# Agua Hedionda Watershed Bioengineering Management and Implementation Report

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# 1 Introduction

Recognizing the desire to begin to take action to address the watershed issues identified as part of the Watershed Management Plan (WMP) for the Agua Hedionda watershed, a number of opportunities for project implementation were identified. The purpose of these opportunities is to provide restoration and continued management of the watershed.

These opportunities fall into two categories – stream restoration and stormwater retrofits. Stream restoration opportunities focus on in-stream constructable projects that meet goals and objectives established as part of the WMP. Stormwater retrofit opportunities focus on structural best management practices (BMPs) that also serve to meet the goals and objectives of the WMP.

The stream restoration opportunities identified for this plan support Goal #2 – to protect, restore and enhance habitat in the watershed. The main focus of the stream restoration projects is objective 2e - maintain stable stream banks and riparian areas to protect instream aquatic habitat and priority tree species. The stream restoration projects also address objective 2b - protect, enhance, and restore terrestrial habitat, especially existing vegetation in riparian areas by providing a stable environment (i.e. stable stream banks). The stream restoration projects also indirectly meet objective 2g - maintain and protect lagoon habitat by limiting the delivery of excess sediment that is a result of mass wasting of unstable stream banks.

The stormwater retrofit opportunities support Goal #2 – to protect, restore and enhance habitat in the watershed. This is accomplished through objective 2f - maintain and protect instream habitat to support native aquatic biology. These opportunities also support Goal #3 - Restore watershed functions, including hydrology, water quality, and habitat, using a balanced approach that minimizes negative impacts. The best management projects (BMPs) recommended as part of the stormwater retrofit opportunities address hydrology/hydromodification as well as water quality issues.

This report was prepared as part of the Agua Hedionda Watershed Management Grant in accordance with the State Water Resources Control Board Grant Agreement No. 06-139-559-0. It satisfies Work Item No. 2.6.6 of that agreement. This report parallels the Acquisition and Restoration Opportunities Report, submitted in April 2008. The Acquisition and Restoration Opportunities Report is aimed at identifying opportunities for preservation (acquisition) and for restoration of the streamside buffers and wetland areas throughout the watershed. These reports will be used to develop the final list of management measures in the Watershed Management Plan.

Funding for this project has been provided in full or in part through an agreement with the State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the State Water Resources Control Board, nor does mention of trade names or commercial products constitute endorsement or recommendation of for use. (Gov. Code 7550, 40 CFR 31.20)

# 2 Stream Restoration

Based on the geomorphic analysis, the most significant stream concern is the widespread channel erosion. Some channel banks in the watershed have experienced significant bank erosion while other locations have been limited to undercutting at the toe (bottom) of the bank. Numerous locations have experienced channel incision (lowering of the channel invert). Some amount of erosion in the channel can be seen in most reaches of the stream systems throughout the watershed. As a watershed becomes urbanized and the percent of impervious area increases, greater runoff volumes and peak flows are generated. Local development ordinances often control increases in the peak discharge of larger storm events; however, in the typical design for detention basins "smaller" storms (often up to the 25-year flood event) are not detained and runoff associated with those smaller storms may increase in the post-development condition. A stream that was previously in a state of equilibrium (i.e. a balance between the amount of sediment that the flow can carry and the sediment available to that flow) may be disrupted once the flow volume and discharge increases. In a disturbed system the water is often capable of carrying a greater sediment load than during previous times. The response of a channel is to obtain the sediment load to fulfill the carrying capacity through channel erosion and alter the channel geometry to reduce the sediment carrying capacity. This situation is further exacerbated by the loss of sediment yield from the watershed due to the increased impervious cover which leads to the unavailability of sediment that is now below that cover.

Within the Agua Hedionda watershed there are pervasive examples of channel erosion. This erosion is largely seen in one of two ways: One, the toe of the bank is undercut to the point where the face of the bank sloughs off and a new steeper bank face develops. The widening of the channel provides additional sediment load to the stream flow. The change in channel geometry changes hydraulic parameters (e.g. reduction in flow velocity) which reduce the sediment carrying capacity of the channel which then slows further channel erosion as the channel begins to approach a new equilibrium. Two, significant drops in the channel invert develop below hard controls such as rock outcrops of manmade structures. The incision of the channel bed provides sediment load to the stream flow while reducing the slope of the channel. The decrease in slope reduces the future sediment load that the channel is capable of carrying which slows continued incision and the channel begins to approach a new equilibrium. The relatively small width:depth ratios of the channels in the watershed indicate that incision has occurred in many channels. Another type of typical channel response is to develop a more sinuous channel alignment. This reduces the bed slope while providing sediment load to the flow. There are very few examples of this process taking place throughout the watershed. The additional sediment load is carried downstream and is likely one of the factors contributing to the sediment impairment at the lagoon. Sediment also is deposited at other locations throughout the watershed. These locations include Agua Hedionda at El Camino Real (where regular maintenance is performed to remove the sediment) and along Buena Creek at Sycamore Avenue where sediment deposition is significant. It appears that the deposition of sediment occurs at few locations in the watershed, indicating that a significant portion of the load reaches the lagoon. However, where it does occur it can cause flooding issues due to the loss of conveyance capacity of the channel.

Restoring sites where the equilibrium balance has been disrupted requires determining what channel configuration, both cross-section and slope, represents equilibrium with the new physical conditions. This includes evaluation of the stream flow seen on a daily basis as well as during various size storm events. One strategy aimed at achieving a channel in equilibrium with the new conditions is to stabilize the grade so that the capacity of the flow to carry sediment matches the volume of sediment that is delivered by the watershed under current and anticipated future conditions. The restoration opportunities identified below are largely based on this strategy. It is important to note that additional hydrologic, hydraulic, and sediment transport modeling will be required to support these conceptual plans. Those

analyses may show that a suitable equilibrium slope can only be obtained with further channel modifications (i.e. increasing the width of the channel in addition to reducing its slope). This would require acquisition of land adjacent to the bank and at many sites would disturb riparian habitat. However, at this level of conceptual design broad assumptions must be made and changes solely to the channel slope are assumed adequate to obtain an equilibrium condition. The changes in channel slope are planned to be accomplished largely through construction of grade control structures.

