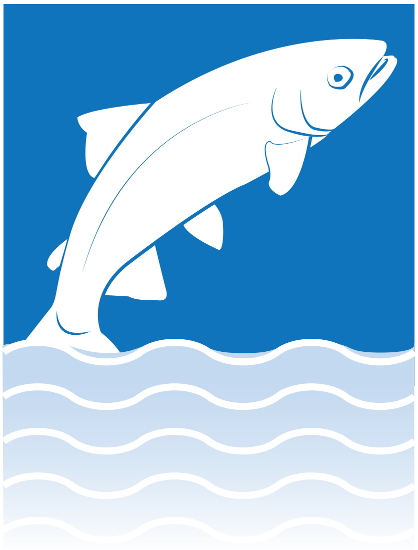

Chapter 4
Six Key Projects

The restoration projects described in this chapter were carefully chosen to represent a broad range of methods of restoring habitats and managing water quality. They are applicable to most of California, proven to be effective, and critical to restoring habitat and water quality in the state. This is not meant to be an exhaustive list; there are many more projects and practices available to restoration practitioners. Additional projects may be added to this evolving manual as their effectiveness and importance are evaluated.

Each project write-up is meant to provide general guidelines for planning and implementing that particular project, either alone or as part of a larger restoration effort. The practitioner is advised to seek out additional resources and experts for help determining if a particular project is appropriate and for assistance in subsequent planning, preparation, and implementation.

Each project offers a wide range of benefits to wildlife, stream health, and water quality. The table below identifies some of the specific benefits associated with each one.

	Removing an In-stream Barrier	Emplacing Large Woody Material	Fencing a Riparian Area	Trapping Stormwater	Buffering a Wetland	Managing Wetland Water Level
Allow fish migration	💧					
Restore hydrologic processes	💧	💧				💧
Increase habitat complexity		💧			💧	💧
Control erosion & sedimentation		💧	💧	💧	💧	
Restore habitat	💧	💧	💧			
Improve water quality			💧	💧	💧	💧
Recharge groundwater				💧	💧	
Control non-native species			💧			💧
Support wildlife populations	💧	💧	💧		💧	💧

This Project description is part of the full publication "Habitat Restoration and Water Quality Management"

For more information email info@elkhornsloughctp.org

Project 4
Constructing a Storage Pond for Trapping Stormwater

The creation of stormwater storage ponds provides flow control for storm-related runoff and can reduce erosion, recharge groundwater, improve water quality, and provide wildlife habitat.

Background

Stormwater runoff is the rainwater that is not absorbed into the soil but instead runs across the soil surface and into streams and rivers. This runoff can transport pollutants, sediments, and debris into drainages and ultimately into larger bodies of water. It can also cause significant erosion. Stormwater runoff is part of a natural hydrologic process, but the impermeable surfaces and altered natural drainage patterns associated wtih human development can greatly increase the volume of stormwater runoff and thus the severity of its negative impacts.

Historically, stormwater management plans focused on managing rare events, such as the large-scale, infrequent storms that occur typically only once in 100 years ("100-year events"). More recently, the increasing frequency of

Benefits

By reducing the amount of pollutants and sediments reaching streams, stormwater storage ponds improve water quality and riparian habitat values. A variety of secondary benefits, noted below, increase their value as restoration projects.

Reduces erosion. By limiting the volume and flow of surface runoff, stormwater ponds reduce erosion downslope.

Recharges groundwater. Runoff held in storage ponds may infiltrate into the ground, replenishing aquifers.

Improves water quality. Stormwater storage ponds remove sediments, nutrients, bacteria, oil, pesticides, and other pollutants contained in runoff. When runoff is held in ponds for sufficient periods of time, sediment and associated particulate pollutants are allowed to settle and are not carried further downstream. Other pollutants are removed as the water percolates through the soil, and as plants growing in the ponds absorb nutrients.

Provides habitat. When they hold water for significant periods, stormwater storage ponds can serve these large-scale events, along with an increasing awareness that storms of medium intensity—and even the low-intensity storms that begin the wet season in California—can produce significant runoff carrying harmful pollutants and sediments, has changed our approach to managing stormwater. It is now recognized that managing the runoff from storms of all sizes is an important way of protecting streams from the negative effects of storm runoff, particularly where human development has altered drainage patterns.

as wetland habitats. Although little information exists from California, studies of stormwater storage ponds elsewhere suggest stormwater storage ponds provide at least low-quality habitat for a limited number of species (Bishop et al 2000a and Bishop et al 2000b).

