of roof and gutter systems.

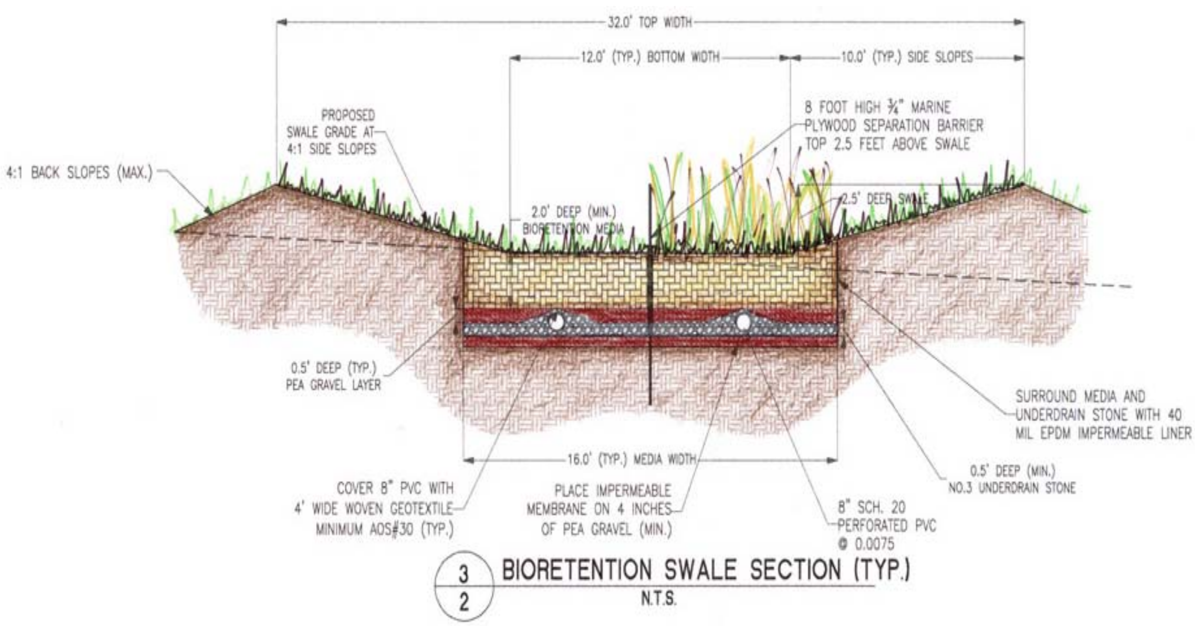


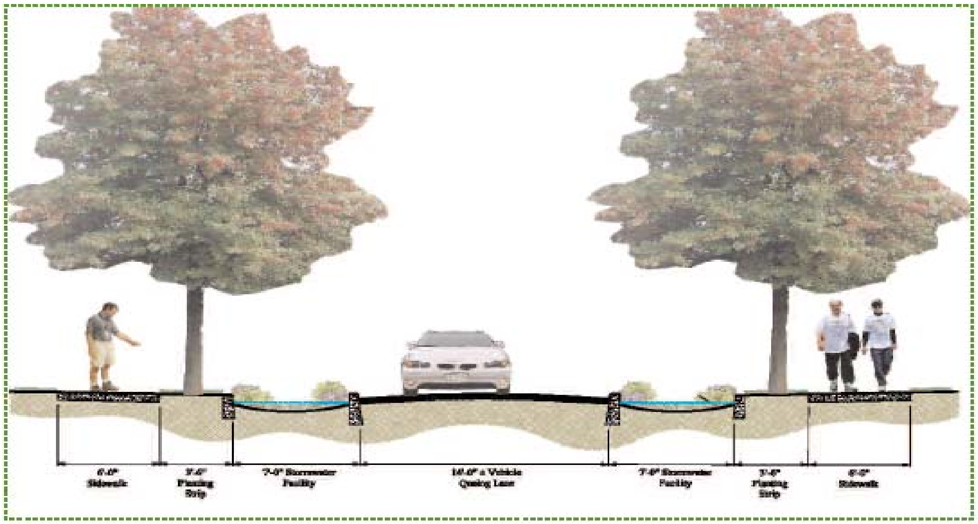
Figure 115: Top: Location along Skyline Blvd. where a biofiltration facility could be installed to improve water quality. Bottom: Drawing of bioretention facility which is defined as filtering storm water through a terrestrial aerobic plant/soil/microbe complex to capture, remove and cycle pollutants through a variety of physical, chemical and biological processes

▲ NE Siskiyou Green Street stormwater curb extension

Landscaped Storm water Curb Extensions: Historically Portland has built curb extensions to improve pedestrian safety. A new variation called a storm water curb extension is landscaped with plants that help filter pollutants from storm water runoff. They have similar benefits to the conventional curb extension but they also improve water quality, reduce storm water flow, and look good.

Portland

Stormwater slows as it enters the landscape area, water soaks into the ground, and wetland plants filter pollutants. ▼



▲ Typical Section of NE Siskiyou Street

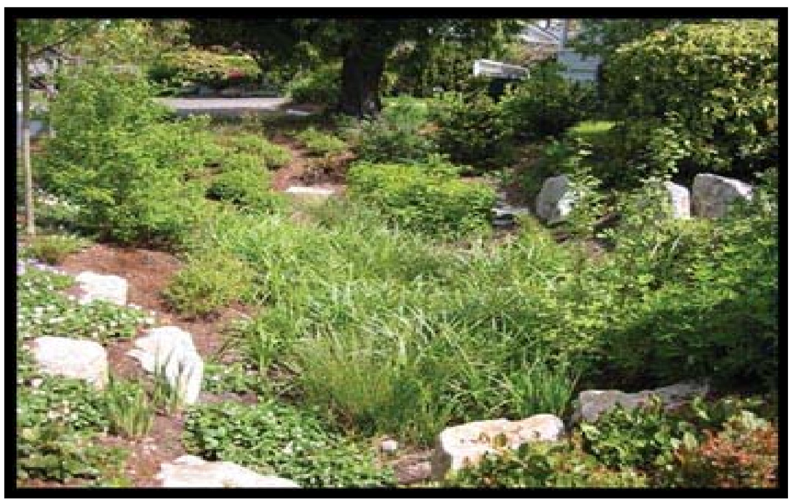
Figure 116: Biofiltration improvements in residential areas of Portland, Oregon. These filtration areas take storm water from streets through a curb cut and return the filtered water into the storm drain system.

Figure 117: Bioswales on the edges of parking lots.

Portland

Figure 118: Biofiltration units in commercial area of Portland, Oregon.

Natural materials—plants and soils—slow, filter, and infiltrate storm water runoff… all within the space of the public right-of-way



A combination of soils and plants to filter storm water and allow it to seep into the ground as it washes off the roadway and parking spaces.

Seattle

Calm traffic by narrowing and curving the roadway; provide adequate parking for residents and guests; ensure safe access for emergency vehicles, bicycles and pedestrians

Figure 119: Examples of biofiltration facilities in residential areas of Seattle.

Figure 120: Permeable pavement allows water to infiltrate into the ground through the spaces between the blocks filled with fine rock. Two layers of rock below the pavers provide a strong base for the street and help the infiltration process. Geotextile fabric layers below the base rock further reduce pollutants carried into the soil as the water infiltrates

downspouts. They provide a rock dissipater or stilling basin and biofiltration to treat the runoff depending on the site. Grass or bioswales are wide vegetated channels that allow stormwater to flow through and deposit particulates and infiltrate before leaving the site (Figure 118).

These practices can remove pollutants and reduce the volume of runoff reaching creeks. The application of these measures to individual home sites, however, needs to consider the slope and soil types of the site. Information on these BMPs is available at a number of websites listed in Table 52.

Table 52: Low Impact Development (LID) and Urban BMP Resources

Resource	Web Address
EPA: Urban BMP Performance Tool	http://cfpub.epa.gov/npdes/stormwater/urbanbmp/bmpeffectiveness.cfm
EPA: Low Impact Development (LID)	http://epa.gov/nps/lid/
Low Impact Development Center	http://www.lowimpactdevelopment.org
Low Impact Development (LID) Urban Design Tools Website	http://www.lid-stormwater.net/
California Stormwater Quality Association: Stormwater Best Management Practice (BMPs) Handbooks	http://www.cabmphandbooks.com/
The Stormwater Manager's Resource Center (SMRC): Bioretention	http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Filtering%20Practice/Bioretention.htm
University of Rhode Island: Healthy Landscapes	http://www.uri.edu/ce/healthylandscapes/index.html
Interlocking Concrete Pavement Institute: Permeable Pavement	http://icpi.org/design/permeable_pavers.cfm
Rain Gardens of West Michigan	http://www.raingardens.org/Index.php
Filterra Bioretention Systems	http://www.filterra.com/ -

EVALUATING WATERSHED IMPROVEMENTS WITH HYDROLOGIC AND HYDRAULIC MODELS

For the hydrology and hydraulics analysis, a subset of the watershed improvements that have the potential to significantly alter hydrologic and hydraulic processes in the watershed were modeled using the SWMM hydrologic model and the HEC-RAS hydraulic model. These improvements are listed in Table 53 and their locations displayed in Figures 110 and 111. For modeling and assessment purposes, assumptions were made in terms of the physical dimensions, amount of storage each facility could achieve, available capture volume, infiltration rates of the facilities, and overflow devices such as the sizing and placement of weirs and orifices. These details are outlined in Table 54.

The watershed improvements were grouped into specific scenarios for the modeling runs, with each scenario then compared to existing conditions. Scenario 1 includes all of the surface detention sites. Scenario 2 includes all of the facilities in Scenario 1 and adds two in-line detention sites or basin/cistern sites in the upper watershed. Scenario 3 includes all of the facilities from Scenarios 1 and 2 and adds two in-line detention sites/cisterns in the lower watershed. These scenarios are listed in the following table.

Table 53: Sausal Creek Watershed Stormwater Improvement Sites

Improvement	Scenario 1	Scenario 2	Scenario 3
Rain barrel at each house in the Shephard and Cobbledick Creek sub-basins	✓	✓	✓
Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 1	✓	✓	✓
Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 2	✓	✓	✓
Joaquin Miller Elementary School/Montara Middle School Parking Lot Detention and Biofiltration Site	✓	✓	✓
Montclair Parking Lot Detention and Biofiltration Site	✓	✓	✓
Joaquin Miller Park Parking Lot Detention and Biofiltration Site 1	✓	✓	✓
Joaquin Miller Park Parking Lot Detention and Biofiltration Site 2	✓	✓	✓
Zion Lutheran Church Parking Lot Detention and Biofiltration Site	✓	✓	✓
Montclair Railroad Trail – Stormwater Detention Basin 1	✓	✓	✓
Montclair Railroad Trail – Stormwater Detention Basin 2	✓	✓	✓

Table 53: Sausal Creek Watershed Stormwater Improvement Sites

Improvement	Scenario 1	Scenario 2	Scenario 3
Montclair Railroad Trail – Stormwater Detention Basin 3	✓	✓	✓
Joaquin Miller Park – Upper Meadow Detention Site	✓	✓	✓
Joaquin Miller Park – Middle Meadow Detention Site	✓	✓	✓
Joaquin Miller Park – Lower Meadow Detention Site	✓	✓	✓
Metropolitan Horseman's Association Parking Lot Detention and Biofiltration Site	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 1	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 2	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 3	✓	✓	✓
Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 4	✓	✓	✓
Shepherd Canyon Park – Underground Cistern		✓	✓
Larry Lane On-stream Detention Pond		✓	✓
Montclair Golf Course – Underground Cistern			✓
Dimond Park Meadow – Underground Cistern			✓

Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis

Tributary Watershed	Sub-basin ID	Scenario	Location	Stormwater BMP	Assumptions	Capturing Drainage Area (ft^2)	Detention Basin Footprint (ft^2)	Detention Basin Berm Height / Cistern Max Depth (ft)	Number of Barrels Per Basin (1 Per Parcel)	Achieved Maximum Storage Volume (ft^3)
Shephard Creek	In-line storage	2	Shepherd Canyon Park	Subsurface cistern	Available average subsurface depth of cistern is 6 ft., 25% of the footprint of park considered for subsurface detention	Shephard Creek sub-basin upstream of park	32,100	6	N/A	192,600
Shephard Creek	SC-13	1	Bike trail Detention Basin 1	Detention site	Surface facility with a berm, will capture upstream runoff	96,703	2,325	12.5	N/A	29,063
Shephard Creek	SC-10	1	Bike trail Detention Basin 2	Detention site	Surface facility with a berm, will capture upstream runoff	83,200	6,000	15	N/A	90,000
Shephard Creek	SC-10	1	Bike trail Detention Basin 3	Detention site	Surface facility with a berm, will capture upstream runoff	308,405	8,640	12	N/A	103,680
Shephard Creek	SC-13	1	Montclair parking lot at Scout Rd. / Mountain Blvd.	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas, includes runoff from rooftops of adjacent commercial buildings, slope of .01%	81,800	8,180	3	N/A	24,540

Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis

Tributary Watershed	Sub-basin ID	Scenario	Location	Stormwater BMP	Assumptions	Capturing Drainage Area (ft^2)	Detention Basin Footprint (ft^2)	Detention Basin Berm Height / Cistern Max Depth (ft)	Number of Barrels Per Basin (1 Per Parcel)	Achieved Maximum Storage Volume (ft^3)
Shephard Creek	Dispersed in SC-0, SC-1, SC-2, SC-3, SC-4, SC-5, SC-6, SC-7, SC-8, SC-9, SC-10, SC-11, SC-12, SC-13	1	Per parcel	Rain Barrels	1 rain barrel per parcel, assume maximum efficiency, assume 75 gallon capacity, assume 2,116 parcels in Shephard Creek tributary watershed, and 151.1 parcels per sub-basin	Varies	505	3	2,116	21,160
Cobbledick Creek	In-line storage C-3, C-4	2	Larry Lane on-stream pond	Surface detention site	Surface detention pond with a dam, in-line with Cobbledick Creek channel, will capture flow from upstream watershed	Tributary to Cobbledick Creek sub-basin upstream of Larry Lane	5,400	12.5	N/A	67,500
Cobbledick Creek	DC-2	1	Joaquin Miller Elementary/Montara Middle School parking lot	Parking lot detention basin / biofiltration	Will provide detention for max 24-hour runoff during 5-yr event, includes runoff from rooftops of school buildings, walkways, and asphalt playground	524,400	33,803	5	N/A	169,015

Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis

Tributary Watershed	Sub-basin ID	Scenario	Location	Stormwater BMP	Assumptions	Capturing Drainage Area (ft^2)	Detention Basin Footprint (ft^2)	Detention Basin Berm Height / Cistern Max Depth (ft)	Number of Barrels Per Basin (1 Per Parcel)	Achieved Maximum Storage Volume (ft^3)
Cobbledick Creek	Dispersed in C-1, C-2, C-3, C-4, C-5	1	Per parcel	Rain Barrels	1 rain barrel per parcel, assume maximum efficiency, assume 75 gallon capacity, assume 732 parcels in Cobbledick Creek tributary watershed, and 146.4 parcels per sub-basin	N/A	489	3	732	7,320
Palo Seco Creek	PS-1	1	Chabot Space & Science Center parking lot 1	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	16,350	1,635	5	N/A	8,175
Palo Seco Creek	PS-1	1	Chabot Space & Science Center parking lot 2	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	46,810	4,681	5	N/A	23,405
Palo Seco Creek	PS-1	1	Metropolitan Horseman's Association parking lot	Parking lot detention basin / biofiltration	Surface facility with a berm, will capture upstream runoff	305,300	45,800	15	N/A	687,000
Palo Seco Creek	PS-3	1	Joaquin Miller Park parking lot 1	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	71,260	7,126	5	N/A	35,630
Palo Seco Creek	PS-3	1	Joaquin Miller Park parking lot 2	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	31,290	3,129	5	N/A	15,645

Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis

Tributary Watershed	Sub-basin ID	Scenario	Location	Stormwater BMP	Assumptions	Capturing Drainage Area (ft^2)	Detention Basin Footprint (ft^2)	Detention Basin Berm Height / Cistern Max Depth (ft)	Number of Barrels Per Basin (1 Per Parcel)	Achieved Maximum Storage Volume (ft^3)
Palo Seco Creek	PS-2	1	Joaquin Miller Park –Upper Meadow	Detention site	Add berms to provide detention	3,843,185	4,685	15	N/A	70,275
Palo Seco Creek	PS-2	1	Joaquin Miller Park – Middle Meadow	Detention site	Add berms to provide detention	6,424,863	19,810	15	N/A	297,150
Palo Seco Creek	PS-3	1	Joaquin Miller Park Lower Meadow	Detention site	Add berms to provide detention	6,424,863	30,680	15	N/A	460,200
Sausal Creek	In-line storage	3	Montclair Golf Course	Subsurface cistern / detention	Available average subsurface depth of cistern is 10 ft., 50% of the footprint of area available for subsurface detention	Sausal Creek watershed upstream of golf course	57,800	10	N/A	578,000
Sausal Creek	DC-3	1	Zion Lutheran Church parking lot	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	55,970	5,597	5	N/A	27,985
Sausal Creek	In-line storage	3	Dimond Canyon Park lawn area	Subsurface cistern / detention	Available average subsurface depth of cistern is 6 ft., 75% of the footprint of park available for subsurface detention	Sausal Creek basin upstream of Dimond Park	86,700	6	N/A	520,200

Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis

Tributary Watershed	Sub-basin ID	Scenario	Location	Stormwater BMP	Assumptions	Capturing Drainage Area (ft^2)	Detention Basin Footprint (ft^2)	Detention Basin Berm Height / Cistern Max Depth (ft)	Number of Barrels Per Basin (1 Per Parcel)	Achieved Maximum Storage Volume (ft^3)
Sausal Creek	DC-6	1	Fruitvale / Macarthur intersection commercial area parking lot site 1	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	132,500	13,250	5	N/A	66,250
Sausal Creek	DC-6	1	Fruitvale / Macarthur intersection commercial area parking lot site 2	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	177,000	17,700	5	N/A	88,500
Sausal Creek	DC-6	1	Fruitvale / Macarthur intersection commercial area parking lot site 3	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	71,280	7,128	5	N/A	35,640
Sausal Creek	DC-6	1	Fruitvale / Macarthur intersection commercial area parking lot site 4	Parking lot detention basin / biofiltration	Will provide detention for adjacent impervious areas	51,280	5,128	5	N/A	25,640

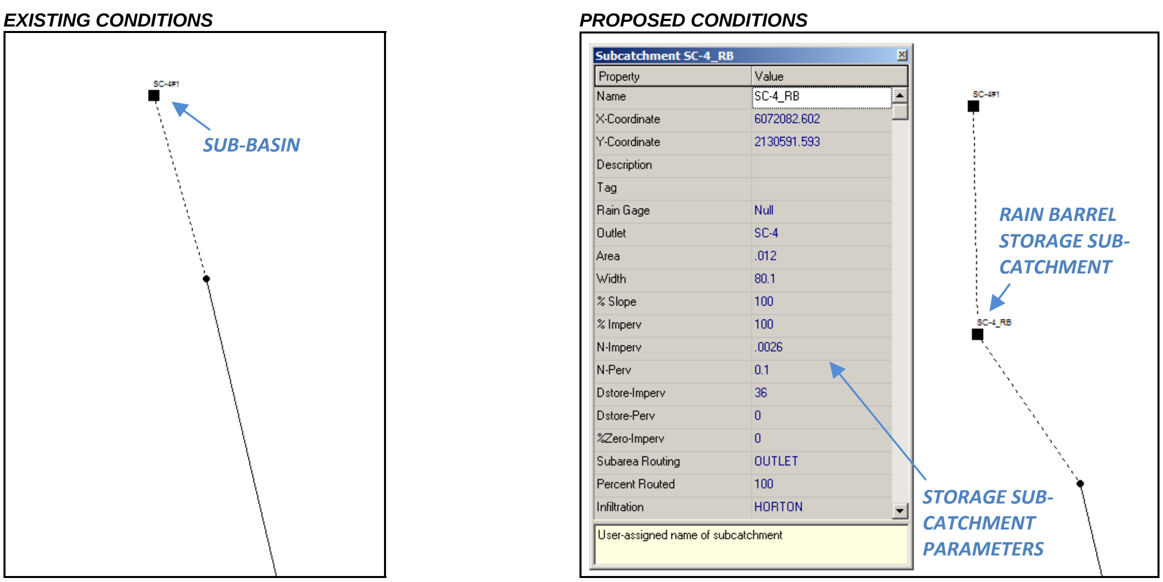
Hydrologic Model

The Sausal Creek existing conditions SWMM model was used as a baseline framework, with proposed improvements “added on” as follows:

Scenario 1

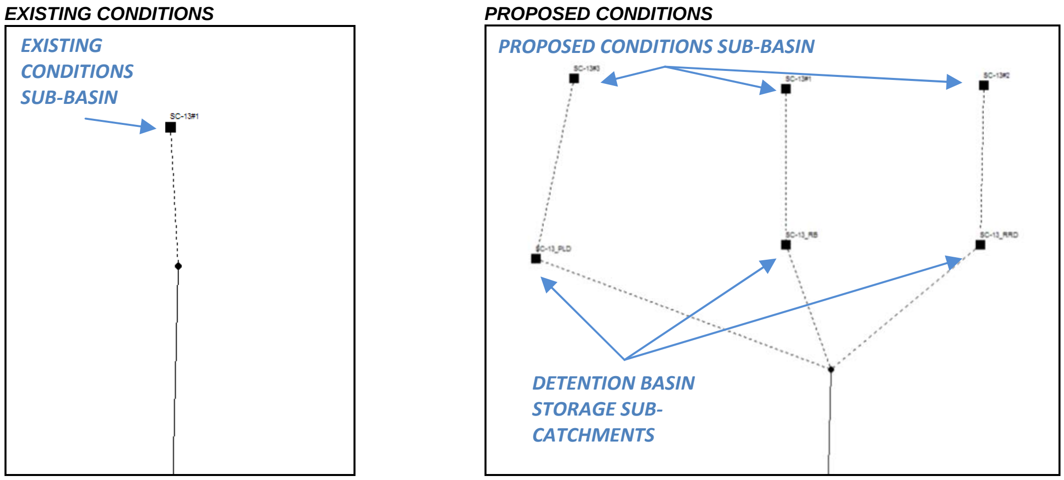
Rain barrels: An analysis of the number of parcels with a housing unit or structure in the Shephard and Cobbledick Creek watersheds was performed using current parcel GIS data from the City of Oakland. Under this improvement, one house could have numerous rain barrels, while other residents did not participate in the program. It was assumed that each housing unit would receive an average of one 75-gallon overflow rain barrel. From this analysis, a total number of rain barrels for each watershed was calculated, and then divided by the total number of sub-basins in each watershed to obtain a number of barrels for each sub-basin. Finally, a total rain barrel storage volume was calculated for each sub-basin. In the SWMM model, the rain barrels were simulated by adding an additional sub-basin to act as a storage node for the rain barrels. These “storage sub-basin” include a depression in the impervious area with a storage capacity equal to that of the total rain barrel storage volume; water is collected in the depression and the residual water is treated as overflow and routed towards the outlet (Figure 122). Sub-basin parameters were adjusted to mimic the performance of an overflowing rain barrel according to guidance from Aad (2009) on modeling green infrastructure using SWMM.

Figure 121: Existing Conditions and Proposed Conditions Demonstrating the Rain Barrel Modeling Technique in EPA SWMM 5.0



Parking lot detention and other watershed detention sites: For the sites that capture overland flow and shallow concentrated flow from adjacent impervious surfaces such as parking lots, rooftops, and sidewalks in a designated sub-basin, additional sub-basins were created that model these drainage areas. “Storage sub-basins” were then developed to model the storage capacities of the individual facilities, in a similar manner as described above (Figure 123). Storage facility dimensions were calculated by measuring available areas from aerial photographs in ESRI ArcMap and by taking field survey measurements.

