A Landowner's Guide to the Design of Constructed Wetlands

Restoration as a Means to Treat Agricultural Runoff

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1.0 Introduction

Ducks Unlimited, Inc., in partnership with the Coalition for Urban/Rural Environmental Stewardship (CURES) and the Central Valley Regional Water Quality Control Board (CVRWQCB), has developed this guide to aid landowners in the development of management strategies to meet water quality standards in the San Joaquin River Watershed. This guide is a companion to *A Landowner's Guide to Best Management Practices,* which provides a general explanation of Best Management Practices (BMPs), including their implementation, funding sources, case studies of existing projects and contact information for further assistance. This guide focuses on the engineering and biological designs of one specific BMP – constructed wetlands. Landowners should not rely on this guide as the sole resource for design and construction, but to rather as an overview for developing a conceptual design and basis for working effectively with biologists and engineers on the final design and construction.

2.0 Background

While there are a variety of BMP options available to the landowner, those that treat runoff before it is discharged to a water body (such as constructed wetlands) can be particularly effective at improving water quality. Land can be set aside to intercept runoff in a settling basin and constructed wetland cells in order to treat the runoff prior to discharge to downstream users or into a water body. Settling basins are designed to slow the flow rate to the extent that silt and other constituents settle out of the water. Constructed wetlands further enhance the treatment by not only continuing to physically filter out remaining sediment but to also remove constituents through biogeochemical interactions with the vegetation and underlying soil. Constructed wetlands have been developed in many areas of the world to treat municipal, industrial and agricultural waters. They have proven to be an effective means to not only improve water quality, but to also provide wildlife habitat.

Given the variety of site conditions and the complexity of wetland systems, there are many ways in which a constructed wetland can be designed to enhance water quality and, if desired, provide habitat benefits. Adhering to a set of guidelines and design factors will significantly improve the performance of any constructed wetland.

A number of financial incentives exist for landowners interested in wetland restoration. Non-profit organizations and public agencies offer a variety of financial and technical assistance programs designed to promote the restoration and enhancement of wetland habitat. See *A Landowner's Guide to Best Management Practices* for more information.

3.0 Participants

This document, part of a CALFED Drinking Water Program grant for the Orestimba Creek Watershed, is designed to assist growers and the local watershed coalition in meeting the state water quality standards for agricultural discharges that took effect in 2004. This guide explores the economics, farm practices, and existing BMPs in the Orestimba Creek Watershed in addition to promoting opportunities for treatment BMPs.

The project is administered by the Coalition for Urban/Rural Environmental Stewardship (CURES) in cooperation with the Westside San Joaquin River Watershed Coalition, the California Water Institute at California State University, Fresno, Ducks Unlimited, Inc., Natural Resources Conservation Service (NRCS), Central California Irrigation District, and Del Puerto Water District. Ducks Unlimited, Inc. was the lead in the development of this specific document.

4.0 Format

The following information is provided in this document:

- **Section 5.0 – How a Constructed Wetland Works** – explains the processes that occur in a wetland and how they can remove pollutants
- **Section 6.0 – Engineering Design of Constructed Wetlands** – site-specific information that influence the engineering design, as well as an overview of engineering features common to constructed wetlands
- **Section 7.0 – Biological Design of Constructed Wetlands** – explores the establishment of vegetation and habitat in a wetland
- **Section 8.0 – Construction** – implementation of a carefully planned project design requires attention to the oversight of construction activities
- **Section 9.0 - Case Study of Wingsetter Wetland Ranch** - take a look at a functioning constructed wetland in the Orestimba Creek watershed.
- **Section 10.0 – Conclusions**
- **Appendices**

5.0 How a Constructed Wetland Works

Wetlands are among the most productive systems on the planet. They provide increased flood storage, critical fish and wildlife habitat, quality recreation opportunities, recharge of groundwater and purification of surface water runoff. Wetlands act as natural filters of non-point source pollutants such as sediment, nutrients and chemicals before flowing to rivers, streams, lakes and coastal waters.

There are several mechanisms through which a wetland removes pollutants from the water column. Generally a pollutant (1) settles out or is filtered out of the water column, (2) chemically interacts with or adsorbs onto a variety of wetland surfaces (soil, vegetation, etc), or (3) is directly taken up by vegetation and algae. These processes occur either in the water column, the underlying soil substrate, or in the vegetation. Both wetland hydraulics and vegetation play a role in how effective these removal mechanisms are. This section discusses hydraulics and how each of the processes removes pollutants.

Sedimentation

Sedimentation plays a major role in removing pollutants, especially in erosion-prone areas. As water enters a basin or wetland, the flow velocity slows and sediments suspended in the water column begin to settle to the bottom of the pond. Many common pollutants such as metals, pesticides, salts and nutrients tend to attach themselves to these sediments, and thus settle out as well. Generally, heavier materials will settle at a more rapid rate than finer sediments. If inflows are high in sediment concentrations, a settling basin should be constructed at the inlet to capture the majority of solids entering the system.

Soils and the Underlying Substrate

The underlying substrate consists of vegetative litter, partially decomposed organic matter, and soils. Pollutants are filtered out of the water column through adsorption to the substrate material and through microbial activity. As wetlands typically have low levels of dissolved oxygen, the microbes present (bacteria, yeasts, fungi, protozoa and ring algae) function through anaerobic respiration which transforms and breaks down certain pollutants. The transformed pollutants are either released back into the water column or remain stored in the soil.

Wetland Vegetation

Wetland vegetation affects the removal of pollutants in various ways. Plants and algae release oxygen to the water, increasing microbial breakdown of certain pollutants. Vegetation slows the flow of water through the wetland, reducing erosion and allowing more time for pollutant removal. Root systems absorb nutrients and other pollutants and incorporate them into plant tissues. Decomposing plant material provides nutrients and carbon to sustain microbes. Invertebrate animals (insects/worms) consume organic material and break up detritus material, enhancing decomposition.

Wetland Dynamics

The ability of a wetland to remove pollutants depends on a dynamic relationship between oxygen availability, carbon levels, pollutant concentrations, soil and vegetation composition, and many other environmental factors that are beyond the scope of this report. The contact time, the amount of time the pollutant is in contact with the substrate, plays a key role. The slower the rate of flow through the wetland, the longer the contact time and generally the more efficient a wetland is at removing pollutants. In addition to contact time, the more surface area (underlying substrate and vegetation surfaces) the pollutants are in contact with, the more efficient the wetland may be at pollutant removal. **See Section 6.4** for more details on wetland hydraulics.

6.0 Engineering Design of Constructed Wetlands

The Landowner's Guide to Best Management Practices provides information on the general guidelines for developing a treatment BMP, including constructed wetlands. These include forming a vision and set of objectives, exploring funding options, entering an agreement (if seeking financial assistance), and finally the planning and design.

The initial vision is a conceptual plan which may vary from a simple sketch to a design that includes site-specific factors. Both levels of conceptual design are valuable in providing a starting point to determine what additional information is needed to develop a desirable and functional final design. As the conceptual plan is modified during the design process to address site factors, it is important to periodically revisit the initial objectives, ensuring that the final design meets those objectives and functional requirements.

There are several phases involved with the design of a constructed wetland. Although these phases may not occur sequentially, it is important that each is incorporated during the design process. These include the following:

- Site Characterization
- Engineering Design
- Biological Design – Discussed in Section 7.0.

6.1 Site Characterization

There are a variety of site-specific data and factors to consider when designing a treatment wetland. A thorough site characterization will expedite the design process and enhance the quality of design.

It is important to collect as much data as possible on the existing property. These data will be useful in designing a wetland that meets functional objectives, is economically feasible, and will give insight into how the wetland can be managed. These data include the following:

Water Availability: Generally, runoff is the main water source for treatment BMPs; however, it is important to assess whether this will supply a sufficient quantity of water at desired times. If not, is there an alternative source available such as a groundwater? Are the maintenance costs for pumping groundwater affordable? Will the wetland be flooded during the winter when the property is not receiving irrigation runoff? Changes in upstream management also need to be considered, as these can impact the quantity and quality of incoming flow.

Flow Rates: The amount of water flowing into the property is a key parameter in determining the size of wetland treatment cells. This may be expressed as gallons per minute (gpm) or cubic feet per second (cfs). Although the flow rate may fluctuate, it is useful to have a general idea of the maximum flow and range of flows that the property typically receives. If the property receives water from a variety of locations (e.g., two ditches flow into the property), identify the flow rates for each location.

Concentrations of Pollutants: If information is available on the concentrations of pollutants entering the property, this can be useful in designing the wetland. There are several water quality models that can be used to determine the size of a constructed wetland needed to remove pollutants given the flow rates entering the wetland and the desired level of pollutant removal. A discussion of these models is beyond the scope of this document. More information can be found in the additional resources listed in **Appendix F.**

Topography: As discussed in the following section the topography plays a key role in determining the location, size, and shape of the wetland cells for both hydraulic and economic reasons. Topographic information is also needed to provide a valid estimate of the amount of earthwork needed to construct the cells, levees and other features.

Soils: The soils make up a large portion of the underlying substrate and play a key role in water treatment. **See Section 5.0.** Hydric soils are more conducive for the establishment of wetland habitat than others. The soil type can significantly affect the design, construction and management practices. National Resource Conservation Service (NRCS) maps provide general information on soil types; however, these maps may not provide enough detail to capture local soil characteristics. If soils are of concern it may be necessary to take soil samples on the property.