## 2.1 STREAM RESTORATION OPPORTUNITIES

The Stream Restoration Design Handbook (NRCS 2007) identifies two basic types of grade control structures: those that control the bed and those that control the hydraulics. The field reconnaissance shows that in areas of the streams where the stream is stable, a natural bed control feature (such as a rock outcrop or boulders) is present. To mimic the natural condition as closely as possible, the grade control type that was selected for stream stabilization is a bed control structure. Typical grade control structures (NRCS 2007) include loose rock structures, channel lining, and rigid drop structures. Again, in an effort to most closely mimic the natural appearance, loose rock structures were chosen for stream stabilization. Future design studies will define the appearance and dimensions of these structures but the conceptual idea is that large rock will be place in the stream bed at a certain elevation to prevent erosion of the bed and encourage the channel to begin to rebuild. It may be necessary to add fill to the channel bed to begin to rebuild the bed elevation to an equilibrium state. The rock grade control structures will be low profile (approximately 2 feet in height) and can be used to create riffles along the stream. The following figure is a conceptual sketch of to show the appearance of a rock grade control structure.

**Figure 2-1. Conceptual sketch of grade control structure**

In addition to grade stabilization, a wide range of other restoration techniques are available to provide stream stability. These techniques usually focus on bank stabilization through some type of soil bioengineering which is defined as the use of live and dead plants in combination with natural and synthetic support materials (NRCS 2007). These options may be difficult to use in the Agua Hedionda Watershed because of the high energy associated with the streams. Even without performing hydraulic analyses, the high energy associated with the streams is obvious by the presence of large gravel and boulders that have been transported in the stream. High energy waters are required to move material of a significant size. The steep slopes and hilly terrain which is characteristic of the watershed is another indication of the high energy of the stream systems. In addition to the difficulty in using soil bioengineering techniques, it was decided to not further investigate bank stabilization because of the high clay content and bedrock outcrops seen in many channel banks. Both of these materials are resistant to erosion, leading to the conclusion that loss of banks is likely a result of undermining of the bank due to erosion of the invert rather than unstable bank material. The channel invert (or channel bed) has a much higher content of sand which is easily eroded by high energy flows. Therefore, channel stabilization recommendations focus on stabilization of the channel bed.

The following opportunity sites are those developed through the field reconnaissance and stakeholder input, as well as the geomorphic analysis. The range of opportunities identified below are the highest priority, and most beneficial sites identified by the project team for stream restoration efforts in the watershed to meet the goals of the WMP. It should be noted that the frequent observation of channel erosion indicates that the problem is a systemwide issue throughout the entire watershed. A systemwide problem is best dealt with as part of a comprehensive treatment plan. However, the funding and effort required for a comprehensive restoration plan is difficult to pursue as a single project. Therefore, single smaller projects have been identified that will allow for progress towards the goal of watershed restoration and stream stability. Where possible, pursuing a group of adjacent projects as a single project or increasing the length of a restored reach will increase the restoration benefit to the watershed.

Project descriptions are presented below that describe the site conditions, major issues and proposed restoration concepts. Each site also includes a concept level cost estimate. Appendix A includes photographs of the opportunity sites. Appendix B includes the concept plan sheets for each site in which the elements of the project are identified. A summary cost estimate is included in the site description; following the description of all the opportunity sites is a more detailed explanation of the assumptions made in developing the cost estimate.

## 2.1.1 Restoration Opportunity at Site SR-1

SR-1 is located at the Agua Hedionda and Buena Creek confluence on and just upstream of the Green Oak Ranch. The Buena Creek crossing under Green Oak Road is clogged (see photo SR1-1) and the inlet is inefficient due to the land protrusion along the upstream east bank (see photo SR1-2). The confluence area of Agua Hedionda and Buena Creek is an unprotected natural riparian zone and is privately owned. According to stakeholders, this area has historically flooded, even during relatively small storms. A full hydraulic assessment would be needed to address flooding properly and that is not the intent of this document or of the WMP.

Further downstream along Agua Hedionda beyond the confluence and through the Green Oak Ranch private property, the creek has experienced erosion of creek banks (see photo SR1-3) due to unchecked runoff, silt build-up, and invasive plant species (see photo SR1-3). These issues were identified by representatives of Green Oak Ranch.

The restoration opportunity at the site includes cleaning out the culvert and performing minor grading to improve the culvert inlet. These activities will allow for better water flow and alleviate the stagnant water that exists. No water quality data is available, but it's likely that the standing water leads to poor water quality which is eventually transported into Agua Hedionda. Additional restoration opportunities in cooperation with Green Oak Ranch exist, and may include grade control structures or other forms of bank stabilization to protect native oaks, removing channel blockages causing silt build up including further investigation of the operation of the onsite dam, as well as invasive species removal. Improvements within the creek would need to investigate the specific causes of flooding experienced on the Green Oak Ranch property (see photo SR1-4). The total length of the opportunity reach is approximately 3,300 feet.

This site is within the City of Vista and is privately owned property. The concept level cost estimate for this project is as follows:

**Table 2-1. Site SR-1 Cost Estimate**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $25,000 | $25,000 | |
| grading | CY | 1852 | $3 | $5,556 | approximate grading area 100'x100'x5' |
| culvert cleanout | LS | 1 | $10,000 | $10,000 | |
| material for 6 grade stabilizers | CY | 2222 | $135 | $300,000 | 1 ton select rock - machine placed |
| toe protection | CY | 83 | $120 | $10,000 | 5 locations - 50' long, 3'w, 3'h - 1/2 ton rock machine placed |
| replant disturbed area | LS | 120 | $500 | $60,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $102,639 | |
| construction cost | | | | $513,194 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $813,194 | |

## 2.1.2 Restoration Opportunity at Site SR-2

This site is located along Agua Hedionda downstream of the Buena Creek confluence. The project reach upstream limit is at the culvert outfall near the exposed sewer crossing adjacent to the Buena Pump Station and the downstream limit is at the boundary of the Dawson Reserve. The project is contained on land owned by the City of Vista.