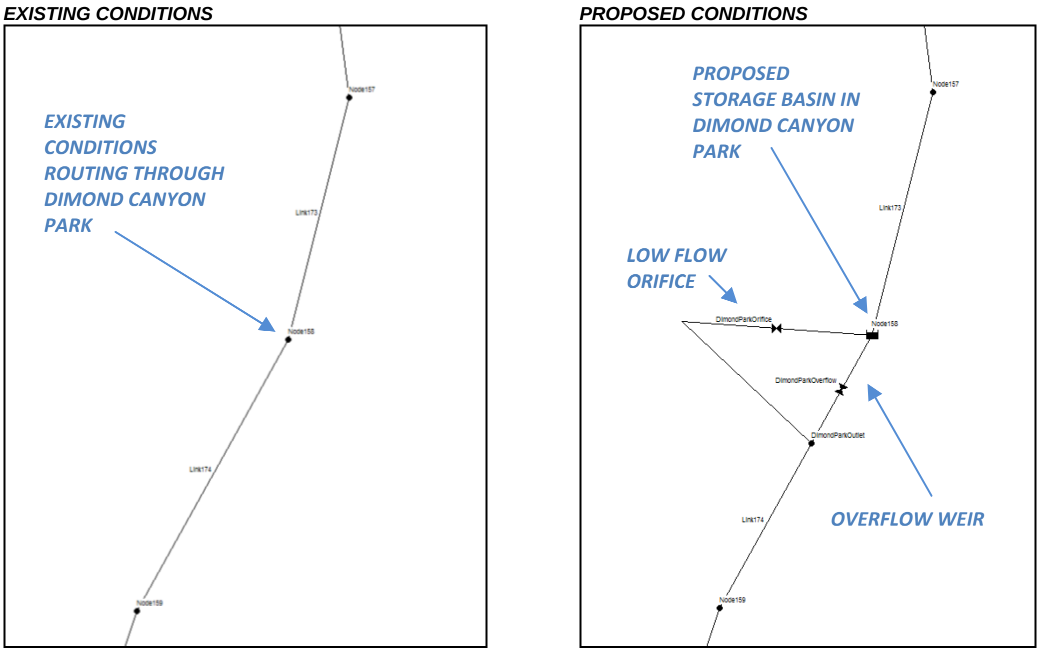
Figure 122: Existing Conditions and Proposed Conditions Demonstrating the Upper Watershed Detention Basin Modeling Technique in EPA SWMM 5.0



Scenarios 1, 2, & 3

In-line detention sites: The upper watershed in-line cistern in Shepherd Canyon Park and the surface detention basin at Larry Lane, as well as the lower watershed in-line cistern at the Montclair Golf Course and Dimond Canyon Park were simulated in EPA SWMM 5.0 by creating a storage basin node in the approximate location of the facility along the channel (Figure 124). EPA SWMM 5.0 requires these in-line storage facilities to have a storage curve that reflects the dimensions of the facility, as well as outlet orifices and weirs to determine how water routes through and overflows the facility. The storage basins were sized according to field measurements, with the assumptions noted in Table 54. Outlet orifices and weirs were designed to accommodate a maximum 100 year flow event without flooding (backwater) effects behind the facility, but to maximize the detention time for all flow events.

Figure 123: Existing Conditions and Proposed Conditions Demonstrating the In-line Storage Basin Modeling Technique in EPA SWMM 5.0



__Comparison of Existing Conditions and Proposed Conditions Using the Hydrologic Model__

The Sausal Creek watershed EPA SWMM 5.0 model was run for the 1, 2, 5, 10, 25, and 100-year recurrence interval precipitation events under existing conditions and three different scenarios of watershed stormwater improvements (Table 55). Complete results from the hydrology modeling output are included as Excel tables in Appendix G, and are summarized in the following sections.

Existing conditions peak discharge values for each sub-basin in the watershed, as well as at the outlets of Shephard Creek, Cobbledick Creek, Palo Seco Creek, and Sausal Creek and other specific locations along the main channel, are provided in Table 14 (page 67). These are compared to Scenarios 1, 2, and 3 in the following sections and the percentage change of each scenario is compared to existing conditions values.

Scenario 1
Results indicate that the implementation of watershed improvements listed under Scenario 1 (Table 53) leads to minor reductions to flow volumes in Sausal Creek by capturing and storing flows in the watershed. However, flow rates and volumes in Palo Seco Creek are significantly reduced (between 14% and 17% from existing conditions), and flow rates and volumes for the 1-year flow event are significantly reduced (Tables 55 and 56).

Table 55: Scenario 1 Hydrology Modeling Results Showing Percent Change in Peak Runoff from Existing Conditions

PEAK RUNOFF (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet)	0.3%	2.3%	0.1%	1.5%	2.3%	-3.1%
Cobbledick Creek Below Larry Lane Basin (Node 47)	0.9%	1.5%	1.2%	0.6%	5.3%	-5.3%
Outlet of Cobbledick Creek (Node 30)	1.1%	1.6%	-0.3%	1.0%	4.7%	-2.0%
Outlet of Shephard Creek (Node SC-R)	-14.6%	0.7%	0.1%	0.4%	-0.1%	-9.9%
Outlet of Palo Seco Creek (Node 121)	-15.7%	-16.6%	-16.2%	-16.9%	-17.0%	-13.8%
Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32)	-11.1%	0.9%	-0.1%	0.5%	1.2%	-7.9%
Inlet to the Golf Course Culvert (Node 52)	-11.9%	-2.5%	-3.0%	-2.7%	-2.2%	-8.8%
Outlet of Dimond Canyon Park (Node 163)	-5.9%	-1.5%	-4.4%	-3.1%	-1.4%	-8.6%
Outlet to the Bay (Node 179)	-6.4%	-1.7%	-3.7%	-1.7%	-1.3%	-7.2%

Table 56: Scenario 1 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions

TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet)	1.8%	1.7%	-0.7%	0.9%	0.5%	-12.3%
Cobbledick Creek Below Larry Lane Basin (Node 47)	2.1%	2.5%	1.8%	1.7%	1.3%	-8.9%
Outlet of Cobbledick Creek (Node 30)	-9.3%	2.0%	-9.4%	1.3%	1.0%	-7.6%
Outlet of Shephard Creek (Node SC-R)	-16.0%	-0.1%	-2.1%	-0.7%	-1.3%	-16.2%
Outlet of Palo Seco Creek (Node 121)	-24.0%	-17.3%	-17.4%	-16.8%	-17.2%	-15.3%
Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32)	-14.2%	0.5%	-8.2%	-0.2%	-0.7%	-13.7%
Inlet to the Golf Course Culvert (Node 52)	-16.0%	-2.7%	-6.5%	-3.1%	-3.6%	-14.0%
Outlet of Dimond Canyon Park (Node 163)	-14.2%	-2.0%	-8.9%	-2.0%	-2.4%	-8.6%
Outlet to the Bay (Node 179)	-11.0%	-1.8%	-6.9%	-1.9%	-2.1%	-6.9%

Scenario 2:
The additional implementation of cisterns in Shepherd Canyon Park and a detention pond along Larry Lane significantly reduces flow rates in the upper watershed for the 1-year event (in Shephard and Cobbledick Creeks especially), and less so for the larger events. There are also additional reductions in flow volumes for the 1-year event (Tables 57 and 58).

Table 57: Scenario 2 Hydrology Modeling Results Showing Percent Change in Peak Runoff from Existing Conditions

PEAK RUNOFF (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet)	-7.2%	-5.4%	-6.0%	-4.8%	-3.1%	-26.1%
Cobbledick Creek Below Larry Lane Basin (Node 47)	-0.5%	11.1%	19.4%	3.3%	17.0%	-59.6%
Outlet of Cobbledick Creek (Node 30)	0.7%	4.6%	9.5%	2.6%	10.0%	-46.6%
Outlet of Shephard Creek (Node SC-R)	-15.5%	-0.9%	-0.7%	-1.1%	-0.7%	-29.3%
Outlet of Palo Seco Creek (Node 121)	-15.7%	-16.6%	-16.2%	-17.0%	-18.2%	-14.4%
Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32)	-11.8%	0.1%	2.0%	-0.1%	2.1%	-34.5%
Inlet to the Golf Course Culvert (Node 52)	-12.5%	-3.2%	-1.4%	-3.2%	-1.7%	-33.2%
Outlet of Dimond Canyon Park (Node 163)	-6.3%	-1.5%	-3.2%	-4.8%	-2.8%	-22.0%
Outlet to the Bay (Node 179)	-6.8%	-1.7%	-2.7%	-2.8%	-2.4%	-21.6%

Table 58: Scenario 2 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions

TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet)	2.6%	4.0%	2.4%	-0.1%	-1.0%	-27.1%
Cobbledick Creek Below Larry Lane Basin (Node 47)	27.4%	37.4%	49.7%	16.2%	19.4%	-30.2%
Outlet of Cobbledick Creek (Node 30)	2.2%	2.0%	12.0%	8.6%	10.2%	-18.3%
Outlet of Shephard Creek (Node SC-R)	-15.9%	-0.1%	-0.4%	-2.2%	-3.2%	-26.2%
Outlet of Palo Seco Creek (Node 121)	-24.1%	-17.3%	-17.4%	-19.0%	-20.0%	-16.0%
Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32)	-11.1%	0.5%	-1.0%	0.7%	0.4%	-24.0%
Inlet to the Golf Course Culvert (Node 52)	-13.4%	-2.7%	-0.3%	-2.7%	-3.2%	-22.7%

Table 58: Scenario 2 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions

TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Outlet of Dimond Canyon Park (Node 163)	-12.2%	-2.0%	-4.8%	-5.0%	-6.0%	-18.3%
Outlet to the Bay (Node 179)	-9.5%	-1.8%	-4.0%	-4.0%	-4.8%	-14.5%

Scenario 3:
The additional implementation of cisterns at the Montclair Golf Course and Dimond Canyon Park along with Scenarios 1 and 2 reduces flow rates in Sausal Creek for the 1-year event and less so for the larger events. Only minor additional reductions in flow volumes occur in Sausal Creek in the lower watershed (Tables 59 and 60).

Table 59: Scenario 3 Hydrology Modeling Results Showing Percent Change in Peak Runoff from Existing Conditions

PEAK RUNOFF (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet)	-7.2%	-5.4%	-6.6%	-4.8%	-4.2%	-26.1%
Cobbledick Creek Below Larry Lane Basin (Node 47)	-0.6%	12.8%	16.3%	3.1%	11.3%	-59.6%
Outlet of Cobbledick Creek (Node 30)	0.7%	6.1%	7.6%	2.6%	6.4%	-46.6%
Outlet of Shephard Creek (Node SC-R)	-15.5%	-0.8%	-1.3%	-1.1%	-1.6%	-29.3%
Outlet of Palo Seco Creek (Node 121)	-15.6%	-16.7%	-16.7%	-17.1%	-18.6%	-14.6%
Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32)	-11.8%	0.9%	1.1%	0.0%	0.4%	-34.5%
Outlet of the Golf Course Basin (GolfCourseOutlet)	-13.7%	-3.9%	-3.5%	-4.2%	-4.8%	-50.6%
Outlet of Dimond Canyon Park (Node 163)	-12.7%	-22.1%	-26.1%	-10.8%	-7.2%	-57.7%
Outlet to the Bay (Node 179)	-9.1%	-5.3%	-7.5%	-6.0%	-6.6%	-49.7%

Table 60: Scenario 3 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions

TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS)						
	Storm Return Frequency					
Reach	100 Year	25 Year	10 Year	5 Year	2 Year	1 Year
Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet)	2.7%	0.7%	-2.2%	-0.2%	-4.3%	-27.1%
Cobbledick Creek Below Larry Lane Basin (Node 47)	26.6%	17.9%	22.5%	16.2%	1.6%	-30.2%
Outlet of Cobbledick Creek (Node 30)	1.8%	9.8%	-0.1%	8.6%	1.2%	-18.3%
Outlet of Shephard Creek (Node SC-R)	-15.8%	-1.3%	-3.7%	-2.2%	-5.4%	-26.2%
Outlet of Palo Seco Creek (Node 121)	-24.1%	-18.7%	-18.8%	-19.1%	-20.5%	-16.0%
Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32)	-11.2%	1.7%	-6.7%	0.7%	-3.7%	-23.9%
Outlet of the Golf Course Basin (GolfCourseOutlet)	-11.2%	-0.9%	-4.3%	-1.8%	-8.1%	-35.7%
Outlet of Dimond Canyon Park (Node 163)	-10.9%	-3.9%	-10.7%	-4.8%	-11.2%	-30.8%
Outlet to the Bay (Node 179)	-8.5%	-3.2%	-8.2%	-3.9%	-8.5%	-24.2%

As shown in the preceding tables, there were small flow continuity errors in the model (created when nodes or conduits flood or surcharge) that caused minor increases in flow volumes and rates for some of the scenarios. These increases are small and do not indicate a significant problem with the model output. There is additional error associated with the model results for the 100-year event. When flooding or surcharging of nodes or conduits occurs, EPA SWMM 5.0 effectively deletes flow beyond a designated ponding value. Thus, flooding of storage basins associated with the 100-year event is expressed as reduced flow compared to existing conditions. Finally, the peak runoff and peak volume increases for Cobbledick Creek (below Larry Lane and at the sub-basin outlet) for flows above the 1-year recurrence interval event are attributed to the sizing of the detention facility at Larry Lane, as well as flow routing and continuity problems in the Cobbledick Creek basin.