Shallow groundwater: Shallow groundwater tables can contribute to drainage problems, construction issues, and structure instability. Conversely, it may provide a source of water during the winter season if managed effectively. Groundwater concerns should be addressed during the design phase and accounted for in the design and in management practices.

Prevailing winds: Winds play a role in wetland design when there is open water and the potential for wave erosion on the sides of levees. Vegetation and broader levee slopes may be designed to compensate for this.

Site History: Information on the history of a site can be of great assistance during the design process and enhance the longevity and economics of the project. For example, information on the historical flooding of a property can be useful in determining the level of erosion control that may be necessary. The location of natural water features (historical sloughs and river channels) that have been altered may provide valuable insight into soil types and how to restore the property back to its natural state.

6.2 Engineering Features

Engineering features common to constructed wetlands include wetland cells (ponds), levees, water control structures, ditches and swales, and settling basins. This section describes the purpose of each feature and design recommendations.

Cells (Ponds) - Constructed by excavating an area or building a levee around the perimeter, ponds provide temporary storage of runoff.

- Design to ensure cell drains sufficiently - a slope of one percent is generally adequate.
- Design multiple ponds to enhance treatment and habitat value.
- Design ponds at varying depths to provide a variety of habitat and enhance nutrient removal.

Levees - Form perimeter of pond to retain water. Interior levees may also be built to control water flow and assist with management.

- It is imperative that the levees are made of impermeable earth material (avoid sand and organic materials) and compacted well to prevent seepage, erosion and failure.
- Recommended side slopes of 5:1 - this provides a sufficient slope for mower. Slopes greater than 5:1 are recommended if exposed to open water and windy conditions where erosion is a concern.
- Allow for a freeboard (difference between the top of the levee and the design water surface elevation) of at least one foot.
- Riprap or erosion control fabric may be necessary in areas where erosion is a concern.
- The top width should allow for vehicular traffic (10 – 12 feet) where needed.
- Levee tops may need to be graveled for all-weather access.

Water Control Structures (WCS) - Concrete, steel, or plastic structures that typically consist of a riser with a culvert conveying the water under a levee, used to regulate water flows and depths.

- Ensure the WCSs are durable yet simple and easy to adjust.
- Position in a manner to encourage flow throughout the entire wetland cell.

- Minimize local flow velocities around the water control structures to reduce erosion and re-suspension of sediments

Swales – Facilitates drainage of cell while also providing a variety of water depths and associated vegetation.

- Curvy alignments provide more of a natural appearance and enhance habitat value
- Slopes and width should be adequately sized for a mower or other means of vegetation maintenance.

Ditches – Convey water between cells and provide additional water treatment via the soils and vegetation in the ditch.

- Should be of adequate size to convey flows (minimum capacity equal to that of a 10-year, 24-hour storm)
- Minimum side slopes of 3:1

Islands - Islands within the interior of the cells increase habitat value and diversity.

- A mixture of submerged islands (6″ below water level) and islands slightly above water level (6 inches to 1 foot) attract a variety of wildlife.
- Islands should be spaced out and not placed too close together.

Sedimentation Basin - Captures sediment entering the wetland by slowing the flow velocity and allowing particles to settle out, reducing sediment deposition in downstream cells.

- The basins will most likely need to be cleaned out on a routine basis. Allow access for heavy machinery.

- The basins should be sized to facilitate the settling of the majority of sediments. This is dependent on the incoming flow rates and the amount/type of sediments entering the wetland - the finer the materials, the longer it will take for the material to settle out.

Additional features such as clay liners, erosion control measures, seepage collars, and pipelines and valves may be necessary depending on site conditions. Seepage or piping around water control structures may also be a problem - seepage collars have been used to address this problem.

Erosion may also pose as a potential threat to levee integrity or to the ditch and swale alignments. If the wetland is to have large areas of open water, the wind wave action against a levee slope may induce erosion. Levee slopes can be increased to compensate for this. Planting vegetation on the slopes as soon as possible following construction can minimize erosion. If severe erosion is expected, the installation of riprap on the water side may be necessary. Erosion in ditches and swales tends to occur at the outlet of water control structures when a

wetland cell is draining and localized flow velocities are relatively high. If velocities are expected to be relatively high, rip rap should be installed for protection.

6.3 Engineering Plans

Engineering plans show the layout of all the engineering features, while also providing the detail necessary for construction. Items that should be included in the plans include:

- *Existing topography* – This may require a topographic survey of the property to create a contour map.
- *A plan (bird's eye) view of the engineering features to be constructed* – This includes levee and swale alignments, cell locations, water control structures, etc.
- *Location, dimensions, and elevations of water control structures* – Locations, elevations and dimensions should be detailed on the plans.
- *Key elevations* - This should include the top elevations of levees and islands, design water surface elevations for each cell, and the bottom elevations of swales, ditches, and cells.
- *Profiles and details* – Cross sections of levees, islands, swales, ditches, and any other major feature. Details of water control structures, pipelines, and valves necessary for construction should also be included.

Appendix B provides a set of fictitious construction plans for a constructed wetland. This set of plans includes the items listed above, providing a general idea of what a finished set of construction plans should look like.

6.4 Engineering Design Factors

Important factors to address during the design phase involve the wetland hydraulics (how water flows through the wetland), soils, water quality improvement goals, biological (habitat) goals, construction, and maintenance considerations. This section discusses these factors and how they are instrumental in final design.

Wetland Hydraulics

The hydraulic behavior of a wetland plays a key role in its treatment efficiency. A variety of elements influences the hydraulics and should be addressed during the design phase:

Hydraulic capacity: When designing the size of the wetland cells it is important to ensure that the cells, ditches, swales, and water control structures can handle the volume of water entering the wetland. These features should be designed for a maximum flow rate to prevent overtopping. Ideally, these features are designed using the known flow rates entering the property; however, if this information is not available, the designer may be able to estimate a flow by assessing the irrigated acreage upstream that produces the runoff leading to the property. Higher flows require larger wetland cells, and hence a greater flow capacity in the ditches, swales and water control structures.

Hydraulic Residence Time: As discussed in **Section 5.0**, the contact time the pollutants have with the underlying substrate and vegetation plays a key role in treatment efficiency. Wetland cells should be large enough to provide an adequate amount of time for sedimentation and for pollutants to be transformed and up taken up by the vegetation and soils. Generally, the larger the wetland cell, the slower the flow rate and the longer the contact time. The hydraulic residence time, the average time it takes for water to flow from the inlet to the outlet, is a parameter that is often used to measure this. It is expressed as the flow rate (Q) per wetland cell volume. See Equation 1 below.

Equation 1:

$$HRT = \frac{V}{Q}$$

Where:

HRT = Hydraulic residence time

Q = Flow rate

V = Volume

For example, a 2400 ft^3 wetland cell with a flow rate of 2 cfs has a hydraulic residence time (HRT) of $2400ft^3/2cfs$ = 20 minutes.

Flow Distribution: Treatment is most effective when flow is uniformly distributed over the entire cell, maximizing the amount of treatment surface area. Cells that experience short circuiting that result in dead zones will not be as efficient. Dead zones occur where water is stagnant, and therefore don't effectively contribute to the treatment of water flowing through the wetland. Short circuiting is a result of channelization, where flow is confined to narrow flow routes through the cell, decreasing the overall treatment efficiency. Dead zones and short circuiting can be minimized through the proper placement of inlet and outlet water control structures, slope design, and the number of cells and shape. These are discussed in further detail below.

Multiple wetland cells: Multiple cell designs often provide greater treatment efficiency than single cells. This is because as water flows through the series of cells, it is redistributed at each new cell, reducing the potential for short circuiting. Multiple cells also provide greater management flexibility. Certain cells may be dried out for maintenance while still keeping the system on line. Furthermore, multiple cells encourage diversity. Certain cells may be managed for seasonal emergent habitat while other cells may be semi-permanent.

Shape of cells: The shape of cells should also be designed in a manner to encourage an even distribution of flow. Irregular shapes that tend to reduce flow in certain areas may promote dead zones and reduce treatment efficiency. Cells should be dimensioned to facilitate an adequate hydraulic residence time. Generally, the larger the cells, the slower the flow velocities and time for treatment. Swales can be optimized by designing them to be long and winding, lengthening the flow path and treatment time while reducing flow velocities. Swales within the pond can also facilitate drainage of the unit.

Slope: Generally it is most economical to design gravity flow systems where the inlets are higher than the outlets, eliminating the need for a low-lift pump. It is also advantageous to grade along the natural fall of the property to minimize the amount of earthwork. Natural gradients that are excessively flat or steep may pose as design constraints; gradients that are extremely steep may require a terraced design approach, whereas flat slopes may limit the amount of flow that can be conveyed through the property. Slopes within the interior of the cells should provide an adequate gradient for drainage but not be too steep to encourage channelization and short circuiting. It is also important to ensure that the gradient is uniform throughout the entire cell to encourage an even distribution of water and minimize the potential for short circuiting. In general, the gradient should be kept to a minimum, but should be greater than 0.2%.