Along the reach there is a narrow riparian buffer along both sides of the creek which is protected as open space. Beyond the riparian buffer are trails that provide access to the area for the public. Erosion at the toe of the bank is evident throughout this area and is most severe along the first 500 feet upstream of Melrose Avenue (see photo SR2-1 and SR2-2). Large trees along the stream have been undercut and several have fallen into the stream. Just upstream of the Buena Pump Station a large culvert conveys stormwater and urban runoff from the commercial area to the south into the creek (see photo SR2-3a and SR2-3b). Just downstream of the culvert outfall a sewer pipe has been exposed (see photo SR2-4a and SR2-4b). The sewer line acts to some degree as a grade control for the creek upstream of this point. Downstream of the exposed sewer line the channel invert drops approximately 4 feet in the 2008 photo (photo SR-4a); the drop across the sewer line appears to be limited to less than 1 foot in 2005 (photo SR-4b). During this time period the channel bed upstream of the sewer line appears to be stable with only minor aggradation (sediment build up) occurring. Between the sewer line and Melrose Avenue several large in-stream boulders and bedrock outcrops help stabilize the channel (see photo SR2-5a, SR2-5b, and SR2-5c). Downstream of Melrose Avenue a failing concrete wall provides stabilization to the channel (see photo SR2-6 and SR2-6b). The channel invert drops approximately 4 feet vertically past this wall. Further downstream fallen logs and placed rocks provide additional grade stabilization (see photo SR2-7), with invert drops of approximately 2 feet at each location.

Restoration at this site would incorporate more permanent grade controls to the reach. The grade would be selected to establish an equilibrium slope based on existing conditions. The concrete wall downstream of Melrose Avenue has begun to fail. If this structure or other grade stabilizers along the reach fail, significant channel bank failure/erosion would be expected. As a result the large trees that line the channel bank would be lost. Many of these trees are oak trees and are considered to be a valuable

resource. Restoration would include more immediate protection (such as boulders or willow stakes) at trees that appear to be in imminent danger. In addition, the exposed sanitary sewer line presents a potentially serious impact to water quality should it become damaged and a more stable grade control should be constructed at this location. The total length of the opportunity reach is approximately 2,500 feet.

There are several ongoing and proposed upgrades to the sanitary sewer system in this area that are included in the City of Vista and Buena Sanitation District Sewer Master Plan Update (January 2008). In particular the replacement of the ductile iron project (DIP) that runs adjacent to the creek as well as the enlargement of the 18-inch PVC pipe that crosses the creek is included in the City plan. Theses projects could be coordinated with the stream restoration project in order to pool resources, limit the number of disturbances to the creek, and combine permitting efforts.

This site is within the City of Vista and is within property owned by the City of Vista. The concept level cost estimate for this project is as follows:

**Table 2-2. Site #SR-2 Cost Estimate**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 5 grade stabilizers | CY | 1852 | $135 | $250,000 | 1 ton select rock - machine placed |
| toe protection | CY | 83 | $120 | $10,000 | 5 locations - 50' long, 3'w, 3'h - 1/2 ton rock machine placed |
| replant disturbed area | LS | 100 | $500 | $50,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $90,000 | |
| construction cost | | | | $450,000 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $750,000 | |

## 2.1.3 Restoration Opportunity at Sites SR-3 and SR-4

Both sites SR-3 and SR-4 are located along Agua Hedionda downstream of the confluence with Buena Creek. SR-3 is located through the Dawson Los Monos Canyon Reserve which is part of the University of California, Natural Reserve System and SR-4 is located downstream of the Preserve. This entire reach has protected riparian zones, particularly associated with the preserve.

Throughout this 2.3 mile stream reach there are locations of significant bank erosion, some eroded banks up to 10 feet high (see photo SR4-1). The reach is also characterized by soft bedrock outcrops that may act to limit vertical and lateral erosion. Investigations should be made to characterize the soils in more detail before any restoration plans are made. Once locations are identified that are likely to experience additional erosion, restoration opportunities that include toe protection in select 'at risk' locations could be implemented. Grade stabilization opportunities to address longer reaches of instability could also be identified. The total length of the opportunity reach is approximately 9,000 feet at site SR-3 and 4,000 feet at site SR-4.

Site SR-3 is located through the State Reserve property. Site SR-4 is located within the City of Carlsbad and is owned by the City. The concept level cost estimates for these projects are as follows:

**Table 2-3. Conceptual Cost for Site SR-3**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 14 grade stabilizers | CY | 5185 | $135 | $700,000 | 1 ton select rock - machine placed |
| toe protection | CY | 67 | $120 | $8,000 | 5 locations - 50' long, 3'w, 3'h - 1/2 ton rock machine placed |
| replant disturbed area | LS | 280 | $500 | $140,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $224,500 | |
| construction cost | | | | $1,122,500 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $1,422,500 | |

**Table 2-4. Conceptual Cost Estimate for Site SR-4**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 12 grade stabilizers | CY | 4444 | $135 | $600,000 | material - rock, soil cement, etc. |
| toe protection | CY | 67 | $120 | $8,000 | assume 4 locations - 50' long, 3'w, 3'h |
| replant disturbed area | LS | 240 | $500 | $120,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $194,500 | |
| construction cost | | | | $972,500 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $1,272,500 | |

## 2.1.4 Restoration Opportunity at Site SR-5

The Oak Lake area refers to a reach of Agua Hedionda downstream of the Dawson State Preserve. Historical aerial photographs indicate that this area has had unique characteristics compared to the rest of the creek. The conceptual plan sheet for Site SR-5 shows that in 1939 this area had two distinct bends to the channel and consisted of braided channels through a sandy area. In 1963 significant vegetation has grown up in the area but a lake is now visible in the area as well. This lake (identified as Oak Lake on the USGS maps) was located on the property currently known as Oak Lake Ranch (see photos SR5-1 and SR5-2). Discussions with local residents indicate that the lake was drained in the early 1970s. The 1980 aerial photograph indicates an open area with an unidentified use. This area is located at a significant

break in the profile of the channel invert which occurs approximately 2000 feet upstream (see profile shown on the SR-5 concept plan sheet in Appendix B). The invert upstream of this grade change is relatively steep (3% approximate slope) while downstream the slope flattens to approximately 1%. This area is a mix of natural area and tended ranch estates on private land. The riparian corridor is mostly natural. All of it is unprotected.