Comparison of Existing Conditions and Proposed Conditions Using the Hydraulic Model

The hydraulic model uses the hydrologic model outputs to simulate stream flow and the velocity of flow, depth of flow, and shear stress of the flow on the stream bed.

NRBS ran the calibrated HEC-RAS model for the 1, 2, 5, 10, 25, and 100-year recurrence interval discharges under existing conditions and with the three different scenarios. Complete results from hydraulic modeling comparisons of existing (E) and proposed (P) conditions are summarized in standard HEC-RAS output tables in Appendix F.

The following sections present comparisons of existing and proposed conditions for each of the three proposed scenarios and highlight results that are most relevant to channel form, sediment transport, and habitat in the modeled reaches of Sausal Creek. For each scenario, the potential hydraulic improvements are reviewed by comparing water surface elevation, velocity, and shear stress results for the existing and proposed hydrologic conditions. Water surface elevation changes indicate the impact that improvements in the watershed have on conveyance and flooding, while changes in velocity and shear stress indicate the impact of improvements on erosion, scour, sediment transport, and riparian vegetation regeneration, and therefore on the overall creation and maintenance of channel form and associated aquatic and riparian habitats.

Figure 124: Existing conditions longitudinal shear stress plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.

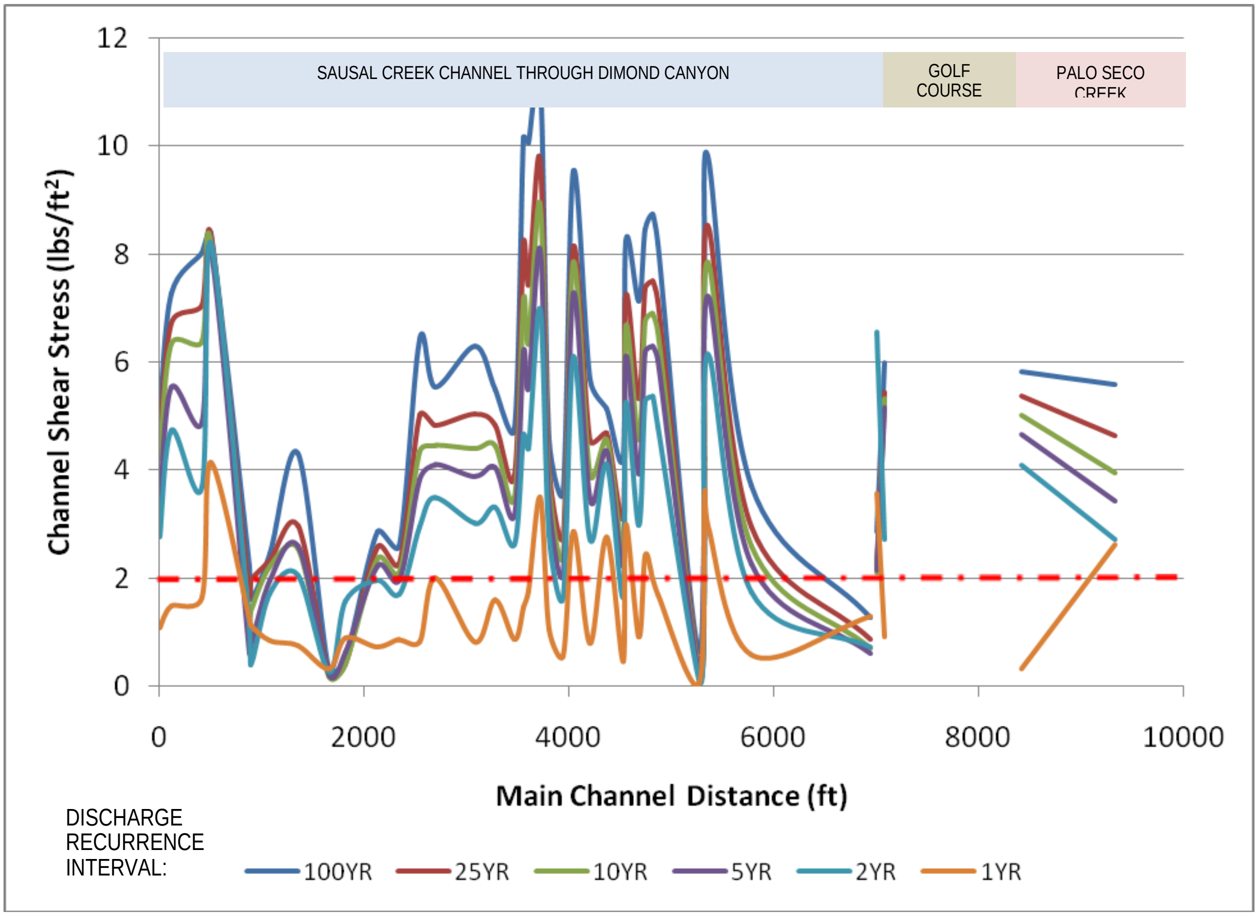


Table 61: Permissible velocities and shear stresses for channel sediment and vegetation types similar to Sausal Creek (after Fischenich 2001)

Material	Permissible Velocity (ft/sec)	Permissible Shear Stress (lbs/ft^2)
Gravel (2 inch)	3.0 – 6.0	0.67
Cobble (6 inch)	4.0 – 7.5	2.0
Riprap (18 inch)	12.0 – 16.0	7.6
Emergents	n/a	0.1 – 0.6
Grasses	3.0 – 6.0	0.7 – 1.7
Woody Vegetation	3.0 – 10.0	2.1 – 3.1

Scenario 1
The implementation of Scenario 1 results in minor reductions to flow volumes by capturing and storing flows in the watersheds before they are significantly channelized. Flow volumes in Palo Seco creek are significantly reduced, especially for the 1-year recurrence interval discharge event.

Water Surface Elevation
Figure 126 is a plot of existing and proposed water surface elevations in the modeled reaches of Sausal Creek and Palo Seco Creek for the 1-year recurrence interval discharge. The differences between existing and proposed water surface elevations are extremely small and are not discernible on this plot. The other modeled discharges showed similar small changes.

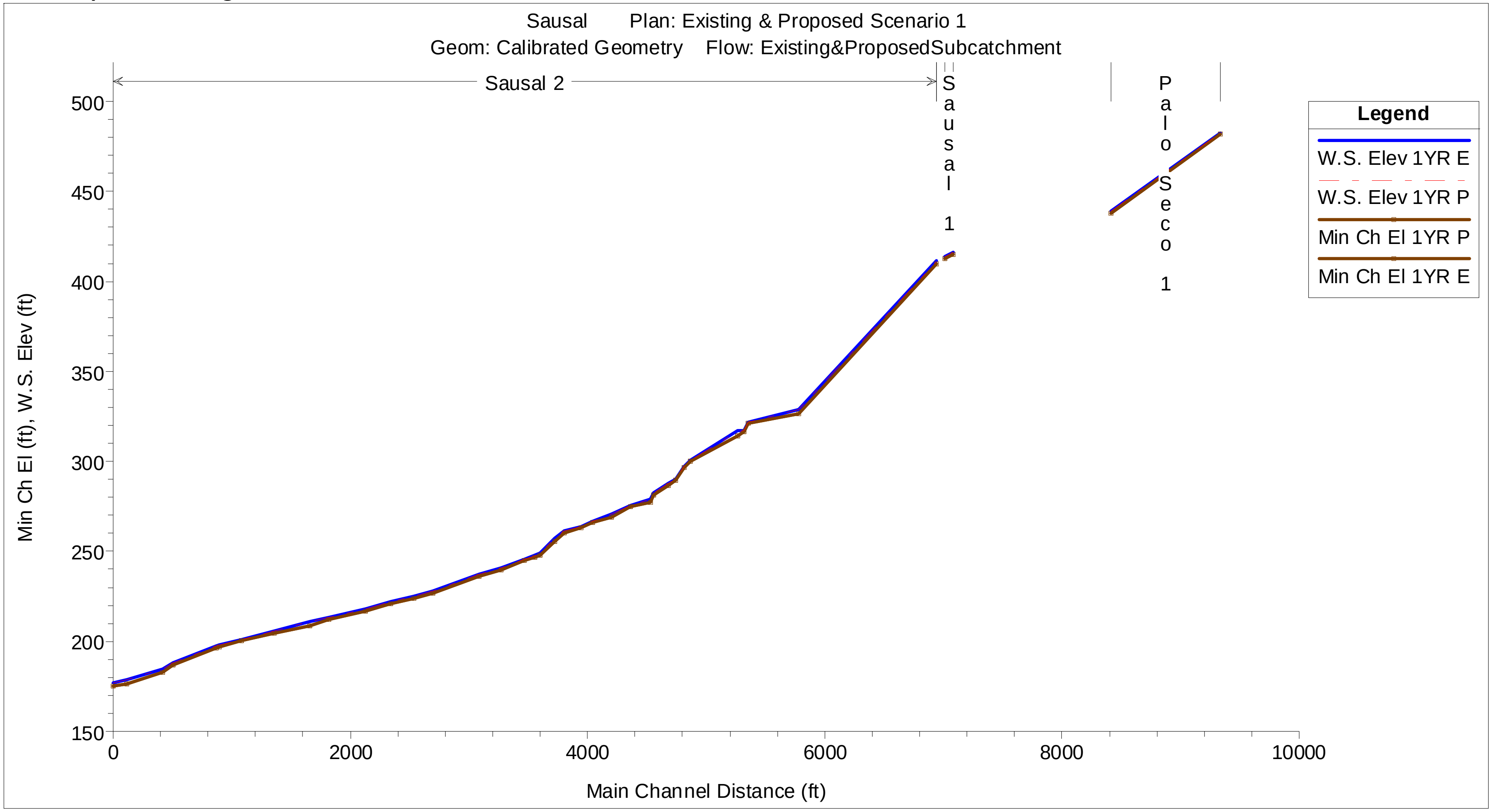
Table 62 is a summary of the average, minimum, and maximum difference between existing water surface elevations and water surface elevations with Scenario 1 improvements. Except for the 1-year and 100-year recurrence interval discharge, proposed water surface elevations are less than 2% smaller than existing water surface elevations. This suggests that Scenario 1 improvements alone would not yield significant conveyance improvements over existing conditions for most peak flows. However, proposed water surface elevations are more than 4% lower than existing conditions for the 1-year flow with Scenario 1 improvements. This is more than twice the reduction shown for all other recurrence intervals except the 100-year flow. Therefore, for smaller, more frequent annual flood peaks like the 1-year discharge event, the measures proposed for Scenario 1 could yield significant reductions in flow depths that make channel conditions closer to the natural hydrologic and hydraulic conditions present in the watershed before urbanization.

While the measures in Scenario 1 also reduce the water surface elevation for the 100-year discharge by 5.7%, conveyance capacity during such an extreme event has already been exceeded and is therefore not likely a critical consideration. The minimum and maximum water surface elevation reductions in Table 64 are presented to show the full range of potential change under Scenario 1. Extreme values in these two columns are typically a result of local hydraulic conditions and are therefore not representative of the entire project reach.

Table 62: Summary of average, minimum, and maximum water surface elevation difference between existing and proposed conditions for all modeled reaches. Negative values indicate increases in water surface elevation under proposed conditions.

Discharge Recurrence Interval	Average Water Surface Elevation Reduction		Minimum Water Surface Elevation Reduction		Maximum Water Surface Elevation Reduction	
Years	ft	%	Ft	%	Ft	%
1	0.05	4.2%	-0.07	-8.0%	0.13	9.2%
2	0.03	1.4%	-0.06	-2.0%	0.14	7.4%
5	0.06	1.8%	-0.01	-0.3%	0.15	8.3%
10	0.07	1.9%	0.02	0.3%	0.20	8.1%
25	0.05	1.3%	-0.05	-0.8%	0.15	8.4%
100	0.27	5.7%	0.13	2.4%	0.91	12%

Figure 125: Longitudinal water surface elevation profile under existing (E) and Scenario 1 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.