Planning

The first step in addressing stormwater runoff or pollutant issues is to complete a stormwater management plan. This type of plan analyzes the watershed as a whole and determines the most feasible means of addressing stormwater-related issues. Increasingly, this planning is being done in conjunction with proposed development, so that stormwater solutions can be integrated into the planning and address the issue of how to maintain surface permeability and soil water retention in the built landscape. However, in some cases stormwater management planning or mitigation takes place *post hoc*, when means of addressing stormwater issues are more limited. In both situations, stormwater storage ponds can be a primary means of addressing runoff issues.

When a stormwater storage pond is called for in a plan, or otherwise deemed appropriate, pond location, soil permeability, pond size, inflow runoff volume, hydraulic residence time, and maintenance requirements are important planning considerations. Data related to some of these factors are gathered in the Advance Analysis phase discussed below.

A key choice to make during the planning phase is what type of storage pond to construct. Stormwater storage ponds can be designed for either detention or retention. Detention ponds hold water during a storm event and slowly release the water via infiltration or evaporation. Retention ponds are designed to hold water year-round. Both are beneficial in controlling stormwater runoff but offer different conservation benefits. The choice between the two is determined by the size of the site, the permeability of the soil, and the objectives of the project, as determined by the stormwater management plan. A detention pond is the better choice for groundwater recharge benefits; a retention pond carries the potential of creating its own wetland habitat.

Site constraints strongly influence stormwater storage pond design. It is best if the site is accessible and relatively flat; if the site is more than gently sloped, it should be geologically stable so that the pond does not pose a threat to downslope property and lives. Retention

Photo P4.1 Black wildlife exclusion fencing to exclude sensitive amphibians. Orange fencing to preserve native plants. Photo: ESNERR

ponds require more space than detention ponds, and are not recommended for small areas. With either type, a large pond is often necessary to make up for the loss of water-storage capacity in the soil that is associated with covering significant areas of soil with non-permeable surfaces such as roads and roofs.

Planning a stormwater storage pond often involves a landscaping plan. The terrestrial vegetation uplsope of the pond and downstream of its outlet may play an important role in reducing the sediment load of stormwater runoff, and may be nearly as important as the aquatic and semi-aquatic plant life in the pond in removing nutrients and other pollutants.

Advance Analysis

Site Assessment

Soil permeability determines the anticipated hydraulic residence time of the pond, which in turn has important implications for the type of pond to be constructed. Soil analysis, therefore, is the most important assessment informing pond design. Sandy soils offer greater permeability and so are more appropriate for detention ponds; clay soils are less permeable and more appropriate for retention ponds (Lemus, et al. 2003). If the soils are determined to be particularly porous, pond design may need to account for the possibility that soluble chemicals such as nitrate and chloride may leach through the soils into groundwater.

A hydrological assessment is also crucial because the potential rate and volume of runoff to be directed into the pond determine the pond's minimum size and volume and the amount of runoff that may need to be released from the pond.

The landscape contours of the immediate site determine how much engineering will be required to create a pond with the desired volume and function. A steeper site will require a taller impounding embankment; in a relatively flat site much of the pond volume can be created through excavation. The relative steepness of the slopes perpendicular to the main slope are an important factor as well because they affect the length of the impounding embankment. These basic characteristics of the site must be surveyed prior to creating a design for the pond.

Seasonality

As with most restoration projects in California, actual construction of the pond should be completed during the dry season from late spring to early autumn.

Expertise Needed

Hydrologist. As noted above, it is necessary for a hydrologist to assess the proposed pond's catchment area and its runoff potential. A hydrologist may also help determine how best to manage the water levels in a retention pond.

Biologist. If sensitive species may be impacted by pond construction or operation, or if growth of invasive species is anticipated to be a problem, a biologist may be needed to provide guidance on mitigating these concerns.

Botanist. A person with expertise in native plants can help to design more natural conditions and promote better water quality benefits.

Engineer. An engineer provides valuable input on pond design, particularly as it applies to the pond's impoundment barrier and outflow. An engineer may help direct pond excavation, construction of the impounding embankment, and installation of the drainage and outlet devices.

Photo P4.2 Expertise is important for designing stormwater storage ponds.

Implementation

Design

Pond size (surface area and volume) is a primary design issue. Storage pond volume must account for small but frequent annual storms and larger 10- to 20-year storm events, and do so in the specific context of the pond's catchment area. Storage ponds are often shallow (3–9 feet deep), in part to allow for more rooted wetland vegetation around the perimeter. The depth of the pond's pooled water is determined by the elevation of the outlet above the basin floor at the far end of the pool. The recommended length-to-width ratio is 3:1 to allow for level spreading of water over the entire basin (Lemus, Devinney et al. 2003). It should be noted that ponds designed to effectively contain and treat pollutants from first-flush scenarios may need to hold considerably higher volumes of water than previously thought (Sansalone and Christina 2004).