Water depth: The depth of water influences the hydraulic residence time and the type of vegetative growth. Wetland vegetation tends to grow at relatively shallow depths up to 18 to 24 inches; however, different species prosper at different depths. Open water areas are generally deeper, limiting dense macrophyte growth, such as cattails. Depths can be managed (via the outlet water control structure) to manage vegetation and promote diversity. Varying the depth of water (including both shallow and deeper areas) provides the necessary conditions for nitrogen breakdown.

Soils

Soils play a key role in the treatment of pollutants by harboring the bacteria key to the transformation of pollutants and providing the medium for vegetation establishment. Certain soil types are more conducive to wetland establishment than others. Permeable sandy soils may pose a challenge because they generally are not able to retain a sufficient amount of water in a cell. Conversely, impermeable clay-like soils provide an excellent seal, but can be too dense, inhibiting root growth. Soil that is loose enough for root growth, contains a sufficient amount of nutrients for the establishment of vegetation, and retains water is optimum for a wetland bottom. Loamy soils consisting of a mixture of clays, silts and sands typically have excellent plant growth characteristics while still retaining water.

Soils are often stratified, meaning that the soils' properties change as depth increases. If a substantial amount of excavation is to occur, it is advisable to investigate the soil properties present at the depth of excavation prior to construction. If the soils are not suitable for a wetland bottom, they may need to be amended with silt or clay.

Water Quality Goals: Constructed wetlands filter out a variety of pollutants, and each pollutant is uniquely removed by specific physical or biogeochemical reaction. Some pollutants are removed more slowly requiring a greater hydraulic residence time. It is important to identify the primary water quality objectives for the constructed wetland system and how to design it so that these objectives are met. For instance, a sedimentation basin at the wetland inlet is necessary for constructed wetlands receiving agricultural runoff high in sediment loadings. The sedimentation basin should be sized to allow for the settling of the majority of sediments before the runoff enters the main wetland system. This prevents the remainder of the system from clogging with sediment and provides a confined area where the sediments may be cleaned out on a routine basis.

Biological Goals

Constructed wetlands may be designed for the sole objective of improving water quality or for the dual benefit of water quality and habitat value. If habitat value is a component of the design, specific biological goals should be defined early during the project development stages. For example, is the goal to attract specific species of wildlife, or restore specific types of habitat? Will the wetland be used for recreational purposes? These biological goals can significantly influence the engineering design.

The overall objective in constructing a wetland of high habitat value is to mimic natural healthy ecosystems which are diverse and self-sustaining. The two key components of enhancing the habitat value of constructed wetlands are diversity and aesthetics. It is recommended that constructed wetlands contain a diverse mixture of habitats, including upland, emergent wetland, and semi-permanent water. Engineering designs should allow for various water depths (facilitating different vegetation types) and incorporate a variety of engineering features, such as deep open water ponds, shallow ponds, vegetated swales, and islands.

Engineering features should be designed to blend in with the natural landscape. Rigid structures such as rectangular basins and straight channels should be avoided - soft features such as curvy swales and rounded ponds appear more natural and may attract more wildlife. If a constructed wetland is located near a river, levee alignments could follow the contours of the river. These basic principles will enhance the quality of habitat.

Construction

During the design phase it is also important to consider how easily the engineering features can be constructed. Borrow sites should be relatively close to where the levees are to be constructed to reduce the haul route (and hence the construction costs). Engineering plans and construction specifications should be clear to the contractor and include all relevant information needed to estimate construction costs and build the project.

Maintenance Considerations

Maintenance is extremely important to the longevity of the system and overall performance of the wetland. This involves water management, vegetation control, sediment removal, infrastructure maintenance (e.g., levees and roads), and any monitoring needs. To reduce maintenance efforts and costs, the following considerations should be incorporated into the engineering design:

- Levees should be wide enough to facilitate vehicular traffic in areas that will need to be accessed. This is about ten to twelve feet wide at the top.
- If the soils are very slick following periods of rain, gravel may be necessary for all-weather access.

- Water control structures should be easily accessible.

- Levee side slopes should be flat enough to minimize erosion.

- Drainage of the wetland units is essential to managing vegetation, drying up the units to allow the access of maintenance equipment, and minimizing mosquito production.

7.0 Biological Design of Constructed Wetlands

The biological design entails the design of vegetation types that will assist in meeting water quality objectives and, if desired, habitat objectives. As with the engineering design, the biological design is still a relatively new field for constructed wetlands. As more constructed wetlands are developed and information is collected, more recommendations for biological designs, soil preparation, and plantings will be available. This section provides some general guidelines on biological designs and wetland vegetation establishment. **See Appendix A** for an Example of Engineering and Biological Plans.

This guide deals with three primary categories of wetlands: seasonal, semi-permanent and permanent marsh. Each is unique in its makeup and maintenance, and all are described below in further detail. **See Appendix D** for PRINCIPLES OF CENTRAL VALLEY WETLAND MANAGEMENT.

Seasonal Wetlands

A seasonal wetland has continuous standing water throughout the fall and winter, before a spring drawdown in which the surface water is completely drained until the end of summer. During the spring and summer, the exposed mud flats support a wide variety of "moist-soil" plants such as watergrass, smartweed, swamp timothy and sprangletop. The drawdown can be timed to coincide with optimal germination conditions of desired plant species. The depth of these wetland cells is between 0 and 16 inches. This type of wetland is particularly good for attracting wintering waterfowl.

Semi-Permanent Wetlands

Also referred to as brood ponds, semi-permanent wetlands are flooded during the spring and summer, but are dry for a period of 2-6 months each year. They are relatively small in size (2-10 acres) and contain a combination of shallow (6 - 12 inches) and deeper (1 – 2 feet), open-water areas. Semi-permanent wetlands require periodic discing to prevent vegetation from becoming too dense, and are therefore smaller in size to reduce maintenance costs.

Permanent Marshes

Permanent marshes are wetlands that remain flooded the entire year at a depth of 4 – 6 feet. Vegetation typically consists of submerged plant species such as sago pondweed, horned pondweed and water hyssops, which provide food for a wide variety of waterfowl. The plants, however, will only grow if the water is clear enough to allow the penetration of sunlight. The primary maintenance concern is the prevention of carp and other rough fish that typically reduce water clarity and inhibit the growth of these desirable plant species.

Vegetation Control

While an abundant and diverse plant population is necessary for the success of a wetland, unchecked growth can have negative impacts. The primary concern is the overgrowth of cattails and tules, which can overtake the entire water surface and clog up inlet and outlet areas. Typically, stands of cattails/tules should not occupy more than 60% of the surface area of a pond. Excessive stands can be controlled through discing, mowing, or burning. Discing not only removes cattails and tules, but also opens up the soil for growth of desirable moist-soil plants. While mowing and burning are effective means of control, they must be followed by discing and then 2-3 months of sun exposure to prevent re-growth.

Discing can be done with one of two types of disc, a “stubble disc” or a “finish disc”. A stubble disc (diameter of 26 - 36 inches), which makes a cut of 7 – 10 inches deep, is typically used for pond-bottom discing; however, caution must be used to not break through the shallow clay pond bottom and underlying sandy soil, which can reduce the pond’s water-holding capacity.

Finish discs (diameter of 18 – 24 inches), which make a cut 4 – 6 inches deep, are useful for discing low-growing vegetation (pricklegrass, swamp timothy), but are not effective for the control of cattails, tules, river bulrush, Baltic rush or other robust wetland plants. A finish disc is most effective in creating strips, channels and potholes in areas of dense vegetation, typically in July or August when summer irrigations can cause large, dense stands of plants that impede water flow. Finish discs can also be used to reduce clod size following a stubble disc to make walking easier if the ponds are to be used for activities such as waterfowl hunting once flooded.

Diversity

If a wetland is to be designed to serve the dual benefit of water quality and habitat value, biological goals should be defined during the early project development stages. For instance, is the wetland to attract certain species of wildlife, be used for recreational purposes, or restore specific types of habitat?

Biological diversity is extremely important in establishing a healthy self sustaining ecosystem of high habitat value. It is recommended that constructed wetlands contain a diverse mixture of habitats, including upland, emergent wetland, and open water. The engineering designs should allocate for various water depths and incorporate a variety of engineering features, while the biological sign should incorporate a variety of vegetation and habitat.

Types of Wetland Vegetation to be used in Constructed Wetlands

There are a variety of plants that have proven to be effective in improving water quality in constructed wetlands. It is recommended that an inventory of existing native wetland species be taken prior to the biological design. This will give an indication of what species are successful in the local area. Incorporating these species into the biological design will enhance the habitat value. **Table 7.1** lists species common to constructed wetlands, the water depths the species tend to grow at, and their strengths and weaknesses in meeting both water quality and habitat benefits.

Cocklebur, sweet clover, river bulrush, tuberous bulrush, Baltic rush, jointgrass, dock, and salt grass are invasive and undesirable wetland plants.

Table 7.1 Vegetation Types in Constructed Wetlands

Plant	**Water Depth**	**Strengths and Weaknesses**
Cattails, Bulrush (Tules)	0 to 3 feet	Can be effective in improving water quality, but does not provide good habitat benefits.
Smartweed, Watergrass	0 to 2 feet	Can be moderately effective in improving water quality and provides excellent waterfowl forage.
Swamp Timothy	0 to 16 inches	Moderately effective in improving water quality and provides excellent waterfowl forage.
Sago Pondweed, Wigeon Grass	2 to 7 feet	Can be effective in improving water quality, and provides moderate habitat benefits.
Spikerush	0 to 6 inches	Can be effective in improving water quality, and provides moderate habitat benefits.