Velocity

Figure 127 is a longitudinal plot of existing flow velocity under Scenario 1, and Table 63 summarizes these velocity reductions. Similar to water surface elevation, average velocities are only significantly reduced for the 1-year and 100- year flows. The flow reductions from Scenarios 1, 2, and 3 can locally reduce or eliminate backwater controls in some locations (e.g., at culverts or channel constrictions). Therefore, even though there is less flow volume, flow velocity can increase. These are extremely small increases in these locations. In general, channels with sediment and vegetation characteristics similar to Sausal Creek are eroded by flow velocities of greater than approximately 7 ft/sec (see Table 61). The 100-year discharge is not very important with respect to the long-term geomorphic conditions in Sausal Creek because it occurs so infrequently. The 3.5% average velocity reduction in peak flow from the 1-year discharge achieved under Scenario 1 could yield long-term geomorphic improvement in Sausal Creek in locations where flow velocities are slightly above the critical geomorphic stability thresholds of 7 ft./sec. This slight reduction could improve habitat creation and maintenance by reducing the frequency of damaging flow velocities.

Table 63: Summary of average, minimum, and maximum velocity difference between existing and Scenario 1 conditions for all modeled reaches. Negative values indicate increases in velocity under Scenario 1 conditions.

Discharge Recurrence Interval	Average Velocity Reduction		Minimum Velocity Reduction		Maximum Velocity Reduction	
Years	ft/sec	%	ft/sec	%	ft/sec	%
1	0.11	3.5%	-0.07	-2.4%	0.49	24.2%
2	0.04	0.9%	-0.34	-4.7%	0.32	7.0%
5	0.06	1.0%	-0.28	-6.0%	0.36	6.8%
10	0.09	1.3%	-0.12	-2.5%	0.41	7.2%
25	0.08	1.1%	-0.15	-3.0%	0.46	7.3%
100	0.24	3.4%	-2.4	-25.4%	0.88	9.6%

Shear Stress

Figure 128 is a longitudinal plot of existing channel shear stress and channel shear stress under Scenario 1, and Table 64 summarizes channel shear stress reductions. Similar to water surface elevation and velocity, average shear stresses are only significantly reduced for the 1-year and 100-year flows. In general, channels with sediment and vegetation characteristics similar to Sausal Creek experience erosion at channel shear stresses of greater than approximately 2.0 lbs/ft^2 (see Table 61). Similar to the results for flow velocity, the reduction in shear stress for the 100-year flow is not likely to change long-term geomorphic conditions significantly. However, the small (5.1%) average shear stress reduction under Scenario 1 conditions for the 1-year discharge could benefit long-term geomorphic conditions where shear stresses are at or just above critical thresholds for scour and erosion. In these locations, the reduced peak shear stresses produced by measures in Scenario 1 could yield improvements in channel form and habitat.

Figure 126: Longitudinal velocity profile under existing (E) and Scenario 1 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

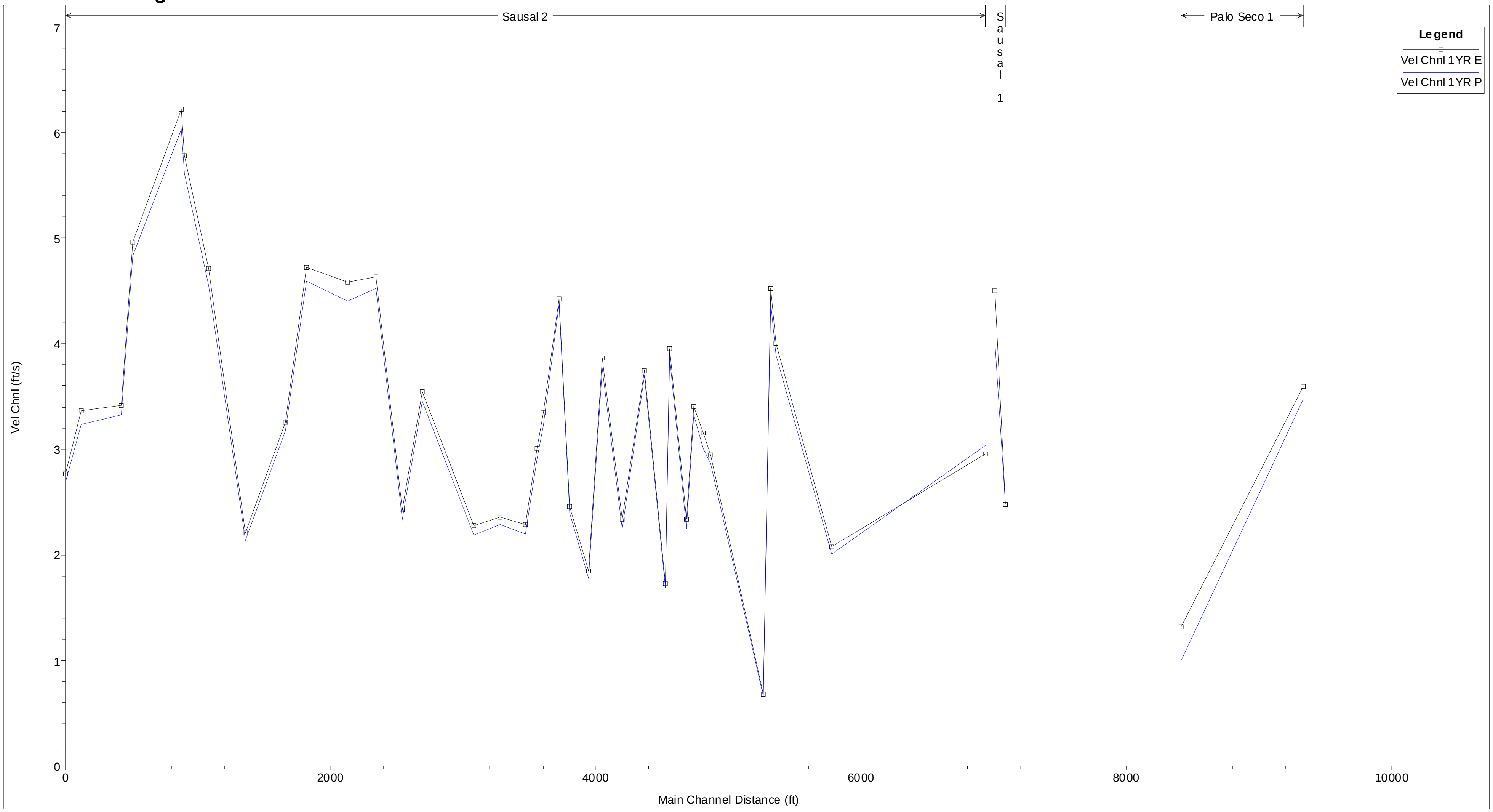


Figure 127: Longitudinal shear stress profile under existing (E) and Scenario 1 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

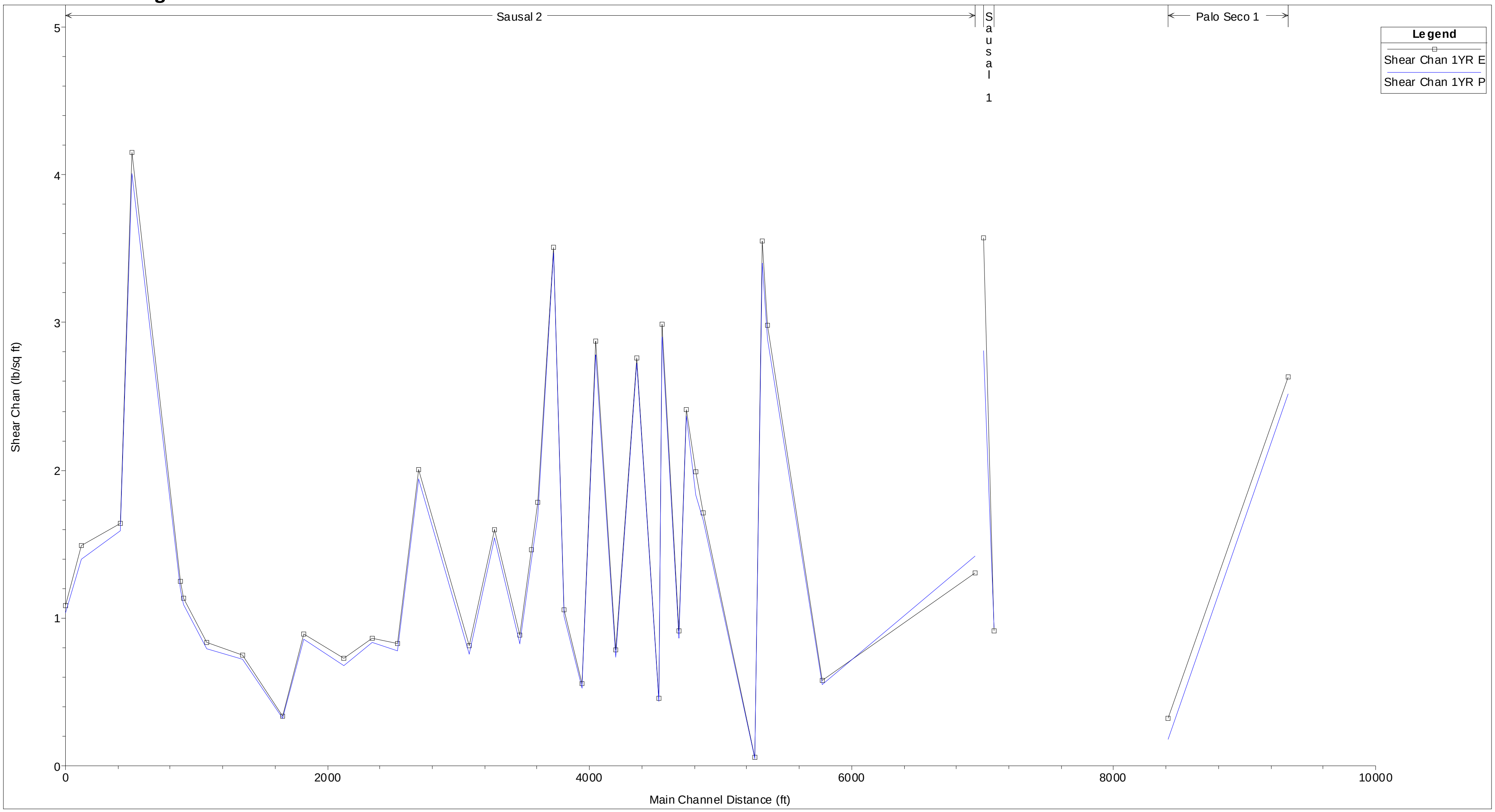


Table 64: Summary of average, minimum, and maximum shear stress difference between existing and Scenario 1 conditions for all modeled reaches. Negative values indicate increases in shear stress under Scenario 1 conditions.

Discharge Recurrence Interval	Average Shear Stress Reduction		Minimum Shear Stress Reduction		Maximum Shear Stress Reduction	
Years	lbs/ft^2	%	lbs/ft^2	%	lbs/ft^2	%
1	0.07	5.1%	-0.12	-9.2%	0.76	43.8%
2	0.03	1.1%	-0.72	-11.0%	0.29	10.3%
5	0.06	1.2%	-0.30	-14.0%	0.38	11.0%
10	0.08	1.8%	-0.13	-7.0%	0.45	11.4%
25	0.07	1.7%	-0.16	-7.1%	0.56	12.1%
100	0.30	4.3%	-1.04	-64.6%	1.27	17.7%

Scenario 2

Scenario 2 includes all of the watershed improvements in Scenario 1 as well as a cistern at Shepherd Canyon Park and a detention basin in the Cobbledick Creek sub-basin on Larry Lane. The implementation of Scenario 2 reduces peak flow rates in the upper watershed for the 1-year discharge event, especially in Shephard Creek. Peak flow rates for larger storm events are not reduced as significantly, however, total flow volumes for these larger events are significantly reduced.

Water Surface Elevation

Figure 128 and Table 65 both show that the hydrology under Scenario 2 translates into very small changes between existing and proposed water surface elevations for all recurrence intervals except the 1-year flow, for which water surface elevations were reduced by 15% on average. This change in peak flow depths could translate into meaningful improvements in long-term geomorphic conditions in Sausal Creek, as the 1 year discharge event is likely very important in the maintenance of channel conditions in Sausal Creek. This reduction in flow depths that could also facilitate channel and riparian habitat restoration by making riparian vegetation hydroperiods (i.e. the hydrologic conditions that can be tolerated by riparian vegetation) more similar to their pre-disturbance condition, and therefore more conducive to native vegetation.