A stormwater storage pond is typically built with three distinct volume levels. The top level should have the storage capacity to manage large, infrequent storms (10-, 25-, or 100-year). The middle level or "water quality" level is designed to hold runoff from smaller storms for a period of time that allows pollutants to settle out and be removed. The third or bottom level can be designed to be either a permanent storage pond or to be seasonally dry.

Pond shape, surrounding vegetation, and optional enhancements are additional design considerations. Long, narrow ponds or wedge-shaped ponds are the preferred shapes for extending settling time and improving water quality of streams downslope. The vegetation around the pond helps remove pollutants and provides habitat. Additionally, creating a forebay, an area of the pond that is more easily and regularly maintained, can reduce the build-up of pollutants in the rest of the pond, improving habitat function and extending the pond's useful lifetime.

The steepness of a storage pond's sides is another important design consideration. The selected slope must balance ease of access, available space, and erosion potential. The side slopes of storage ponds should be no steeper than 3 units in the horizontal to 1 unit in the vertical. Gently sloping sides encourage vegetation in the shallower areas of the pond and provide rearing habitat for aquatic larvae. Flatter slopes also allow for easy access for maintenance and protect the sides from erosion during large storm flow events. However,

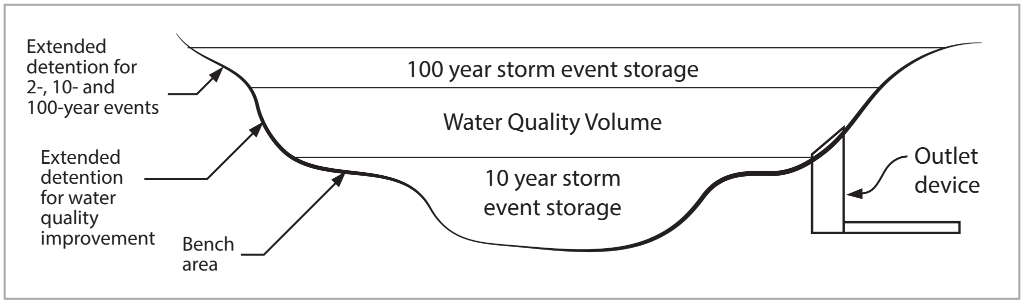

Figure P4.3 Cross sectional design of a typical stormwater storage pond (from Pitt 1996).

in cases where space is limited, side slopes may need to be relatively steep to create a larger storage volume. In urban settings, vertical concrete retaining walls may be used, although this does not allow for rooted vegetation. If rooted vegetation is not possible, non-rooted vegetation may be retained around the perimeter.

It is important that the downslope embankment or dam impounding the stormwater be properly designed. It must, first of all, be capable of holding the pond's maximum volume without any risk of failure. This is a minor concern for ponds on relatively flat slopes constructed primarily through excavation, but the steeper the slope and the more that fill from the excavation is used to create a dam that increases pond volume, the more attention must be given to the integrity and strength of the impounding embankment. A related issue is the design of the pond outflow and emergency spillway; they must together be capable of handling the maximum anticipated volume of overflow without causing downslope/downstream erosion. The level of water in the pond must not be capable of rising high enough to overtop the impounding embankment, because this could cause it to quickly erode and fail.

Materials

The materials needed to create a typical stormwater storage pond are piping and other materials for the outflow, riprap for reinforcing embankments, and concrete or riprap for the spillway. Many ponds will also incorporate aquatic plants, terrestrial plants for landscaping around the pond, and imported earth/rock material for construction or reinforcement of the impounding embankment. Some ponds (e.g., retention ponds in sites with sandy soil) will need lining materials.

Adaptive Management

Monitoring

Whether monitoring is part of a stormwater storage pond project or not depends on the goals and objectives of the stormwater management plan and the role of the pond within that plan or another restoration or management plan. Since a stormwater storage pond is usually intended to protect the water quality of a stream or wetland not in the immediate vicinity of the pond, the most relevant environmental monitoring would occur in that stream or wetland. Data from this monitoring might then inform adaptive management of the pond. If a goal of the pond is to create new wetland habitat, then the pond itself might require monitoring in order to assess how it is meeting that habitat goal.