Vegetative Plantings

Guidelines for soil preparation and vegetation plantings are listed below:

- Avoid soils that have seed bank of unwanted weeds and invasive species. Using this material can propagate these species and make the vegetation management more difficult and costly.
- Seeding of some beneficial plants may be necessary if they are not in the seedbank.
- Soils should be loose for root penetration, yet be of low enough permeability to provide an adequate seal and retain water. Discing may be a means to loosen the soil and encourage plant growth.

- Controlling the water surface elevation is necessary to ensure optimal germination of various plant species. Annual (moist-soil) plants will require a yearly drawdown (draining of surface water) for adequate germination and at least one irrigation for optimal vegetative and seed head growth.
- In deeper areas of the wetland cell, submerged plants such as widgeon grass and sago pondweed can attract diving waterfowl species (Canvasbacks, Redheads, etc.)
- Be patient. It will take several years for vegetation to establish itself. It has been shown that pollutant removal improves as the vegetation matures.

Biological Considerations in the Design of Constructed Wetlands

- Engineering design is critical to providing optimal germination of wetland plants and their availability to wildlife. Annual moist-soil forage plants require an upper bench for proper management.
- The upper bench should be constructed as a shallow (0 to 16 inches) undulating seasonal wetland to provide optimal habitat conditions for a variety of wildlife.
- The wetland design should incorporate user-friendly maintenance considerations, e.g., areas that require occasional excavation of sediments or vegetation should be located near accessible roads.

Wherever conditions allow, side slopes of levee banks should be at least 10:1 up to a depth of 1 foot below the water surface to allow additional foraging by wetlands wildlife.

8.0 Construction

While each project is unique, there are general guidelines and construction recommendations which can be applied to common engineering features. Following these guidelines will help ensure the success of a project.

Cells (Ponds)

- Finished ponds should be graded to drain to outlet.
- Typical costs of overall restoration construction range from $400 to $1000 per acre.

Levees

- Footprints should be stripped to provide a seal between the existing ground and the levee fill material.

- All earth fill should be clean and free of organics. This may require the top organic layer to be stripped from the borrow areas prior to excavation.
- During construction, fill material should be placed in six inch layers and compacted between each layer. Levee fill material must be slightly moist but not wet to attain suitable compaction.
- Cost of compacted fill is $2.00 to $3.00 per cubic yard of placed material.

Water Control Structures

- Backfill material should be free of any organics, debris, boulders and rock.
- Recommend that material around the structure be compacted well to prevent piping or blow out.
- Installation of structures and pipe should be set to closely match design elevations in order for the system to function properly.
- Ensure rip rap (erosion control) is properly keyed into the contours of the swale/ditch.
- Cost of water control structures average $2000 each installed, with culvert pipe.

Swales and Ditches

- Ensure that the swales and ditches are excavated in a clean manner and drain effectively.
- Cost of swales generally is incidental to levee construction as borrow material.

- Additional excavation averages $1.50 to $2.50 per cubic yard of cut material.

Islands

- Footprints should be disced or stripped to a solid foundation between the ground and base of island.
- If islands are to have a specific top elevation, such as for a nesting island, they should be constructed of compacted fill.
- Stripping material can be placed into loafing bars with reasonable compaction. Keep in mind that this material will decay and the mounds will melt down somewhat.
- Ensure that material is reasonably compacted to reduce erosion potential.
- Cost of island construction may be incidental to stripping or cost similar to levees for compacted fill.

Plantings

- Plant a quick-growing cover crop on levees to provide wind and water erosion protection.
- Stripping material has a rich seed bank, and can be replaced on finished levee side slopes to provide protection.
- Trees, such as willow cuttings, and tules can be planted to jump start the diversity of habitat.
- Generally, the seed bank for desired wetland plants is present even in previously farmed areas. Proper management of water is needed to propagate the moist soil vegetation.
- Costs range widely depending on scope of planting.

9.0 Case Study – Wingsetter Wetland Ranch

The Wingsetter Wetland Ranch is an excellent example of a treatment BMP in which sedimentation is a primary process in improving water quality. Sediment laden agricultural runoff is intercepted and conveyed through a collection of ponds and sedimentation basins before discharge into the San Joaquin River. As shown in **Figure 1,** the Ranch is immediately west of the San Joaquin River (just north of the Merced County line).

The range was formerly a 2,000 acre row crop farm operation. Mickey Saso purchased the property in the early 1990s as a place for recreation with the condition that he build a wetland system to treat the silt laden agricultural runoff discharging into the San Joaquin River. After ten years of restoration and management, Mr. Saso has created a natural system that effectively treats the runoff of 3,000 to 4,000 acres of upstream farmland and supports an abundance of wildlife.

Although Mr. Saso has done the majority of work himself, he has received financial and technical assistance from a variety of sources including the Natural Resources Conservation Service, the Wildlife Conservation Board and Ducks Unlimited.

9.1 Engineering Features and Maintenance

Agricultural runoff is directed to the Ranch via pipelines and ditches. **Figure 2** shows the location of the engineering features and the primary flow routes on the ranch. The runoff enters the Ranch in three locations. At two of these inlets, sedimentation basins allow for the settling and removal of sediment. The water is directed through a collection of ponds, natural sloughs, pipelines and ditches. The treated water is then discharged into the San Joaquin River through four outlets. Water control structures throughout the ranch are used to manage water levels and direct water into selected ponds. In addition to runoff, a well and pump provides groundwater on an as-needed basis.

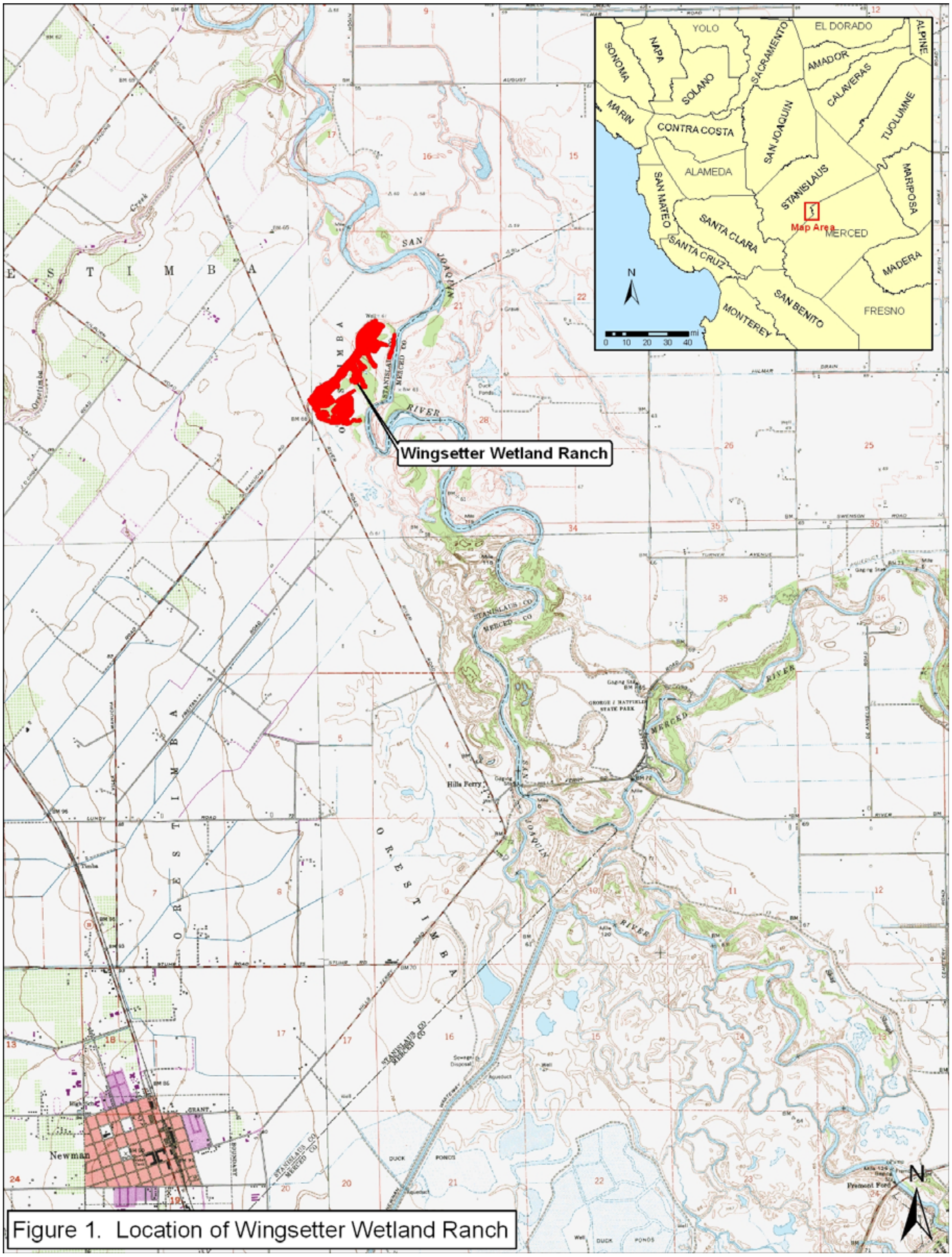


Figure 1. Location of Wingsetter Wetland Ranch

Construction and Materials

A series of restoration projects have been implemented over the past ten years to transform the 150 acre Wingsetter Wetland Ranch into a treatment system and productive habitat. Mr. Saso used aerial photos taken prior and after major flooding events to assess the water flow direction and used this information to determine the placement of water control structures and major water bodies.