Figure 128: Longitudinal water surface elevation profile under existing (E) and Scenario 2 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

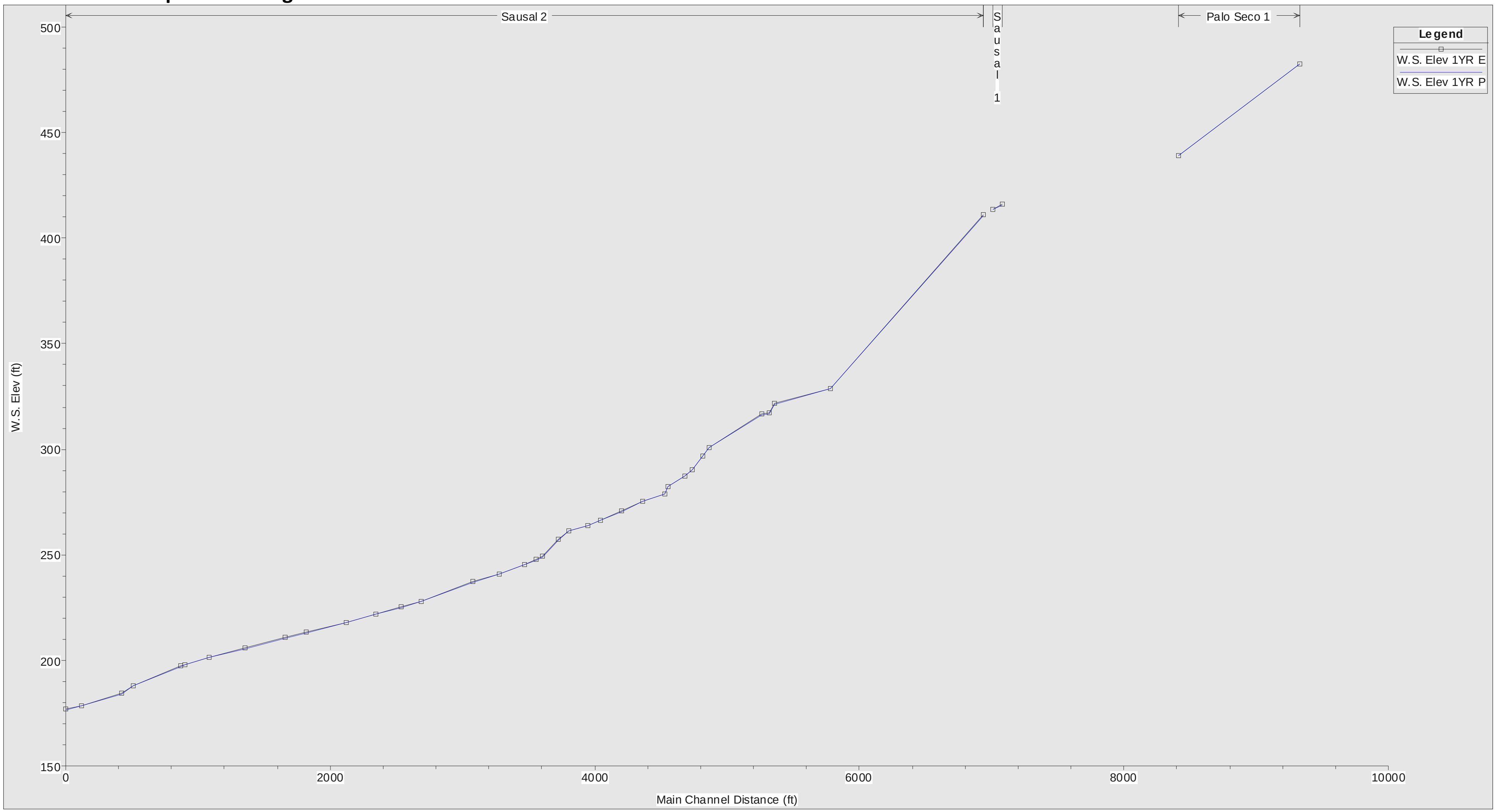


Table 65: Summary of average, minimum, and maximum water surface elevation difference between existing and Scenario 2 conditions for all modeled reaches. Negative values indicate increases in water surface elevation under Scenario 2 conditions.

Discharge Recurrence Interval	Average Water Surface Elevation Reduction		Minimum Water Surface Elevation Reduction		Maximum Water Surface Elevation Reduction	
Years	**ft**	**%**	**Ft**	**%**	**Ft**	**%**
1	0.18	15.0%	-0.37	-42.5%	0.58	44.3%
2	0.03	1.3%	-0.07	-2.3%	0.16	8.2%
5	0.07	2.1%	0	0.0%	0.18	8.3%
10	0.04	1.1%	-0.04	-0.6%	0.15	8.1%
25	0.05	1.6%	-0.05	-0.8%	0.15	8.4%
100	0.29	6.0%	0.13	2.4%	0.92	13%

Velocity

Figure 129 and Table 66 both show that the hydrology under Scenario 2 translates into very small changes between existing and proposed average velocity for all recurrence intervals except the 1-year flow, for which velocities were reduced by 11.5% on average. This reduction would certainly translate into meaningful improvements in the long-term geomorphic conditions in Sausal Creek. There are many locations where this magnitude of velocity reduction could change erosion and scour characteristics for frequent peak flows, and therefore returns the sediment transport regime closer to pre-disturbance conditions. This change could yield significant improvements in aquatic and riparian habitat as a new dynamic equilibrium would be established in Sausal Creek. In addition, the reduced velocities could also improve conditions of fish and macroinvertebrates during regular peak flows, potentially allowing them to remain in Sausal Creek for longer periods than under current conditions.

Figure 129: Longitudinal velocity profile under existing (E) and Scenario 2 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

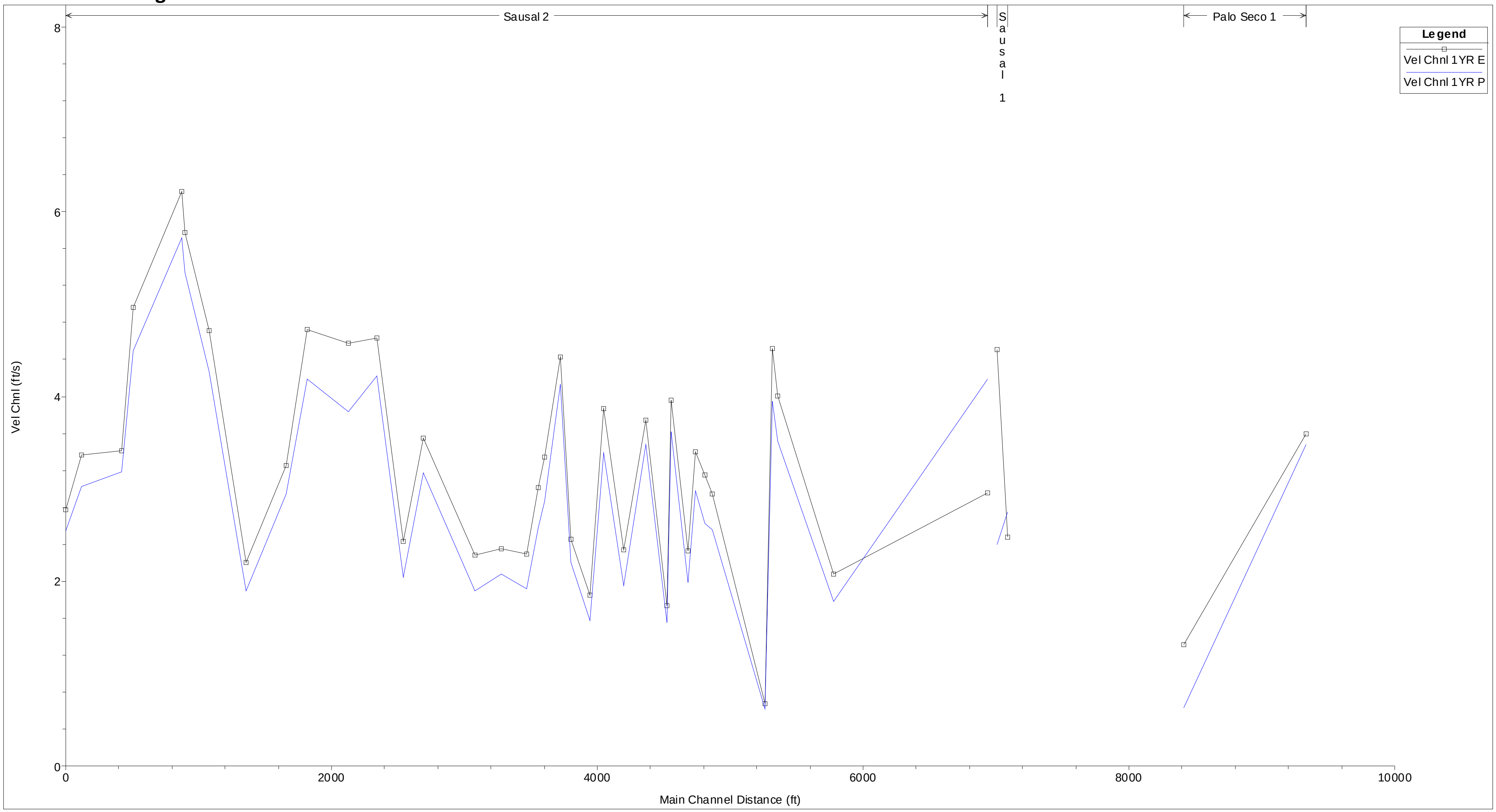


Table 66: Summary of average, minimum, and maximum velocity difference between existing and Scenario 2 conditions for all modeled reaches. Negative values indicate increases in velocity under Scenario 2 conditions.

Discharge Recurrence Interval	Average Velocity Reduction		Minimum Velocity Reduction		Maximum Velocity Reduction	
Years	**ft/sec**	**%**	**ft/sec**	**%**	**ft/sec**	**%**
1	0.37	11.5%	-1.23	-41.6%	2.11	52.3%
2	0.04	0.8%	-0.36	-5.0%	0.34	7.5%
5	0.08	1.2%	-0.30	-6.5%	0.37	7.0%
10	0.06	0.8%	-0.16	-3.4%	0.41	7.2%
25	0.09	1.4%	-0.13	-2.6%	0.46	7.3%
100	0.26	3.6%	-2.36	-25.0%	0.94	10.3%

Shear Stress

Figure 130 and Table 67 both show that the hydrology under Scenario 2 also translates into very small changes between existing and proposed average shear stress for all recurrence intervals except the 1-year flow, for which shear stresses were reduced by 13.4% on average. Similar to velocity, this reduction would certainly translate into meaningful improvements in long-term geomorphic conditions in Sausal Creek. There are many locations where this magnitude of shear stress reduction could change erosion and scour characteristics for frequent peak flows, and therefore return the sediment transport regime closer to pre-disturbance conditions. In addition, the reduced shear stress regime could also allow vegetation, fish, and aquatic insect species with lower shear stress tolerances to return to Sausal Creek. This could increase the overall diversity of organisms in this urbanized watershed.