Maintenance

Because they are designed to trap sediment, stormwater storage ponds will gradually fill with sediment. Sediment build-up greatly reduces the efficacy of a retention pond. Monitoring sedimentation and minimizing sediment inflow are therefore two primary maintenance activities. Regular maintenance and sediment removal ensures better performance and extends the useful life of a pond. Studies suggest a need for inspections at least as frequently as every two years (U. of Minnesota 2015).

A maintenance plan should include inspection for and removal of rotting plants, debris, and invasive or nuisance pests. Regular repairs to the sides and bottoms prolong the life of a pond. In addition there should be an established schedule for mowing, plant and sediment removal, and regular cleaning to insure unobstructed flow. Mosquito abatement may be necessary.

Ponds designed as retention ponds may require supplemental water to counter evaporation during dry periods. In the case of detention ponds, is important to mimic natural hydroperiods to provide habitat that favors native aquatic and semi-aquatic wildlife.

Table P4.4 Typical maintenance activities for dry ponds

Activity	Schedule
Assess erosion of pond banks	Semiannual
• Inspect for damage to the impounding embankment • Monitor sediment accumulation in the facility and forebay • Examine to ensure that inlet and outlet devices are free of debris and operational	Annual
Repair undercut or eroded areas Mow side slopes Manage input of pesticides and nutrients Remove litter and debris	Standard maintenance
Seed or sod to restore dead or damaged ground cover	Annual, as needed
Remove sediment from the forebay	Every 5 to 7 years
Remove sediment when the pond volume has been reduced by 25 percent	After 25 to 50 years

Table modified from Livingston, E., et al. 1997.

Potential Concerns

Negative impacts to wildlife. Stormwater storage ponds may benefit or harm sensitive species, depending on their design and management. To avoid detrimental impacts, ponds should be designed so that construction and management measures avoid negative impacts to species. Stormwater storage ponds offer the greatest benefits if operated like ponds found in the vicinity. The further the pond moves away from these local natural conditions, the greater the potential for doing harm. A survey of ponds in the vicinity identifies species that are likely to be attracted to the newly created pond. Management plans that involve seasonal draining or infrequent dredging must consider the life history of species that are predicted to use the pond.

Attraction of pest species. Stormwater storage ponds that hold water for longer periods of time risk attracting pest species such as mosquitoes. Mosquito control can be addressed through proper design and maintenance of these ponds. During the planning stage, local vector control agencies should be consulted as they understand the highly variable regional issues associated with mosquito control. In general, mosquito breeding potential depends on the depth and location of standing water. Design and maintenance manuals contain recommendations for minimum pool depths and suggest how to create habitat for mosquito predators such as dragonflies (Lemus, et al. 2003).

Anoxic conditions. In retention ponds where water sits for extended periods and nutrient levels are sufficient, conditions can promote the growth of algae. While algae may benefit some species, if left unmanaged it can bloom, creating anoxic conditions and nuisance odors. The potential for algal blooms may be reduced by limiting the pond's nutrient input and managing the pond's aquatic ecosystem to ensure the presence of algae-consuming organisms. If these strategies are inadequate, it may be necessary to introduce air to the bottom of the pond to oxygenate the water and encourage mixing.

Flooding. During heavy flow periods, stormwater storage ponds may fill too rapidly to contain the volume. Flooding can occur if the pond overflows in an uncontrolled manner or the impounding embankment fails. This risk is minimized by employing experts in hydrological analysis and engineering during the planning and design phases. A properly designed impounding embankment includes an emergency spillway that can handle unusually large volumes of water (such as those generated by 100-year flooding event) and prevent overtopping of the embankment.

Habitat damage. During pond construction, heavy ground moving equipment may be used; the resulting disturbance can present risks to the surrounding area and species. Careful advance planning that accounts for the specifics of site access can minimize this damage. If sensitive species may be present, it is important to survey for them and undertake appropriate mitigation steps.

Photo P4.5 Stormwater pond Photo: ESNERR

Contaminant accumulation. As stormwater flows over the landscape, it can accumulate various pollutants and nutrients. As it passes through urban areas, stormwater can capture oil, chemicals, and trash. Stormwater flowing from agricultural fields often contains nutrients from fertilizers as well as pesticides. Stormwater storage ponds are designed to allow these materials to settle out of the water or be absorbed by plants. Over time, these materials will accumulate in pond sediment. At the very least, this means that when sediments are removed from the pond for maintenance purposes, the potential load of toxics must be accounted for. Some contaminants, such as mercury, do not remain inert but are instead incorporated into the aquatic food chain and bio-accumulate in living tissue; this presents a different set of management issues.

Human safety risks. Finally, there is the potential risk to human life associated with open water. Drowning, while rare, may occur in ponds, especially when they are located near urban areas. It is recommended that exclusionary fencing and informative signage be placed near and around all ponds. A gradual slope around a pond eases maintenance access and limits the risk of people accidentally falling into the pond.