Prior to construction there were a number of historical sloughs and depressions on the ranch. These sloughs now receive agricultural runoff during the irrigation season and are connected via pipelines and ditches. Three ponds, Mile Long Lake, Teal Ponds, and Front Pond were excavated to provide additional water treatment and habitat. Levees were also constructed around Mile Long Lake to provide additional storage.

Mr. Saso has been resourceful in finding inexpensive materials and services. All of his ponds have been excavated by a large contractor based in Los Banos, who excavates the ponds to Mr. Saso's specifications and hauls the material offsite. In turn, the contractor receives the excavated sand for free. Mr. Saso has received the following materials for little or no money:

- Rip Rap – Approximately 100 - 150 truck loads of relatively clean (rebar free) broken concrete from the City of Newman who tore out a large number of sidewalks.
- Concrete Pipe – Old concrete sewer pipe from the City of Modesto
- Supports for nesting boxes – Old telephone poles from PG&E
- Sealant for ponds – Clay that a winery had used for filtration of wine
- Native grass seeds – Donated by the NRCS
- Pre-cast concrete water control structures purchased from a local vendor

Survey Information

A survey conducted by Ducks Unlimited, Inc in February of 2005 provides details on the exact locations and elevations of specific engineering features. Appendix B displays the data collected from the survey. Key findings are highlighted below.

- The Back Sedimentation Basin is approximately 270 feet long and 45 feet wide. The Front Sedimentation Basin is about 260 feet in length and 25 feet wide.
- The average depth of the excavated ponds (Mile Long Lake, Teal Pond, and Front Pond) is two feet. Profiles of the three excavated ponds can be found in Appendix B**.**

Water Management and Sediment Maintenance

The Ranch receives agricultural runoff during the irrigation season from March through November. During this period a sufficient amount of water is provided to flood all of his ponds and sloughs. During the winter season, groundwater is pumped to provide wetland habitat. In November or December Mr. Saso raises the water level higher than irrigation season water levels to provide some seasonal variability, overtopping the sloughs and saturating the majority of trees on the property. In January, he begins to dry out portions of his Ranch for maintenance purposes.

In addition to the management of water, Mr. Saso engages in a variety of management activities to optimize habitat value and maintain treatment efficiency. He removes 2,000 - 3,000 cubic yards of sediment from the two sedimentation basins annually. The material is excavated using a long reach excavator and used to refurbish and build levees on the property. The silt makes an excellent foundation for native grasses and shrubs.

Engineering Challenges

Mr. Saso has dealt with a variety of site specific challenges. The majority of the site consists of porous sand that does not retain water - he has sealed these ponds with a 4 to 6 inch layer of bentonite clay; although this has generally been effective, there is still evidence of seepage. Maintenance of the clay layer has been necessary in areas disturbed by rodents.

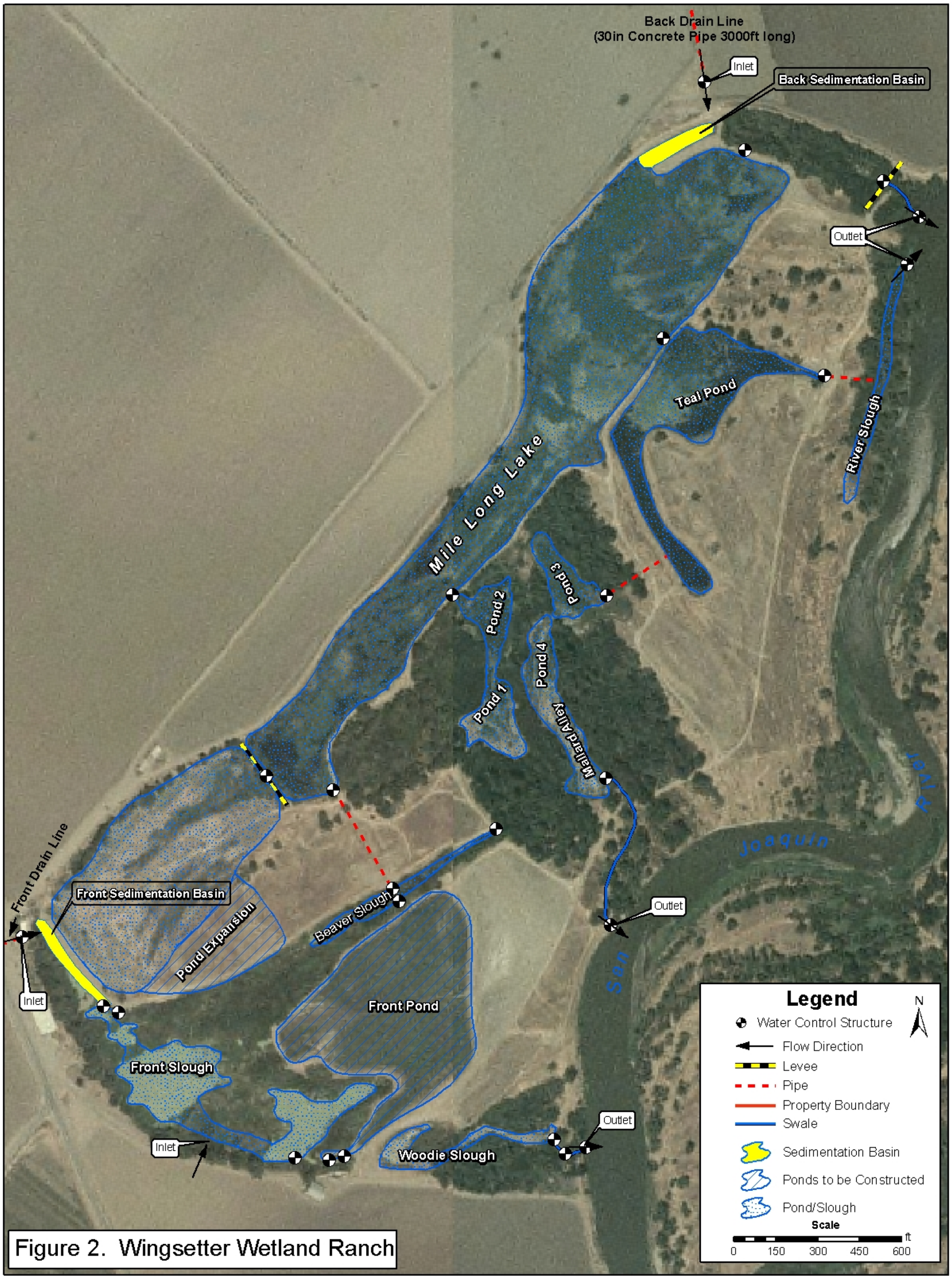


Figure 2. Wingsetter Wetland Ranch

The potential for flooding has also been a challenge, as the San Joaquin River has flooded the property four times within the past decade. As a result Mr. Saso has used heavy concrete pipe for his culverts and pipelines, preventing the possibility of them floating and moving. He has also protected the slopes of his levees with rip rap (broken concrete) to minimize erosion during floods. A layer of sediment overtops the rip rap to provide a foundation for vegetation and enhance aesthetics and habitat. Mr. Saso hopes that through these efforts, "the Ranch will stay intact after I am (he is) gone."

The abundant amount of sediment loading and deposition has also influenced the design and management approach - if unchecked, the sediment would plug the system. Many of his concrete pipes are of large enough diameter (36 to 60 inches) to facilitate the manual removal of silt.