The historical character of the area as well as the slope change indicates that this portion of the channel has likely trapped sediment over the decades. A preservation / restoration opportunity in this area would include preserving this area as a sediment sink and providing habitat opportunities to complement it. A lake or potentially instream wetlands would be a compatible use for this area. The total length of the opportunity reach is approximately 600 feet. Because the land use would change with this project and would likely need to be put into public ownership, the cost of the land purchase is included in the cost estimate.

This site is within the City of Carlsbad and is privately owned property. The concept level cost estimate for this project is as follows:

**Table 2-5. Conceptual Cost Estimate for Site SR-5**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $25,000 | $25,000 | |
| land purchase | acre | 3 | $200,000 | $600,000 | |
| grading | CY | 11111 | $3 | $33,333 | area 1000' x 100'; depth 3' |
| revegetation | LS | 200 | $500 | $100,000 | 200 trees |
| 25% construction contingency | LS | 1 | 25% | $189,583 | |
| construction cost | | | | $947,917 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $1,247,917 | |

## 2.1.5 Restoration Opportunity at Site SR-6

This site is located along Buena Creek and extends from the Hollyberry Trail crossing (see photo SR6-1) to a wooden footbridge (see photo SR6-2) approximately 1,330 feet upstream. At the upstream limit a bedrock outcrop at the bridge stabilizes the upstream invert, which drops approximately 4 feet vertically after the crossing. Failed bank heights downstream of the crossing are up to 5 feet. A patchwork of bank protection (likely constructed by adjacent homeowners) is in place (see photo SR6-3). Approximately 600 feet downstream of the crossing the channel is almost entirely clogged with debris (see photo SR6-4) and channel aggradation is evident just upstream of the blockage (see photo SR6-5). Downstream of the debris blockage the channel has been meandering (high sinuosity) and causing bank erosion (see photo SR6-6). Approximately 600 feet upstream of the Hollyberry Trail crossing a triangular open space (approximately 6,000 square feet) is susceptible to erosion due to the complete lack of vegetated cover (there recently was a large vegetative cover, likely of oak trees, as seen in aerial imagery , however, now only wood chips and acorns remain) (see photo SR6-7). Downstream of this open space the channel banks are significantly eroded to a height of 5 – 6 feet. This reach consists of unprotected, privately owned, semi-natural riparian zones. It is mostly maintained and/or landscaped by local homeowners.

Restoration opportunities through this reach include cleaning out the debris blockage and providing a cohesive stabilization plan including replanting the disturbed area. Due to space limitations between the

channel banks and property lines and the lengthy extent of erosion, grade control structures would likely provide the best solution. The total length of the opportunity reach is approximately 1,500 feet.

This site is within the unincorporated areas of San Diego and is privately owned property. The concept level cost estimate for this project is as follows:

**Table 2-6. Conceptual Cost Estimate for Site SR-6**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 2 grade stabilizers | CY | 741 | $135 | $100,000 | 1 ton select rock - machine placed |
| toe protection | CY | 33 | $120 | $4,000 | 5 locations - 50' long, 3'w, 3'h - 1/2 ton rock machine placed |
| clear channel & existing protection | SY | 214 | $15 | $3,208 | 25% of stream length (1,100') x 7' high - light material |
| replant disturbed area | LS | 40 | $500 | $20,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $44,302 | |
| construction cost | | | | $221,510 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $521,510 | |

## 2.1.6 Restoration Opportunity at Site SR-7

This site is located along Calavera Creek upstream of the Melrose Avenue crossing. The project extends from Melrose Avenue to a point 500 feet upstream of Melrose. This reach consists of unprotected, privately owned, non-natural riparian zones. It is mostly maintained and/or landscaped by local homeowners.

Calavera Creek in this reach has been severely constrained by the private development on each side of the creek. It is incising and does not support any habitat associated with the creek (see photo SR7-1). Directly south of the creek is an inactive ranch (horse) operation (see photo SR7-2). This land is currently for sale and could provide an opportunity for expanding the footprint of the creek. Because the land use would significantly change with this project, the cost of the land purchase is included in the cost estimate. This could allow for the establishment of some riparian corridor or implementation of demonstration BMP projects. Signage on the next property to the south indicates that a shopping center is planned. Aggressive LID practices on this site could be incorporated into the demonstration project elements of the project. The total length of the opportunity reach is approximately 500 feet.

This site is located within the unincorporated areas of San Diego County and is privately owned property. The concept level cost estimate for this project is as follows:

**Table 2-7. Conceptual Cost Estimate for Site SR-7**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $25,000 | $25,000 | |
| land purchase | acre | 4 | $200,000 | $800,000 | |
| channel regrading | CY | 2222 | $3 | $6,667 | 150' x 100' area; 4' deep |
| revegetation | LS | 25 | $500 | $12,500 | 25 trees |
| 25% construction contingency | LS | 1 | 25% | $211,042 | |
| construction cost | | | | $1,055,208 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $1,355,208 | |

## 2.1.7 Restoration Opportunity at Site SR-8

This site is located along Calavera Creek adjacent to Lake Boulevard in Oceanside. The upstream limit is at the point where the stream daylights northwest of the intersection of Lake Boulevard and Cannon Road and the downstream limit is at Chauncey Road. This reach consists of unprotected, privately owned, semi-natural riparian zones.

This is a small stream between Lake Boulevard and a residential tract (see photo SR8-1). Upstream of Windsor Avenue the more significant channel erosion is seen with vertical banks up to 8 feet high (see photo SR8-2). In several locations natural bedrock outcrops act to stabilize the channel grade (see photo SR8-3). In other locations placed rock (SR8-4) or sand bags act as grade stabilizers; however these features have begun to fail (SR8-5). Irrigation lines have been exposed along the creek and further channel bank erosion and channel widening could threaten the adjacent infrastructure. The closest infrastructure to the existing channel is Lake Boulevard to the north of the channel.