Figure 130: Longitudinal shear stress profile under existing (E) and Scenario 2 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

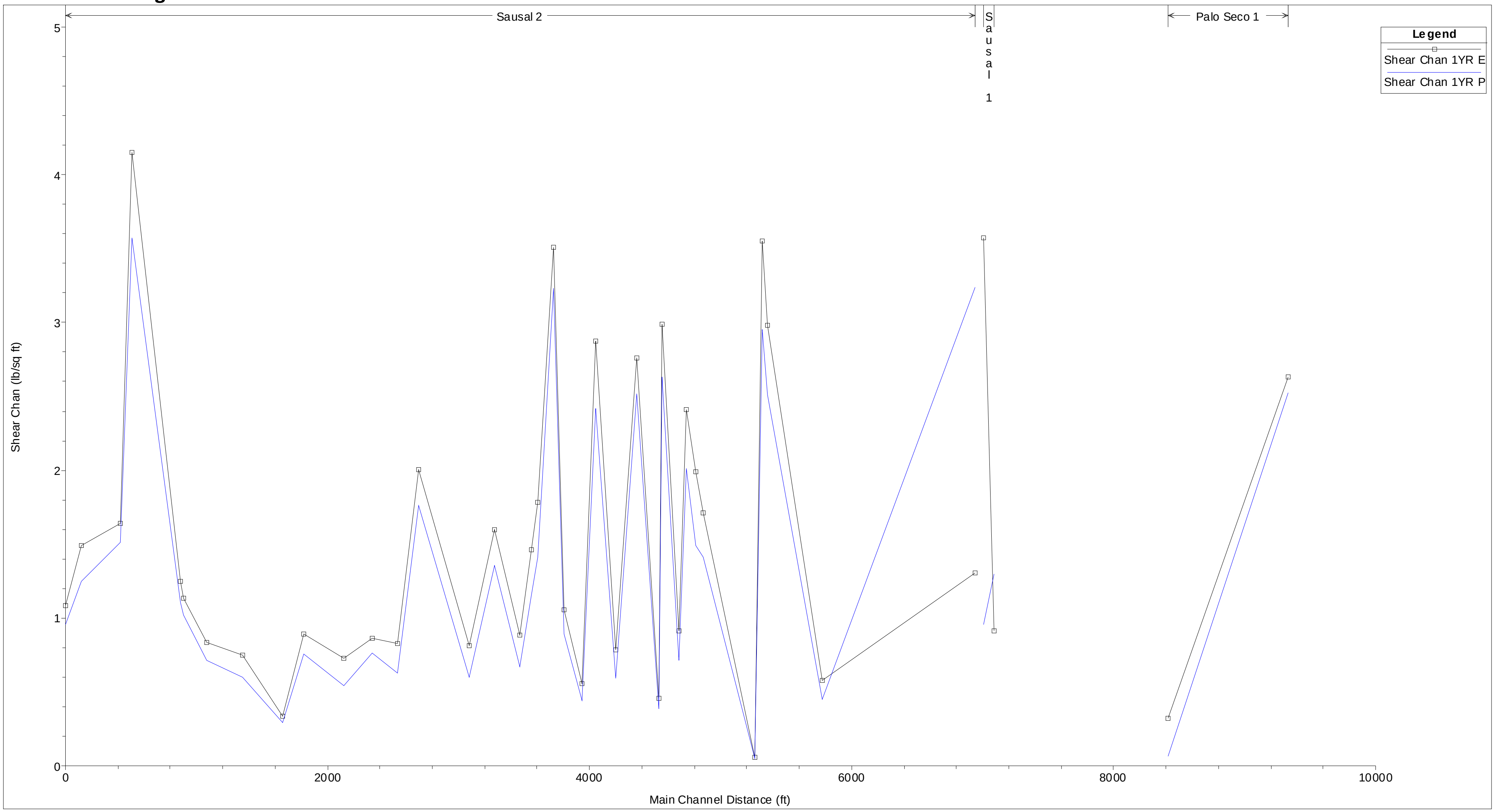


Table 67: Summary of average, minimum, and maximum shear stress difference between existing and Scenario 2 conditions for all modeled reaches. Negative values indicate increases in shear stress under Scenario 2 conditions.

Discharge Recurrence Interval	Average Shear Stress Reduction		Minimum Shear Stress Reduction		Maximum Shear Stress Reduction	
years	lbs/ft^2	%	lbs/ft^2	%	lbs/ft^2	%
1	0.22	13.4%	-1.94	-149.2%	2.62	78.1%
2	0.03	1.0%	-0.74	-11.3%	0.31	11.4%
5	0.07	1.7%	-0.33	-15.4%	0.38	11.0%
10	0.04	1.1%	-0.16	-7.6%	0.45	11.4%
25	0.08	2.0%	-0.14	-6.2%	0.56	12.1%
100	0.32125	4.6%	-1.02	-63.4%	1.35	18.9%

Scenario 3

Scenario 3 includes the watershed improvements in Scenarios 1 and 2 as well as cisterns in the Montclair Golf Course and in Dimond Park. The implementation of Scenario 3 reduces peak flow rates in the main channel for the 1-year frequency discharge event, especially in Sausal Creek. Scenario 3 does not reduce peak flow rates as significantly for larger events, but does reduce total flow volumes.

Water Surface Elevation

Figure 131 and Table 68 both show that the hydrology under Scenario 3 translates into relatively small changes between existing and proposed water surface elevations for all recurrence intervals except the 1-year flow, for which water surface elevations were reduced by 27.5% on average. This scenario produces a substantial reduction in frequent peak flow depths and would certainly improve long-term geomorphic conditions by making the hydraulic conditions more like natural hydraulic conditions for small peak flows in Sausal Creek.

Figure 131: Longitudinal water surface elevation profile under existing (E) and Scenario 3 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

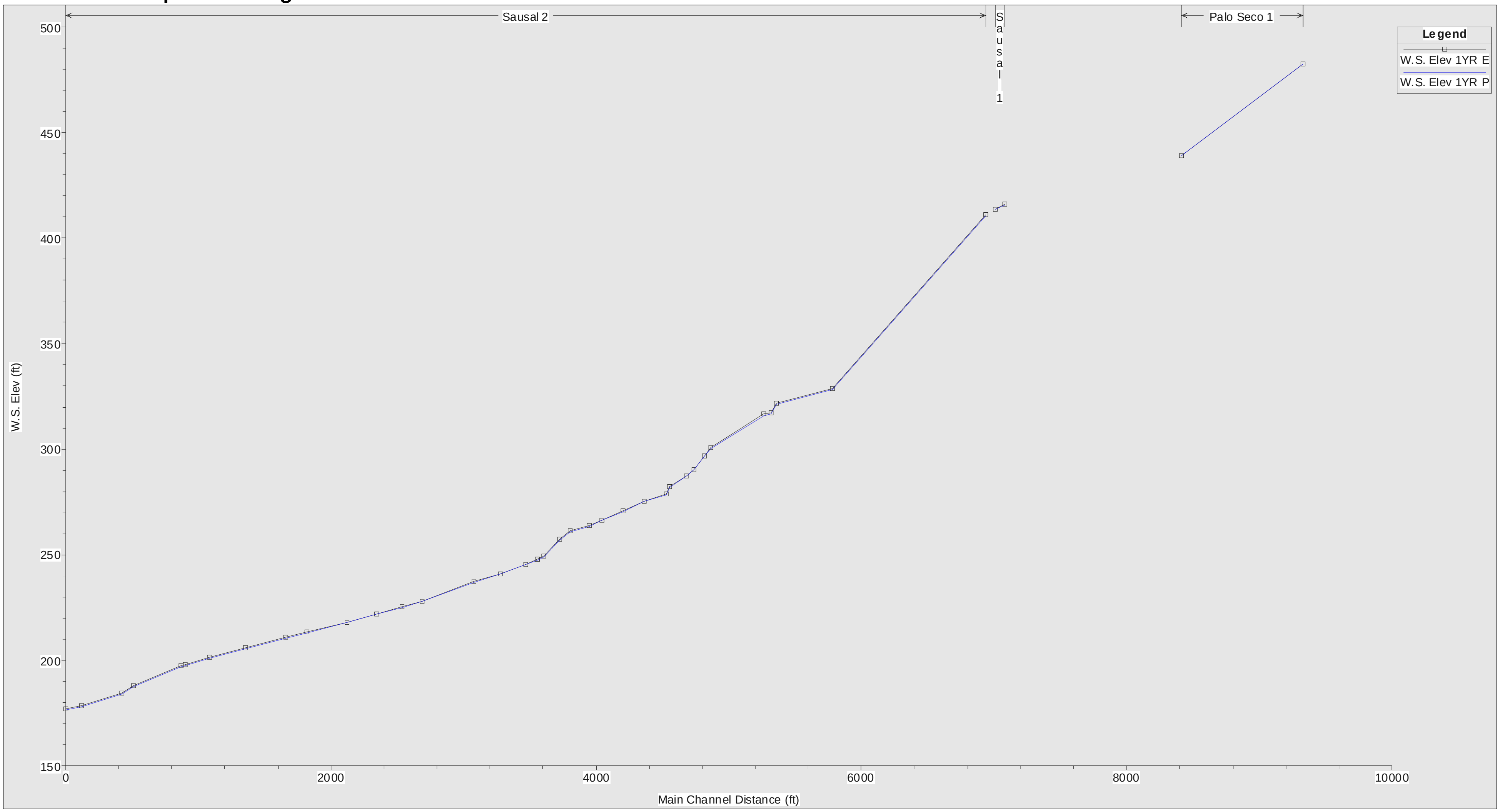


Table 68: Summary of average, minimum, and maximum water surface elevation difference between existing and Scenario 3 conditions for all modeled reaches. Negative values indicate increases in water surface elevation under proposed conditions.

Discharge Recurrence Interval	Average Water Surface Elevation Reduction		Minimum Water Surface Elevation Reduction		Maximum Water Surface Elevation Reduction	
years	Ft	%	ft	%	ft	%
1	0.33	27.5%	-0.27	-31.0%	0.86	52.7%
2	0.08	2.9%	-0.05	-1.7%	0.20	8.2%
5	0.11	3.0%	-0.01	-0.3%	0.33	8.3%
10	0.17	3.8%	0.01	0.3%	0.90	18.9%
25	0.15	3.4%	-0.12	-1.7%	0.81	15.7%
100	0.33	6.9%	0.15	2.8%	0.96	13%

Velocity

Figure 132 and Table 69 both show that the hydrology under Scenario 3 translates into substantial velocity reductions (average 20.5%) during the 1-year flow, and still relatively small velocity reductions for all other recurrence intervals. The improvements in long-term geomorphic conditions under this scenario would be similar to those expected under Scenario 2, except the improvement would occur in Sausal Creek.

Figure 132: Longitudinal velocity profile under existing (E) and Scenario 3 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

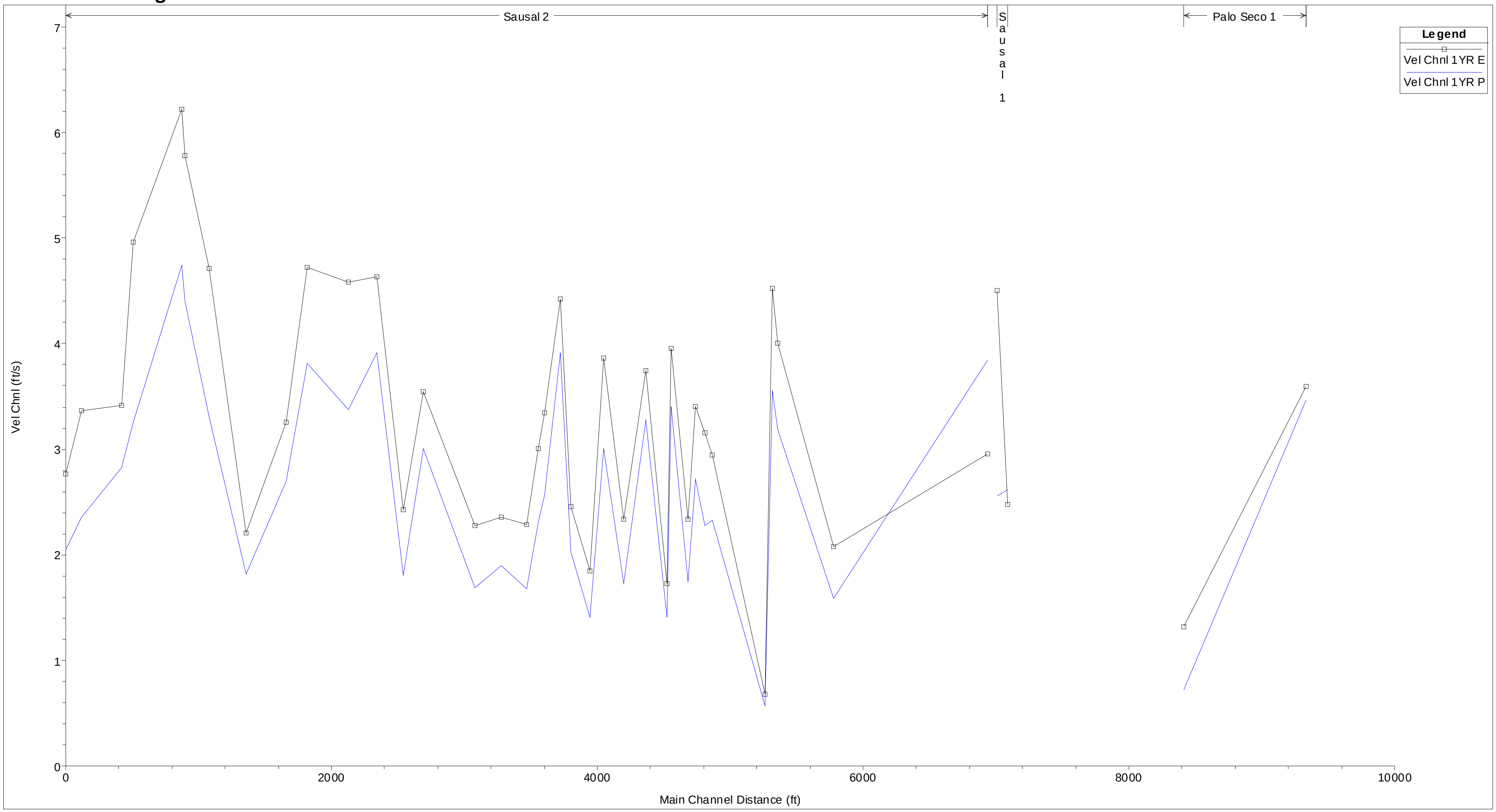


Table 69: Summary of average, minimum, and maximum velocity difference between existing and Scenario 3 conditions for all modeled reaches. Negative values indicate increases in velocity under Scenario 3 conditions.