9.2 Biological Features and Maintenance

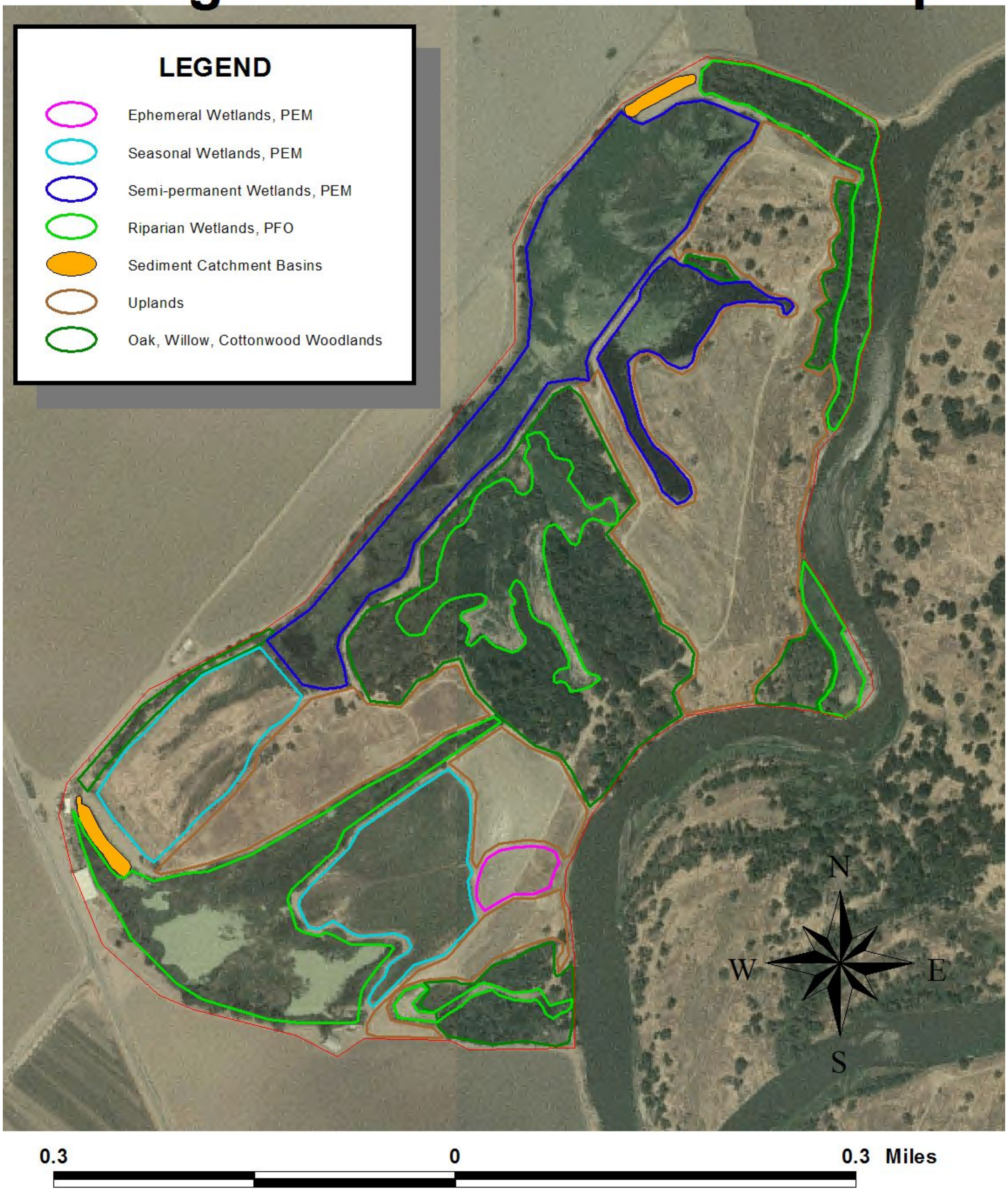
The major habitat types present on the 143-acre Wingsetter Wetland Ranch include, Semi-permanent, seasonal, and ephemeral palustrine emergent wetlands, seasonal palustrine forested wetlands, grassland and shrub/scrub uplands, and oak and riparian woodlands. The semi-permanent wetlands (2'-5' deep) were dominated by giant burrhead, willows sp., watergrass, and cattails, and receive use by many waterfowl species including Canada geese, mallard, northern shoveler, green-winged teal, and American wigeon; colonial waterbirds including great-blue and black-crowned night herons and great egrets; American white pelicans, and double crested cormorants. Seasonal wetlands (2"-24" deep) were dominated by smartweed, watergrass, spikerush, and cattails and receive use by northern pintail, mallard, green-winged teal, gadwall, wood ducks and American wigeon; shorebirds including greater yellow-legs, killdeer, dunlin, western sandpipers, and white-faced ibis and colonial waterbirds. Ephemeral wetlands (0"-6" deep) were dominated by smartweed, common cocklebur, and annual introduced grasses and received use by mallard, green-winged teal, shorebirds and colonial waterbirds to name a few. Forested wetlands (4"-4' deep) on the site were dominated by black and sandbar willows, cottonwoods, and cattails, and received use by wooducks, mallard, green-winged teal, and colonial waterbirds. The riparian canopy provides habitat for myriad wildlife species including, colonial waterbird rookery, thermal and nesting cover for songbirds and wood ducks.

The grassland uplands were dominated by weeds, introduced grasses, and wildlife friendly varieties such as millet, barley, and safflower. Native species present include dove weed, wild sunflowers, and creeping wildrye. The oak and willow woodlands consisted of valley oaks, buttonbush, cottonwoods, and black and sandbar willows. These habitats provide thermal and nesting cover for wood ducks, a colonial waterbird rookery, songbirds, and hawks. The understory consisted of carex sp. and introduced grasses.

Semi-permanent wetland habitats are drawn down in the spring to promote wetland plant germination and flooded once the agricultural season begins, usually in June. Seasonal wetlands are drawn down at the same time but remain dry later into the summer, receiving periodic irrigations to grow lush vegetation for waterfowl use. Ephemeral wetlands are not managed and depend on rainfall for hydrology and usually only remain flooded for a few weeks after a major rain event. Mr. Saso has worked with NRCS staff to seed the upland habitats to a variety of plantings including native grasses, introduced grasses and a blending of safflower, barley, and other grains for waterfowl. These plantings are periodically mowed and/or sprayed to control problem vegetation and promote the target plant species. He has also installed wood duck nesting boxes and built islands for nesting waterfowl habitat.

Waterfowl and birds, including egrets, herons, pelicans, bald eagles, kite hawks, king fishers, red-tailed hawks, geese, diver ducks, mud hens, cacklers, mallards, wood ducks, shore birds, quail, dove, pheasants, great horned owls, and white-face ibises take refuge on his Ranch. Other wildlife including river otters, cottontails, and coyotes frequent his property. Although not open to the public, Mr. Saso's family and friends are often invited to go fishing and hunting.

Wingsetter Ranch Habitat Map



Management Plan

The Wingsetter Ranch (Ranch) Enhancement Project is an ambitious effort to enhance approximately 80 acres of wetlands and 63 acres of associated riparian and grassland habitat along the San Joaquin River. This project encompasses approximately 143 acres located on the Wingsetter Ranch near Newman, California. This project will enhance hydrology by installing a deep well to flood existing wetland habitats. This system is already set up to handle excess agricultural tail-waters through the irrigation season and extreme flood events that occur occasionally. The proposed management plan for the project area is described below.

- **GENERAL MANAGEMENT GUIDELINES**

This management schedule will be closely tied to needs of migratory bird species. This management plan will serve as the framework for management, allowing for enough flexibility to incorporate natural stochastic events and to work with Natural Resources Conservation Service staff should this property be accepted for a floodplain easement. Water management will be used to achieve desired wetland habitats and well water will be used when surface water is not available.

- **WATER MANAGEMENT IN WETLANDS AND RIPARIAN CORRIDORS**

Currently, water available to this property is provided by agricultural drain water. Short bursts of water (3-5 days) occur approximately once a month during the spring/summer irrigation season and is no longer available after November 15 each year, with the exception of natural precipitation events. This project will provide a dependable water supply by installing a well and diesel drive unit capable of flooding the entire wetland habitat on the Ranch. Fall flood-up will utilize available tailwaters and be supplemented by well water when needed. Water control structures shall have "flashboards" in place to allow the retention of water at depths of 6" to 4′ for the period of approximately September 1 to March 15.

The seasonal wetland shall be managed to provide migrating and wintering habitat for waterfowl and other wetland dependent wildlife. From March 15 to April 15, the shallow seasonal wetland (light blue on map) shall have flashboards removed from the water control structure to allow draw down, encouraging the germination and growth of annual wetland vegetation, such as watergrass and swamp timothy. "Flash" irrigations of tailwater and/or well water will be used two or three times during the summer to encourage maximum growth and seed production of desired wetland vegetation. These irrigations will consist of adding water to the dry wetland at as high a rate as possible and then draining the wetland as fast as possible once the entire pond bottom has been irrigated. The period between the start of irrigation and the day the water is completely drained should be no more than ten days. Holding water for longer periods of time will drown young watergrass and swamp timothy plants. Water management will be the primary means of achieving the desired plant response within the seasonal wetland.

The Front Pond 1 (purple on map) is the first to receive tailwater, and thus will be flooded for most of the irrigation season from approximately March 15 to November 15. Rain and well water will be used to maintain this wetland during fall and winter.

The semi-permanent wetland habitats will be managed to provide migrating, wintering, and breeding habitat for waterfowl and other waterbirds. These wetlands shall be maintained from approximately September 1 to March 15. Each year, 3 of the 5 semi-permanent wetlands (blue wetlands on map) will be maintained through July 15 to provide brood habitat for locally nesting waterbirds. Water levels will be maintained at a lower level to prevent drowning of valley oak trees. Rotating the brood ponds will allow management of undesirable vegetation in one of the semi-permanent wetlands each year. On July 15, flashboards will be removed from the remaining wetlands to allow drawdown, helping to discourage undesirable vegetation.

Tailwater will be used when available to replenish and refresh these systems and maintain water depths suitable for migrating/wintering habitat and brood rearing (1′ to 6′). Well water will be used to supplement surface water when needed to follow management plan. In addition, flooding during this period will provide excellent habitat for many wildlife species such as kingfishers, black-crowned night herons, egrets, white-crowned sparrows, hummingbirds, and wood ducks using this area during the winter period. Flooded habitat during the spring and summer period will also serve to retain soil moisture, allowing young riparian vegetation to flourish.

- **VEGETATION MANAGEMENT**

Although water management will be the primary tool used to achieve the desired plant response in the wetlands, periodic discing and mowing may be necessary to set back succession of undesirable plants such as cattails, tules, and joint grass, and make the desired wetland resources more available to wetland wildlife.

- **EXAMPLE OF YEARLY TIMETABLE**

Dates are approximate and will vary based on weather and other stochastic events.
March 15 to April 15 - Remove boards from water control structures in the seasonal wetland.