Restoration at this site would incorporate more permanent grade controls to the reach. The grade would be selected to establish an equilibrium slope based on existing conditions. A stable reach of the existing channel could be used to identify the equilibrium slope. The total length of the opportunity reach is approximately 2,200 feet.

This site is within the City of Oceanside and is privately owned property. At the upstream limit of the project across Lake Boulevard there is a City Park (Lake Park) and two schools (Madison Middle School and Lake Elementary School). The concept level cost estimate for this project is as follows:

**Table 2-8. Conceptual Cost Estimate for Site SR-8**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 4 grade stabilizers | CY | 1481 | $135 | $200,000 | 1 ton select rock - machine placed |
| replant disturbed area | CY | 80 | $120 | $9,600 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $64,900 | |
| construction cost | | | | $324,500 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $624,500 | |

## 2.1.8 Restoration Opportunity at Site SR-9

This site is located through the Oak Riparian Park (SR9-1a and SR9-1b) upstream and downstream of Calavera Lake. Mass wasting of the channel was identified by Preserve Calavera and can be remediated with the use of grade stabilizers. The purpose of grade control in Oak Riparian Park is largely to preserve the trees adjacent to the creek. Stabilizing the bank for the purpose of sediment control is not significant since any sediment transported from this reach will likely be trapped by the downstream Calavera Lake. Bank stabilization for sediment control is a more significant issue for that part of the project downstream of the Calavera Lake.

Restoration at this site could include establishing an equilibrium slope through the use of grade control structures or providing bank protection along the impacted reach. The total length of the opportunity reach is approximately 6,300 feet.

This site is within the City of Carlsbad and Oceanside and is contained on publicly owned property. The concept level cost estimate for this project is as follows:

**Table 2-9. Conceptual Cost Estimate for Site SR-9**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 9 grade stabilizers | CY | 3333 | $135 | $450,000 | 1 ton select rock - machine placed |
| replant disturbed area | CY | 180 | $120 | $21,600 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $130,400 | |
| construction cost | | | | $652,000 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $952,000 | |

## 2.1.9 Restoration Opportunity at Site SR-10

This site is located along Little Encinas Creek at the current termination of Cannon Road (see photo SR10-1 and SR10-2). This site was recommended by Preserve Calavera as a location where significant bank failure and bank undercutting has occurred.

Restoration at this site could include establishing an equilibrium slope through the use of grade control structures or providing bank protection along the impacted reach. The total length of the opportunity reach is approximately 600 feet.

This site is within the City of Carlsbad and Oceanside and is publicly owned property. The concept level cost estimate for this project is as follows:

**Table 2-10. Conceptual Cost Estimate for Site SR-10**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 1 grade stabilizer | CY | 370 | $135 | $50,000 | 1 ton select rock - machine placed |
| replant disturbed area | CY | 20 | $120 | $2,400 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $25,600 | |
| construction cost | | | | $128,000 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $428,000 | |

## 2.1.10 Restoration Opportunity at Site SR-11

This site is located along Little Encinas Creek from the confluence with Calavera Creek up to a road crossing approximately 1,450 feet upstream (see photo SR10-1). Channel bank erosion is evident throughout the entire reach (see photo SR10-2). The erosion has exposed significant layers of cobbles present in the banks (see photo SR10-3). Approximately 430 feet downstream of the upstream road crossing a footbridge crosses the creek to allow access to a farm stand. Approximately midway between the two crossings the channel erosion has caused damage to the adjacent parking lot (see photo SR10-4). Downstream of the farm stand crossing riprap has been placed along the southeast bank at intermittent locations, likely to prevent additional road damage (see photo SR10-5). At the Little Encinas and Calavera Creek confluence a geofabric was installed along the northwest bank (see photo SR10-6). This bank protection has failed and a portion of it is lying along the invert. This reach consists of an unprotected, privately owned mix of riparian zones.

Restoration at this site could include establishing an equilibrium slope through the use of grade control structures or providing bank protection along the impacted reach. The total length of the opportunity reach is approximately 1,500 feet.

This site is within the City of Carlsbad and is privately owned property. The concept level cost estimate for this project is as follows:

**Table 2-11. Conceptual Cost Estimate for Site SR-11**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 3 grade stabilizers | CY | 1111 | $135 | $150,000 | 1 ton select rock - machine placed |
| channel regrading | CY | 1852 | $3 | $5,556 | 500' long x 20' wide x 5' deep |
| clear existing protection | SY | 389 | $50 | $19,444 | 500' stream length x 7' high - mostly rock |
| replant disturbed area | SY | 60 | $500 | $30,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $63,750 | |
| construction cost | | | | $318,750 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $618,750 | |

## 2.1.11 Restoration Opportunity at Site SR-12

This site is located along Agua Hedionda near South Santa Fe Avenue. Channel bank erosion is evident through the reach and adjacent infrastructure restricts the width of the stream.

Restoration at this site could include establishing an equilibrium slope through the use of grade control structures or providing bank protection along the impacted reach. The total length of the opportunity reach is approximately 2,200 feet. The grade control scheme would take advantage of the road crossings to reduce the number of additional stabilizers needed.

This site is within the unincorporated areas of San Diego and the City of San Marcos and is privately owned property. The concept level cost estimate for this project is as follows:

**Table 2-12. Conceptual Cost Estimate for Site SR-12**

| Item | Units | Quantity | Unit Price | Cost | Assumptions |
|---|---|---|---|---|---|
| mobilization | LS | 1 | $50,000 | $50,000 | |
| material for 2 grade stabilizers | CY | 1111 | $135 | $150,000 | 1 ton select rock - machine placed |
| replant disturbed area | SY | 40 | $500 | $20,000 | 20 trees at each stabilizer |
| 25% construction contingency | LS | 1 | 25% | $55,000 | |
| construction cost | | | | $275,000 | |
| design & permitting cost | | | | $300,000 | |
| total cost | | | | $575,000 | |

## 2.2 COST ESTIMATES FOR RESTORATION OPPORTUNITIES

As noted earlier, additional analysis, modeling and design work will be required to support the restoration opportunities. Broad assumptions are required to develop any level of cost estimate. It should be carefully noted that the following estimates are for a very conceptual level of planning and are more appropriate for identifying the relative cost of opportunities among the various sites. The cost estimates should not be used for funding allocation.