Costs

The costs associated with the creation of stormwater storage ponds vary greatly between sites and projects. Detention ponds tend to be less expensive than retention ponds because they are often smaller. Cost estimates should consider all phases: planning, design, implementation, and adaptive management. Annual maintenance costs typically equal 3–5% of construction cost.

One study (Brown and Schueler 1997) evaluated the costs associated with creating stormwater storage ponds. Their findings, which should be adjusted for inflation, are presented in Table P4.6.

Table P4.6 Estimated costs for construction of detention and retention ponds of varying volume

	Detention Pond	Retention Pond
1 acre-foot	$41,600	$45,700
10 acre-feet	$239,000	$232,000
100 acre-feet	$1,380,000	$1,170,000
Formula for cost calculation*	C = 12.4V0.760	C = 24.5V0.705

*Where C = construction, design, and permitting cost and V = volume needed to control the 10-year storm (ft^3). Data from Brown and Schueler 1997.

Related Resources

- The Stormwater Mitigation paper (Lemus, et al. 2003) is an excellent resource for suppliers and designs for storage ponds.
- *The Minnesota Urban Small Sites BMP Manual* (Metropolitan Council 2001) provides guidance on design and maintenance of stormwater storage ponds.
- The Society of Wetland Scientists' paper on mosquito control in wetland management (Megonigal, 2009) provides an overview of the biological context for mosquito control and reviews tools and techniques available to wetland managers to control mosquitoes.

Case Study

Pajaro Valley High School Stormwater Detention Basin

Pajaro Valley Unified School District, City of Watsonville
Watsonville Wetlands Watch

Pajaro Valley High School is a high school located within the Watsonville Slough System watershed, a large and significant predominately freshwater slough system on the California coast. The school opened in 2005 and due to its location within the Coastal Zone and adjacent to sensitive wetland and associated upland habitat, several conditions were placed on the school. One condition was the creation of a series of stormwater detention basins (ponds) along the drainage corridor within which all of the stormwater runoff from the school passes prior to draining into sensitive habitat areas. The project serves as a model for school site stormwater management.

Implementation

All of the drainage from the school is directed to an underground network of drainage pipes that lead to the series of five stormwater detention basins. This includes a series of French drains located within grassed median strips in the school's parking area. Stormwater collects in each basin and then overflows into the next until it reaches the final basin, where it must pass through a carbon filter. Native plants have been planted around the detention basins in order to add natural habitat to the school site and provide an aesthetically pleasing demonstration of low water use landscaping within the school campus. Once the storm water leaves the campus it flows into West Struve Slough, which is part of a wildlife preserve owned by the California Department of Fish and Wildlife. Students have worked with the non-profit involved in this project, Watsonville Wetlands Watch, to install a 1-acre grassed waterway with over 5,000 native plants that provides additional filtration and soil stabilization downstream of the final detention basin.

Results

Water-quality testing conducted by the school district has shown that the water leaving the school is of good quality. Additional water quality testing at the top of the "post-treatment" grassed waterway and bottom of the waterway show additional nutrient and bacteria remediation benefits, with over 90% of total coliform and approximately 50% of nitrates removed. Native habitat has grown in at the entrance to the school, providing an aesthetically pleasing demonstration and learning site for students and the community to better understand stormwater treatment options and the importance of proper handling of stormwater.

For more information, visit http://www.watsonvillewetlandswatch.org/

Task Checklist

Design the project

- [ ] Contact land owner to discuss restoration work
- [ ] Create a team of experts that include but are not limited to; land owner, environmental consultant, local RCD and/or NRCS staff, contractor……
- [ ] Describe objectives and purpose of restoration work
- [ ] Define adaptive management strategy
- [ ] Account for machine access
- [ ] Create work plan
- [ ] Contact regulatory agency to understand regulations associated with practice
- [ ] Contract with sub-contractors

Analyze the site

- [ ] Conduct soil assessment
- [ ] Conduct biological survey
- [ ] Conduct hydrology study

Prepare site for the creation of a storage pond

- [ ] Clear site of brush
- [ ] Excavate site
- [ ] Grade sides to create optimum slope
- [ ] Line bottom if determined necessary in soil analysis
- [ ] Plant aquatic rooted vegetation
- [ ] Install outflow and emergency spillway
- [ ] Place rock and other reinforcement material
- [ ] Plant banks and spillways with vegetation

Maintenance the first year

- [ ] Remove debris
- [ ] Replant where necessary
- [ ] Mow if needed