May 15 to July 15 - Conduct "flash" irrigations for annual waterfowl plants and to replenish brood habitat in semi-permanent wetlands.
July 15 - Remove boards from water control structures in semi-permanent wetlands.
September 1 - Install boards in all water control structures and commence fall flood-up.

9.3 Treatment Efficiency and Habitat Value

Wingsetter Wetland Range has proven to be successful at improving water quality and providing habitat for wildlife. As of this writing, success is based on subjective and observed improvements. The treated water leaving the wetland is clear as opposed to the silt laden agricultural runoff entering the wetland. The two sedimentation basins filter out 2,000 – 3,000 cubic yards of sediment per year, substantially improving the water quality. The diversity of engineering features on the Ranch should allow for the removal of a wide variety of constituents imported with the inflow of drain water. Shallow wetland ponds, deeper open water in the natural sloughs, swales/ditches, and uplands provide a variety of habitat.

The scientific and quantitative analysis of the treatment efficiency of the wetlands is just being developed as of this writing. A three year study through by the University of California (Davis) is currently evaluating the treatment efficiency of Mile Long Lake. Preliminary data gathered at the inlet and outlets of the Lake show that certain pollutant concentrations leaving the Lake have been reduced by more than 50 percent.

If study results indicate that improvements are necessary, the following modifications could enhance treatment:

- Although the existing settling basins remove a substantial amount of sediment, Mile Long Lake still receives a substantial amount of sediment and needs to be cleaned out every 5 to 6 years. Flow rate data and engineering calculations would be necessary to determine how large the settling basins would need to be to filter out the majority of sediments and whether this would be a feasible option, given site conditions. Possible changes include lengthening the back sedimentation basin by extending the interior levee, thus increasing the storage volume of the basin and increasing the hydraulic residence time.

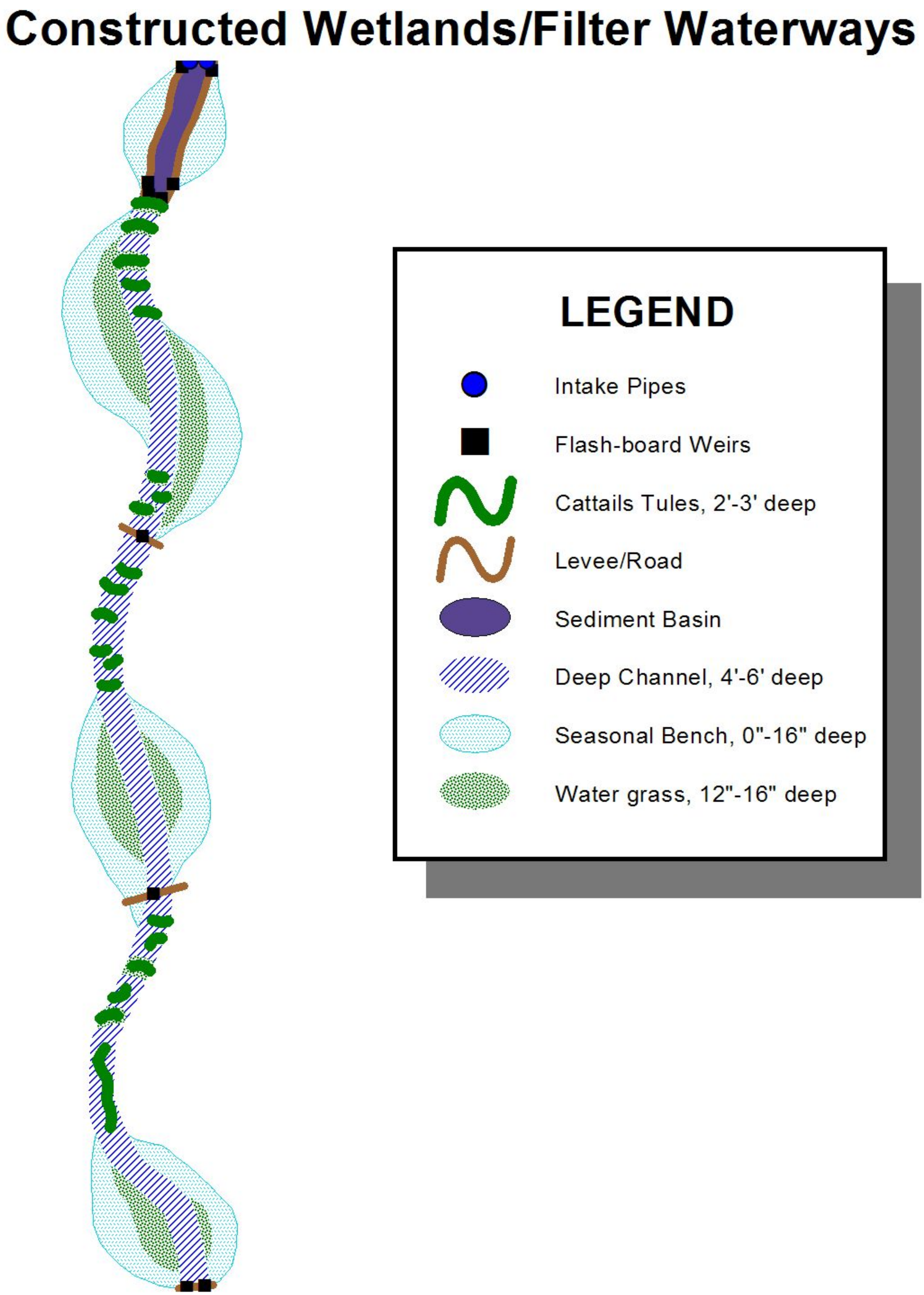
- If site conditions are conducive, a third settling basin located at the front slough inlet would enhance water quality and access. This area is currently very shallow and choked with tules and sediment.
- The flow routes passing through some sections are relatively short. Lengthening these flow routes via vegetated swales or changing the location of water control structures could increase the hydraulic residence time and water treatment.
- As discussed in **Section 7.0,** emergent vegetation such as bulrush and cattails can prove effective in pollutant removal. Establishing these species in the shallow ponds and in the new vegetated ditches could enhance water quality. The establishment of macrophyte vegetation between the west traversing levee and east traversing levee (to be built) in Mile Long Lake could also enhance habitat diversity.

10.0 Conclusions

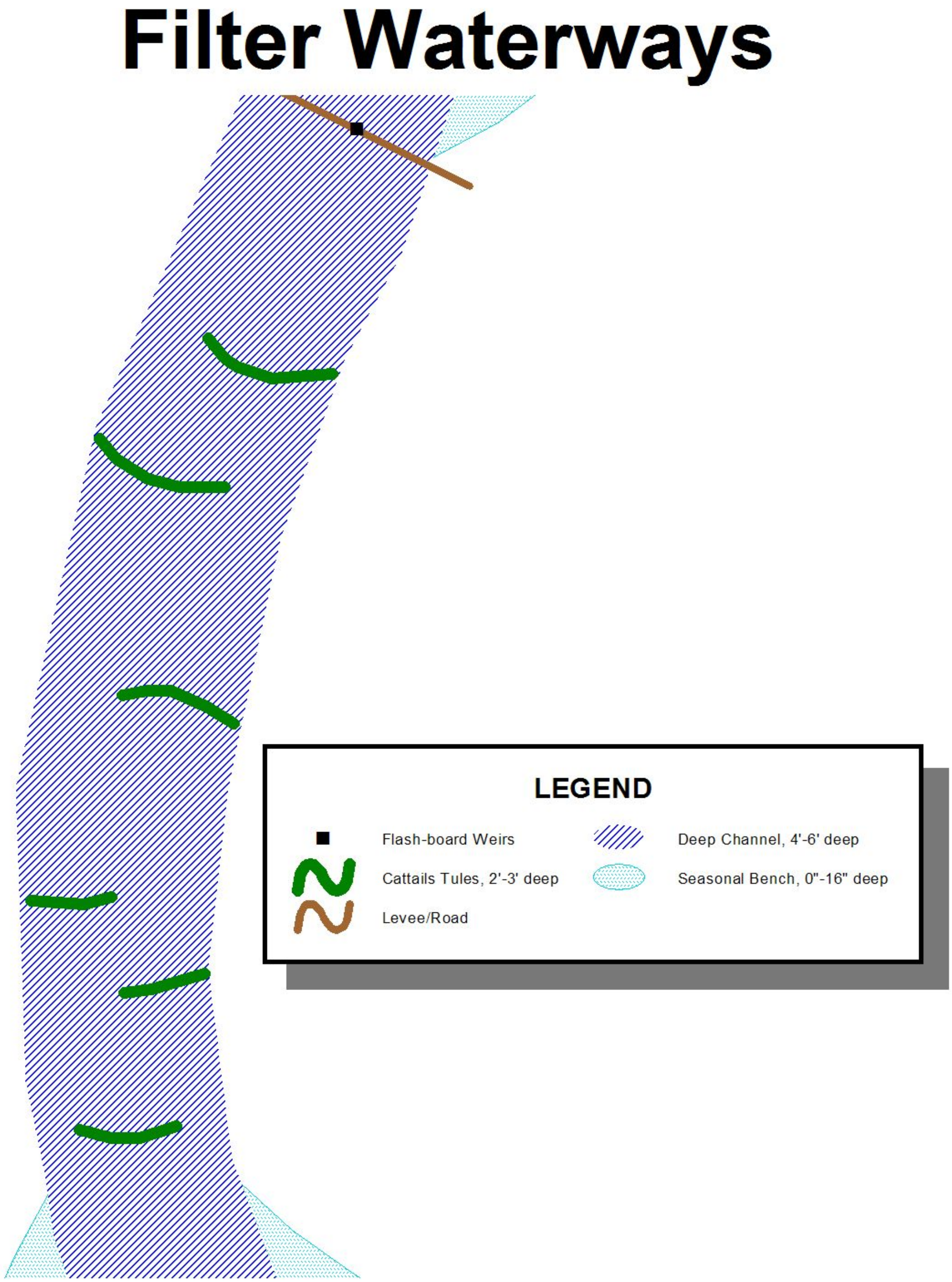
Whether pursuing the development of a constructed wetland treatment BMP independently or acquiring technical assistance, there are basic design elements and guidelines common to the success of all constructed wetlands. The guidelines and case study provided in this document provides the landowner with the necessary information to work more effectively with an engineer or to develop his/her own conceptual wetland design. In addition to this document, *A Landowner's Guide to Best Management Practices* provides additional information on funding and technical programs for the landowner.