Many restoration opportunities include grade stabilization. The number of grade stabilizers is dependent on the equilibrium slope that is determined for the individual stream reach. No analysis has been done to identify those slopes. Therefore a broad assumption was made based on field observations. During field investigations along Agua Hedionda Creek a stream reach upstream of Melrose Avenue and upstream of the exposed sewer line was identified that appears to be in an equilibrium state in that no bank erosion was observed. It should be noted that this was not verified with historical topography and some changes have been noted over the past several years; however for this planning level effort it was assumed to reasonably represent an equilibrium slope. The slope of this reach is 0.4%. Downstream of this reach, Agua Hedionda Creek exhibits typical erosion seen throughout the watershed. The slope of this reach (previously identified as Site #SR-2) is 0.75%. This indicates an approximate 50% reduction in the slope at this reach may lead to an equilibrium slope which results in a 500-foot spacing of the structures. This structure spacing was used throughout the watershed as a concept level approximation of the design requirements to obtain an equilibrium slope. Again, it should be stressed that hydrologic, hydraulic, and sediment transport analyses will be needed to determine an accurate equilibrium slope for each individual reach.

A 25% contingency cost was included in the cost estimate due to the preliminary nature of the project. Design costs were also included and were estimated, based solely on engineering judgment, to be $200,000 for each project. A cost of $100,000 to process the permits was also included. Additional project costs such and annual maintenance and monitoring has not been included.

The cost estimate breakdowns are provided in the project descriptions above. The following table summarizes the total conceptual cost for each alternative:

**Table 2-13. Summary of Conceptual Costs**

| Site | Total Cost |
|---|---|
| Site SR-1 | $813,194 |
| Site SR-2 | $750,000 |
| Site SR-3 | $1,422,500 |
| Site SR-4 | $1,272,500 |
| Site SR-5 | $1,247,917 |
| Site SR-6 | $521,510 |
| Site SR-7 | $1,355,208 |
| Site SR-8 | $624,500 |
| Site SR-9 | $952,000 |
| Site SR-10 | $428,000 |
| Site SR-11 | $618,750 |
| Site SR-12 | $575,000 |

## 2.3 EVALUATION OF STREAM RESTORATION OPPORTUNITIES

All of the stream restoration projects identified herein are considered high priority projects. They represent those projects where the more significant stability issues are present as well as those that have gained local interest. No further prioritization of projects was deemed necessary by the stakeholders because it is understood the various agencies and organizations will be interested in pursuing projects using their own prioritization process considering a variety of different issues. However, critical factors were identified and evaluated to show the benefits or possible constraints for each project. Below is a description of those factors and following is a table that identifies whether that factor applies to the individual project.

WMP Goals: Specific objectives for which the project was evaluated include: (1) Objective 2b: Protect, enhance, and restore terrestrial habitat, especially existing vegetation in riparian areas, and (2) Objective 2e: maintain stable stream banks and riparian areas to protect instream aquatic habitat and priority tree species.

Location: Is the project located in the lower portions of the watershed? It's likely that projects located in the lower watershed can have a greater impact on sediment trapping and prevent that sediment from reaching the lagoon.

Public Ownership: Is the property identified for the project in public ownership? Dependent upon the interest of the owner, project sites on privately held property or in an area with multiple owners may be more challenging to pursue.

Critical Timing: Does the channel exhibit concerns or issues that appear to require more immediate attention? The following critical timing issues have been identified:

SR-2 – imminent failure of concrete grade control structure
SR-6 – channel is completely blocked with debris at one location
SR-7 – development is imminent; property currently available for sale
SR-11 – parking lot damage has occurred and will likely continue

Multiple Benefits: Can multiple benefits be integrated with the project? The following multiple benefits have been identified:

SR-1 – would provide some degree of flooding relief
SR-2 – coordination with planned sewer line upgrades
SR-5 – restoration of significant watershed function prior to planned development

**Table 2-14. Evaluation of Stream Restoration Projects**

| Site | **Obj 2b:** Protect, existing vegetation in riparian areas | **Obj 2e:** maintain stable stream banks | **Located in Lower Watershed** | **Public Ownership** | **Critical Timing** | **Multiple Benefits** |
|---|---|---|---|---|---|---|
| SR-1 – Buena Creek at Agua Hedionda confluence | ● | ● | | | | ● |
| SR-2 – Agua Hedionda at Melrose Avenue | ● | ● | | ● | ● | ● |
| SR-3 – Agua Hedionda in Dawson Reserve | ● | ● | ● | ● | | |
| SR-4 – Agua Hedionda in Carlsbad | ● | ● | ● | ● | | |
| SR-5 – Agua Hedionda at Oak Lake | | | ● | | | ● |
| SR-6 – Buena Creek near Hollyberry | | ● | | | ● | |
| SR-7 – Calavera Creek at Melrose Avenue | | ● | | | ● | ● |
| SR-8 – Calavera Creek at Lake Blvd. | | ● | | | | |
| SR-9 – Calavera Creek in Oak Riparian Park | ● | ● | ● | ● | | |
| SR-10 – Little Encinas near Cannon Road | ● | ● | | ● | | |
| SR-11 – Little Encinas near Don Lorenzo Dr. | | ● | ● | | ● | |
| SR-12 – Agua Hedionda near S. Santa Fe Ave. | ● | ● | | | | |

# 3 Stormwater Retrofits

Agua Hedionda Creek is still a largely natural creek, but is being impacted by the urbanization that is occurring all around it. Development takes the form of suburban residential neighborhoods with landscaped yards, retail shopping areas, and large commercial areas of buildings set in large parking lots. Typical impacts from urbanization on natural creeks and streams include:

- Increased water temperatures from water running across asphalt and concrete
- Higher velocities from increased impervious surfaces and directed flow vs. surface flow
- Increases in flow quantities
- Pollutant loadings from streets and vehicle use (trash, oils, grease, metals)
- Pesticides and fertilizers from landscaped areas
- Year round runoff from irrigation, car washing and other outdoor water use
- Sedimentation from disturbed soils

Few areas in the Agua Hedionda Watershed have Best Management Practices (BMPs) installed to mitigate the stormwater impacts from development along the waterways. BMPs are now installed in all priority new development and redevelopment, however, these sites are not generally adjacent to waterways. Stormwater discharge points along the channels can be retrofitted with BMPs in a number of areas. The BMPs included in the stormwater retrofit opportunities are:

- Trash capture devices on stormdrains that drain primary streets and industrial and retail parking lots where there is evidence of trash. Generally, street trash is found in areas with high densities of fast food restaurants.
- Media filters installed in parking lot drains to capture pollutants before they enter the creek
- Bioswales to slow flow, allow for infiltration, and pollutant removal.
- Detention basins to reduce velocities by controlling the outlet, reducing the volume of water and pollutants by infiltration,
- Median plantings that allow for runoff capture. A typical median planting is above the grade of the street and sloped so that water runs off into the street. A sunken median with curb cuts allows water to infiltrate and prevents some of the water from entering the stormdrain system.
- Rain capture devices near large rooftops to allow water to be stored for landscape irrigation purposes.

Many stormwater retrofits can be installed when maintenance or re-design of a site dictates. For example, rather than simply re-paving exiting parking lots when they become cracked, pervious paving can be explored. If roads are widened, or street trees require replacement, this may be the time to retrofit the landscaped medians. While the stormwater BMPs are likely to be more expensive in the short-term, in the long term the benefits of reduced erosion, maintenance of natural areas, and improved water quality, may outweigh the costs.

## 3.1 Stormwater Retrofit Opportunities

Those areas of the creek experiencing the greatest impacts from urbanization are of course, the highest priority for BMP retrofit projects. However, with limited funding, an integrated approach to stormwater retrofits and creek restoration is recommended. Therefore, for purposes of this project, stormwater retrofit opportunities have been identified along reaches where stream restoration projects have been identified. For example, near site SR-2 substantial scour and bank failure has resulted in an exposed sewer pipe. At this site, stormwater impacts can be traced from the parking lots at the top of the drainage, down the hillside, across a street and eventually into the creek. Installing retrofits along the course of the

drainage will help lessen many of the causes of the current condition, and help ensure that the restoration is successful. Combining stream restoration and stormwater retrofits will increase the benefit of the overall project and should be addressed first. For instance, as stormwater retrofits are installed throughout the watershed, the water quality and morphology of the creek should improve ensuring stable wildlife habitat for the future. There are many locations throughout the watershed beyond the stream restoration sites that the techniques described herein are applicable.

Further research will be needed to determine actual sizes of structural BMPs based on the particular hydrology and hydraulics of each site, and water quality monitoring should be performed to determine the pollutants that are targeted for removal. What follows are stormwater retrofit opportunities for specific sites that correlate to stream restoration sites.

Appendix C includes the concept plan sheets for each site in which the elements of the project are identified.

### 3.1.1 Retrofit Opportunity at Site SW-1 Adjacent to Agua Hedionda

Agua Hedionda's creek ecosystem is still functional in this reach, but is impacted by residential development to the north and commercial development to the south. The major issues in this reach include stormdrain discharges contributing to creek scour and resulting in an exposed sewer line. As reported in the Agua Hedionda Watershed Water Quality Analysis and Recommendations Report, dated December 2007, sediment (TSS and turbidity) and bacteria (coliform and enteroccocus) are the greatest threats to watershed function in the Agua Hedionda watershed. Concentrations of these constituents exceed water quality objectives the majority of the time. While water quality testing has not been performed on the actual discharges to positively identify their characteristics, water quality is likely to be degraded due to untreated urban runoff and high water temperatures from large paved areas and rooftops.

The stormwater retrofit opportunity at this site will remove pollutants before they reach the creek, and decrease water velocities to reduce scour and allow for infiltration. This opportunity includes retrofitting storm drains with filter media to remove oils and grease deposited in the parking lots from vehicles. Maintenance of the BMP (cleaning and replacement of filter media) will be needed and the maintenance frequency will be determined based upon experience at the site, but should not be less than once at the start and once end of the rainy season (October and May).

A second part of this retrofit opportunity is to create a dry detention basin that will temporarily collect rainwater thereby slowing the velocity of water during storm events before water enters the creek. This basin would straddle north and south of the pump station access road with a culvert under the road (see photos SW1-1 and SW1-2). In this location, the gunite on either side of the road would be removed, and the detention area now encased in gunite would be widened and deepened. The slope above the site appears stable with established plantings and is unlikely to be a large contributor of sediment that could fill the detention basin and prevent its functioning as designed. Nonetheless, every several years in the dry season maintenance may be necessary to remove accumulated sediment and organic matter to allow for continued infiltration. This dry detention basin will remove pollutants not captured by the filters before discharging to the creek as well as slow down the flow velocity and allow for infiltration.

In the commercial development to the south (see photo SW1-3), the parking lots and buildings have created impervious surfaces that concentrate and accelerate storm water flows. Under natural conditions rainwater would land on vegetation that would disperse the water and rainwater would have had chance to percolate into the soil before flowing over the land and into the creek. To mitigate these impacts, rainwater can be captured from rooftops, and stored in cisterns for future use such as landscaping on other parts of the site, or slowly released. Pervious parking can further mitigate the hard surfaces by allowing for direct percolation into the soil. Both these measures will detain and reduce water velocities that impact the stream downhill of this site. In conjunction with the dry detention basin, this will provide a

treatment train that will provide benefits to the water quality as well as restoration of the more natural hydrology.

The main objective with these stormwater retrofits is to remove pollutants and reduce the hydraulic pressure on the creek where restoration is recommended. This site is in the City of Vista and is located in the same reach as Stream Restoration Opportunity SR-2.