Discharge Recurrence Interval	Average Velocity Reduction		Minimum Velocity Reduction		Maximum Velocity Reduction	
years	ft/sec	%	ft/sec	%	ft/sec	%
1	0.68	20.5%	-0.89	-30.1%	1.95	46.2%
2	0.10	1.9%	-0.38	-5.1%	0.56	7.7%
5	0.12	1.8%	-0.43	-9.2%	0.53	9.0%
10	0.24	3.1%	-0.38	-7.7%	2.06	24.1%
25	0.28	3.3%	-0.32	-5.9%	2.50	24.4%
100	0.36	4.6%	-1.67	-17.7%	1.02	11.1%

Shear Stress

Figure 133 and Table 70 both show that, similar to the velocity results, Scenario 3 yields a major reduction (26%) in average shear stress for the 1-year discharge event. This suggests that the improvements in long-term geomorphic conditions under Scenario 3 would be similar to those expected under Scenario 2, except in Sausal Creek where the improvements would be greater under Scenario 3 than under Scenario 2.

Figure 133: Longitudinal shear stress profile under existing (E) and Scenario 3 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.

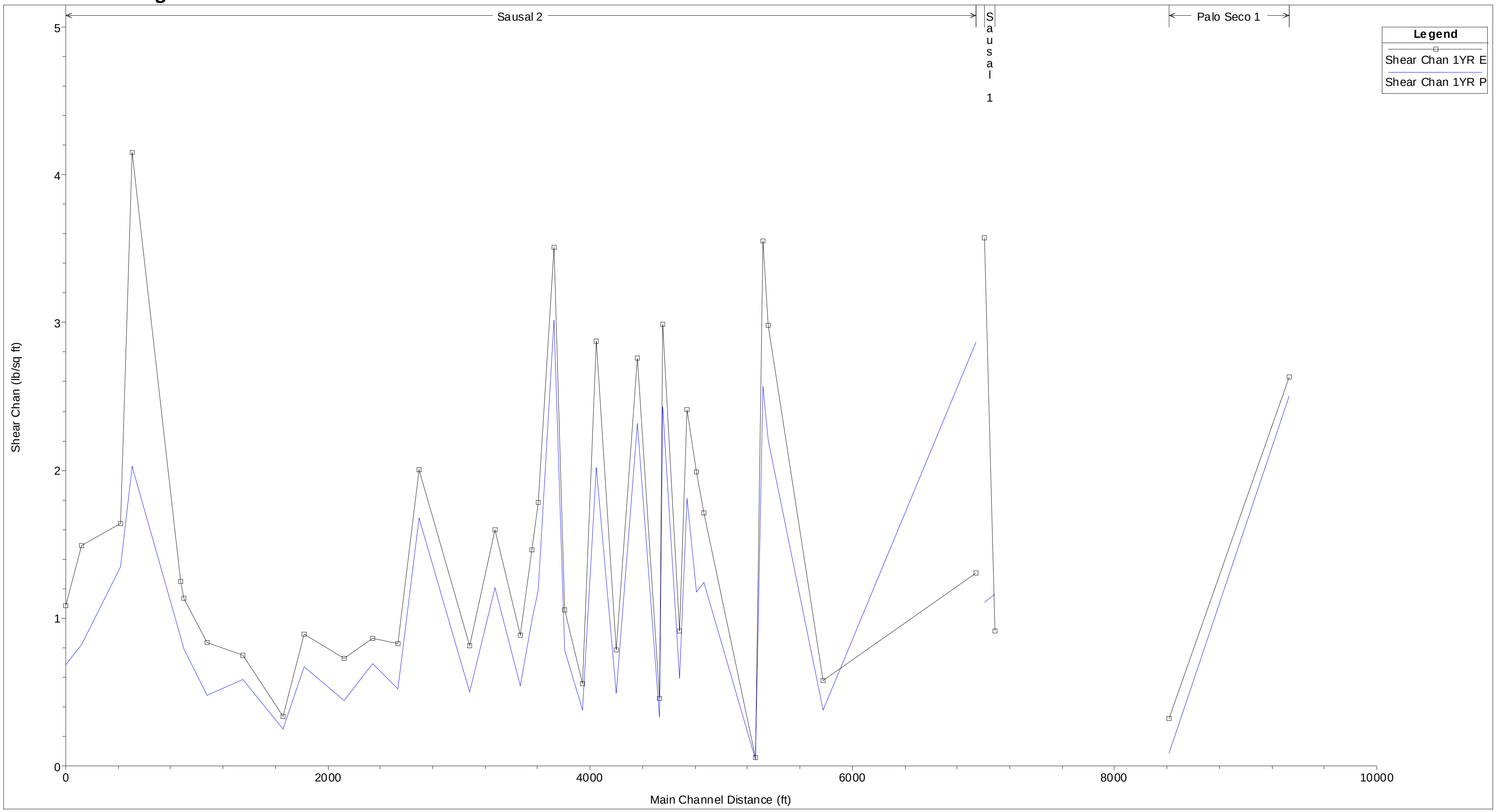


Table 70: Summary of average, minimum, and maximum shear stress difference between existing and Scenario 3 conditions for all modeled reaches. Negative values indicate increases in shear stress under Scenario 3 conditions.

Discharge Recurrence Interval	Average Shear Stress Reduction		Minimum Shear Stress Reduction		Maximum Shear Stress Reduction	
years	lbs/ft^2	%	lbs/ft^2	%	lbs/ft^2	%
1	0.41	26.0%	-1.57	-120.8%	2.46	71.9%
2	0.08	2.6%	-0.70	-14.6%	0.32	14.2%
5	0.09	2.4%	-0.47	-22.0%	0.39	16.7%
10	0.15	4.2%	-0.51	-20.0%	1.23	41.7%
25	0.18	4.7%	-0.45	-15.2%	1.11	43.1%
100	0.38525	6.5%	-0.73	-45.3%	1.45	20.3%

CONCLUSIONS

The watershed improvements under Scenarios 1, 2, and 3 for Sausal Creek watershed would result in localized reductions to flow rates and flow volumes in Sausal Creek and tributaries. The hydrology results indicate that while all three scenarios would reduce runoff rates and volumes in the Sausal Creek watershed, the specific types of stormwater facilities and their locations in the watershed have a great bearing on localized hydrologic patterns. Comparing the three scenarios to existing conditions reveals the following trends:

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year event. Larger storm events produce larger quantities of runoff, which quickly overflow these facilities; thus reductions in flow rates and volumes are minor for the 2 to 100 year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as other, uncontrolled tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements in that sub-basins included in Scenario 1 reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that the Palo Seco Creek sub-basins be considered for a demonstration project.

An additional consideration not addressed in this analysis is the cost-benefit ratio of the proposed stormwater facilities. For example, the strategies included in Scenario 1 tend to be smaller, distributed practices that are low-cost. However, improvements like rain barrels and parking lot detention facilities are located on private properties, are not controlled by a public entity, and potentially could be more difficult to maintain. But with current local and state budget problems, the ability of public agencies to regularly maintain stormwater facilities is also unreliable. In contrast, the larger detention basins are much more expensive to design and install, especially considering that the proposed basins in Shepherd Canyon Park, the Montclair Golf Course, and Dimond Park would require an underground detention facility.

The reductions in flow rates and flow volumes from the watershed improvements have an effect on hydraulic processes in the creek channels, including the depth of storm flows, velocity of flow and the level of scour or shear stress on the channel bed.

Hydraulics

Creek channel beds and banks can withstand certain inundation depths, flow velocities, and channel shear stresses. When peak discharges increase in a watershed, as they do in urban watersheds like Sausal Creek, depth, velocity, and shear stress thresholds for channel stability are exceeded more frequently. Under these urbanized conditions the creek system has an altered sediment transport regime and a more pronounced geomorphic change that typically reduces long-term aquatic and riparian habitat quantity and quality. Therefore, implementing management measures to reduce the magnitudes of peak flows and associated flow depths, velocities, and shear stresses can help restore more natural habitat conditions in and along creek corridors.

Water Surface Elevation

Table 71 summarizes the average reduction in water surface elevations under floods of all recurrence intervals for each of the three proposed scenarios. The table shows clearly that water surface elevations for a given recurrence interval flow event are reduced as watershed improvements are added to the system. However, as noted above, significant reductions occur only for the 1-year and 100-year flow events. The potential reductions in water surface elevation for a frequent peak flow could facilitate establishment of more diverse and natural riparian vegetation and aquatic conditions that are suitable to a wider range of fish and invertebrate species.

Table 71: Summary of average water surface elevation reductions for all three scenarios.

Discharge Recurrence Interval	Average Water Surface Elevation Reduction (%)		
years	**Scenario 1**	**Scenario 2**	**Scenario 3**
1	4.2%	15.0%	27.5%
2	1.4%	1.3%	2.9%
5	1.8%	2.1%	3.0%
10	1.9%	1.1%	3.8%
25	1.3%	1.6%	3.4%
100	5.7%	6.0%	6.9%

Velocity

Table 72 summarizes average reductions in velocity under floods of all recurrence intervals for each of the three scenarios. The table shows clearly that velocity for a given recurrence interval runoff event is reduced as watershed improvements are added to the system. Such reductions could be extremely beneficial with respect to channel and riparian habitat restoration, as artificially high flow velocities that occur frequently in urbanized watersheds can be extremely disruptive to aquatic and riparian species and their habitat. These velocity reductions would also likely yield more natural sediment transport dynamics in Sausal Creek, possibly returning geomorphic conditions closer to pre-urbanization conditions.

Table 72: Summary of average velocity reductions for all three scenarios

Discharge Recurrence Interval	Average Velocity Reduction (%)		
years	**Scenario 1**	**Scenario 2**	**Scenario 3**
1	3.5%	11.5%	20.5%
2	0.9%	0.8%	1.9%
5	1.0%	1.2%	1.8%
10	1.3%	0.8%	3.1%
25	1.1%	1.4%	3.3%
100	3.4%	3.6%	4.6%

Shear Stress

Table 73 summarizes average reductions in shear stress for floods of all recurrence intervals for each of the three scenarios. As with water surface elevation and velocity, shear stress reductions generally increase as measures are added under each scenario. Similar to velocity, these shear stress reductions would likely yield more natural sediment transport dynamics in Sausal Creek, leading to long-term geomorphic conditions closer to pre-urbanization conditions.

Table 73: Summary of average shear stress reductions for all three scenarios

Discharge Recurrence Interval	Average Shear Stress Reduction (%)		
years	**Scenario 1**	**Scenario 2**	**Scenario 3**
1	5.1%	13.4%	26.0%
2	1.1%	1.0%	2.6%
5	1.2%	1.7%	2.4%
10	1.8%	1.1%	4.2%
25	1.7%	2.0%	4.7%
100	4.3%	4.6%	6.5%

In an urbanized watershed like Sausal Creek, reductions in peak water depths, velocities, and shear stresses can lead to habitat improvements in the creeks. However, it can be extremely difficult to identify and acquire adequate space to implement measures that can have meaningful impacts on watershed hydrology in an urbanized watershed. The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

As a first step in implementing the watershed stormwater improvements of Scenario 3 the proposed improvements in Palo Seco Creek sub-basin should be completed as a demonstration projects

This analysis is intended to provide some initial, planning-level estimates of the potential environmental benefits associated with specific improvements in the Sausal Creek watershed. It is intended that the tools developed during this study, specifically the working, calibrated SWMM and HEC-RAS models, be used to continue both planning-level and design-level studies to inform future actions in the watershed.

NRBS recommends that these models be improved and refined to add additional certainty to the results of the hydrologic and hydraulic analyses. Potential improvements should include:

- Verify existing conditions data including culvert dimensions, lengths, channel transects, sub-basin widths, and sub-basin impervious areas
- Refine the level of detail for the specific BMPs in the SWMM model
- Improve hydrology model calibration with a flow gage at the El Centro culvert
- Improve hydraulic model calibration with additional high water mark surveys
- Expand the HEC-RAS model into the upper reaches of the watershed