### 3.1.2 Retrofit Opportunity at Site SW-2

This site has large commercial/industrial areas that have created large impervious surfaces with rooftops and paving. It is recommended that media filters be installed in street stormdrains that discharge directly into natural areas (see photo SW2-1, SW2-2, and SW2-3). If there is evidence of erosion, energy dissipating devices, such as rock riprap at the discharge point, may be necessary to slow water flow and discharge it over a wider surface area.

Because of the size of several of the buildings, it is recommended that rainwater from one of the rooftops be captured, treated and put into an underground cistern for later irrigation of planted median and site (see photo SW2-4). If the amount of water capture and reuse is significant, additional buildings may be slated for similar retrofits in the future. There are a number of systems on the market today which include baffle units buried and encased in liners to custom-made tanks. At street edges, such as Impala Drive, it is recommended that bioswales be installed to capture and infiltrate additional surface and street runoff. Trash traps are also recommended at the storm drains near the restaurants.

This site is in the City of Carlsbad and is within the same subwatershed as Stream Restoration Site SR-4.

### 3.1.3 Retrofit Opportunity at Site SW-3

Hilltop erosion from development and untreated stormwater can degrade water quality in the creek below. At the end of the intersection of Palmer Way and Cougar Drive it is recommended that an area be set aside for a dry detention basin for the purposes of slowing flow and removing pollutants. This dry detention basin will need to be carefully sited and planned to ensure the stability of the basin and to correct and not exacerbate the erosion (see photos SW3-1 and SW3-2). Prior to stormdrain discharge into this basin, media filters should be installed to capture oil and grease from the road and commercial areas.

Trash traps are also recommended at the stormdrains that collect water from the adjacent restaurants.

This site is in the City of Carlsbad and within the same reach as Stream Restoration Site SR-4.

### 3.1.4 Retrofit Opportunity at Site SW-4

This site has had significant residential development and, based on future land use maps, additional commercial and industrial development is planned to the west of the area. While there are still areas of open space, it is recommended that steps be taken now to mitigate current and future development. Major issues here include large stormdrain system discharges near the natural creek and likely water quality degradation from untreated runoff

The recommended retrofits in this area include a dry detention basin just past the end College Road to slow water and remove pollutants (see photos SW4-1 and SW4-2). Filter media should be installed at street stormdrains.

In addition, if at some point in the future the road needs to be widened or the street trees replaced, it is recommended that the paved part of the Cannon Road median be removed and the grade depressed and planted (see photos SW4-3). The existing grade for the trees can remain as currently configured; this will

create an undulating grade within the median. Curb cut-outs can then be made to allow water to drain to the median, infiltrate and relieve the stormdrains.

This site is in the City of Carlsbad and within the same subwatershed as Stream Restoration Site SR-4.

### 3.1.5 Retrofit Opportunity at Site SW-5

In this location, Cannon Road is very close to the creek and it is likely that increased flow velocities from Cannon Road and untreated stormwater impact the creek and degrade water quality (see photos SW5-1 and SW5-2). If Cannon Road is eventually extended, then care should be taken to properly plan and execute the design and construction to impact the creek as little as possible and incorporate BMPs at the start of the road project.

As mentioned previously, if at some point in the future the road needs to be widened or the street trees replaced, it is recommended that the paved part of the Cannon Road median be removed and the grade depressed and planted. The existing grade for the trees can remain as currently configured; this will create an undulating grade within the median. Curb cut-outs can then be made to allow water to drain to the median and infiltrate and relieve the stormdrains.

Alternatively, if it is unlikely that the road will ever be extended, a dry detention facility could be constructed at the end of the road to capture, slow down and treat the runoff.

This project is located in the same subwatershed as Site SR-10 within the City of Oceanside.

## 3.2 COST ESTIMATE FOR RETROFIT OPPORTUNITIES

Under the ideal scenario, water quality and quantity monitoring would take place under a number of conditions and over several seasons to identify pollutant concentrations, and flow velocities discharging from the stormdrains and into the creek. This pre-design work is essential for properly sizing BMPs such as dry detention basins, but also for initial estimates for maintenance regimes such as replacing filter media and removing trash from capture devices and for post-construction effectiveness assessments.

In addition, careful soil testing will be needed to determine percolation rates and subsequent suitability for plant growth and development. During development, it is not uncommon for topsoil to be removed or plowed under during grading and nutrient-poor sub-soils to be left on the surface. When grading is performed, heavy equipment may also severely compact soils restricting natural infiltration and percolation. Therefore, it is recommended that soil testing to determine type (e.g. sand, clay, or loam) nutrient levels, and porosity be conducted at each of the individual sites.

As stormwater technology advances, new products are coming to market and solutions can be tailor-made to each situation. With proper knowledge of the flow, pollutants and soil, future costs can be saved with efficient BMP design.

With new advances in the science and technology of urban and stormwater management, cost estimates can quickly become obsolete. Nonetheless, the chart below can be considered a general guide to costs for purposed of comparison. These should be taken as approximate unit prices. Additional testing, monitoring and design would need to be complete before estimates of costs for each site could be more definitively estimated.

The following table provides conceptual level the unit costs associated with each BMP:

**Table 3-1. Stormwater Retrofit Costs**

| BMP | Unit Price |
|---|---|
| Dry detention | $6.00/cf |
| Bioswales | $1.00/cf |
| Cisterns | $7.5K/1800 gallons |
| Depressed medians | $1.00/cf |
| Grading | $2/cy |
| Media filter | $4.5/cfs -$3k/catch basin |
| Pervious paving | $10 - $15/sf |
| Trees | $3.50/sf |
| Shrubs | $1.75/sf |
| Trash Traps | $350/opening |

## 3.3 WATER QUALITY AND QUANTITY BENEFIT ESTIMATES FOR RETROFIT OPPORTUNITIES

An analysis of the benefits of these projects is underway and will be documented in the Watershed Management Report.

## 3.4 REFERENCES

Center for Watershed Protection. 2007. National Pollutant Removal Performance Database. Version 3. Center for Watershed Protection. Ellicott City, MD. http://www.cwp.org/Downloads/bmpwriteup_092007_v3.pdf (accessed on 05/08/2008)

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