The Wingsetter Wetland Range provides an excellent example of what ingenuity and persistence can create. Mr. Saso has a great sense of personal satisfaction in using his "creativity, knowledge, and ideas to create something for wildlife" and to benefit water quality. He advises other landowners that their projects do not need to be as large as his - treatment BMPs of any scale can provide an environmental benefit.

Appendix A – Example Engineering and Biological Plans



Appendix A – Example Engineering and Biological Plans



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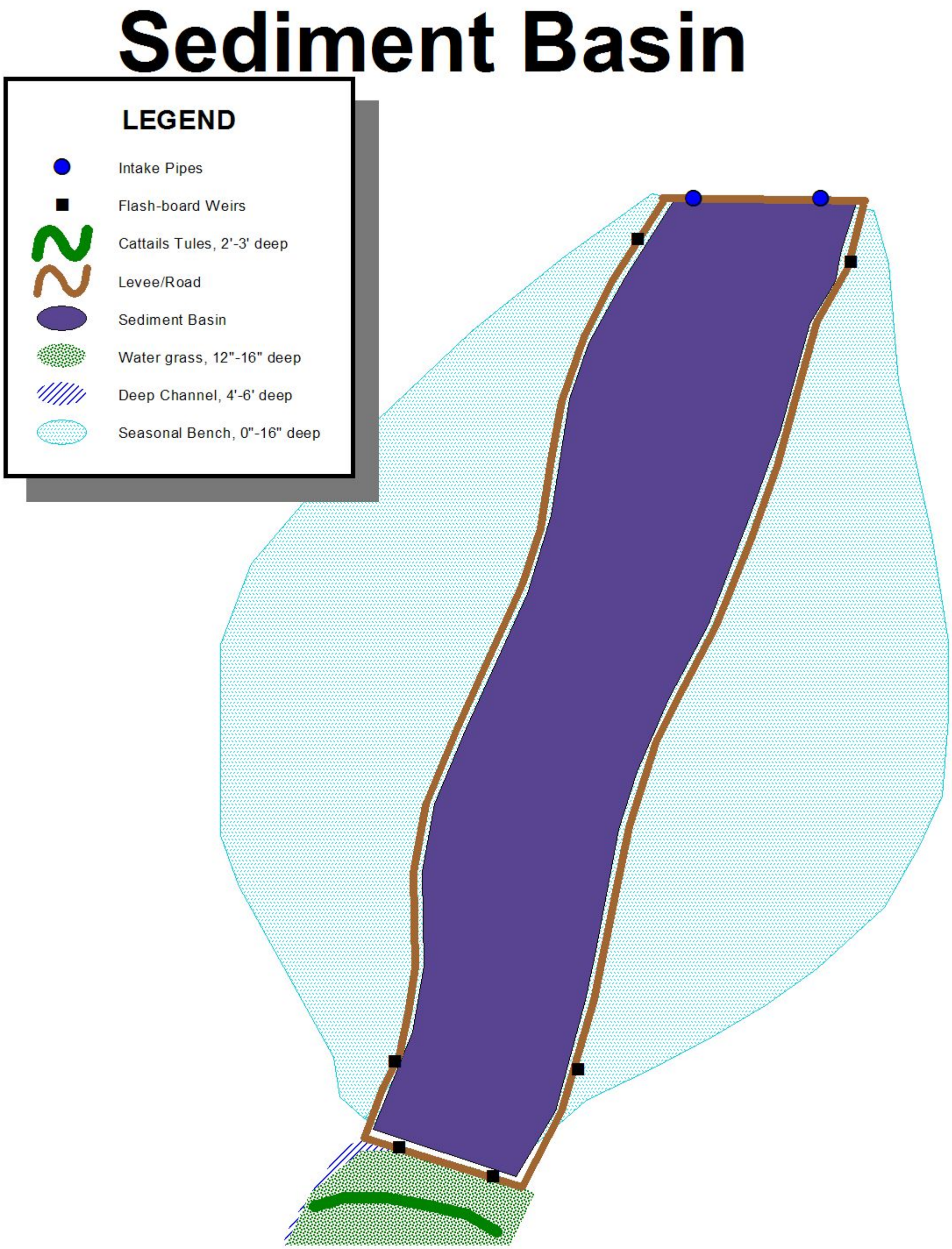
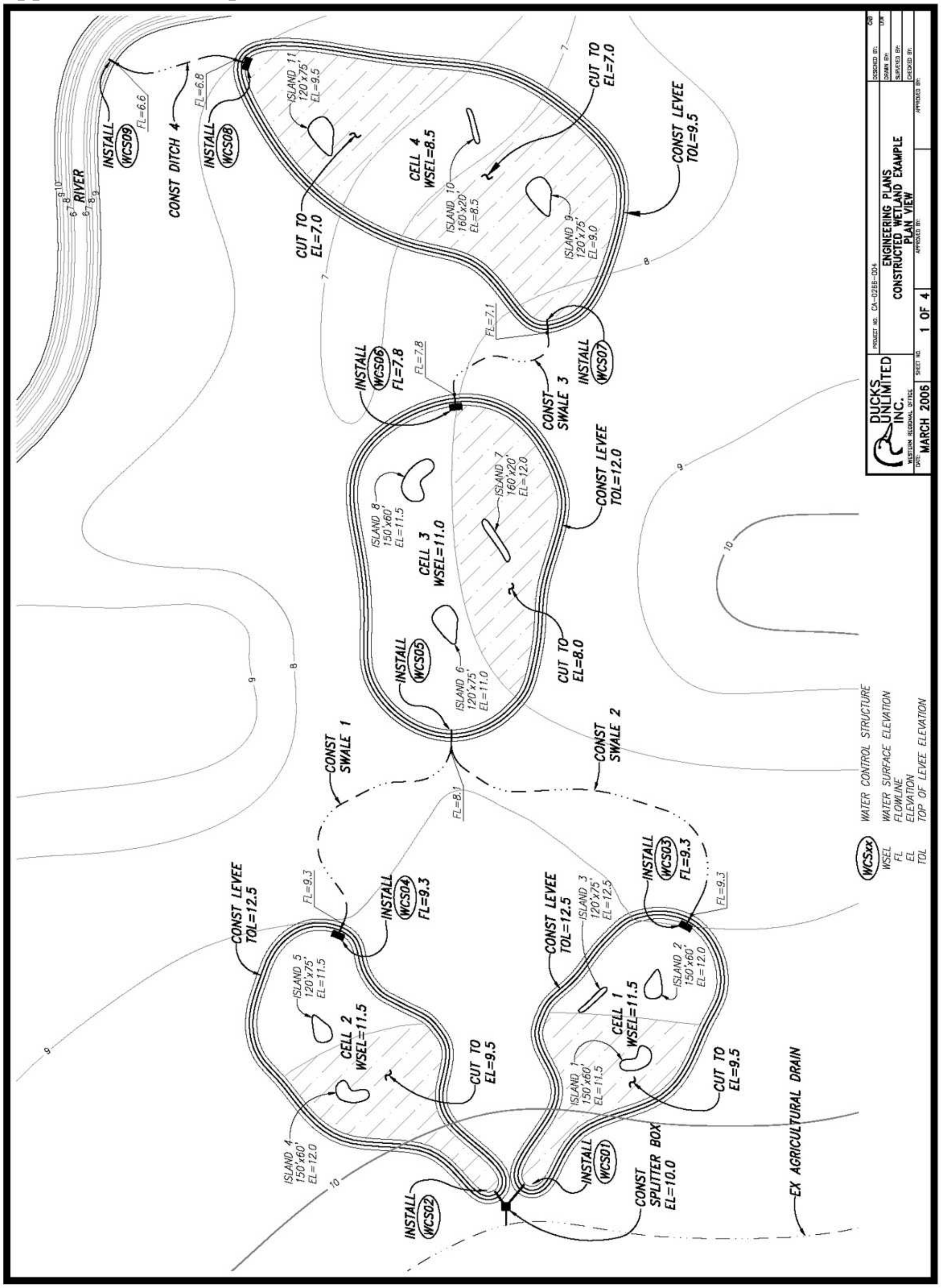


Appendix B – Example Construction Plans



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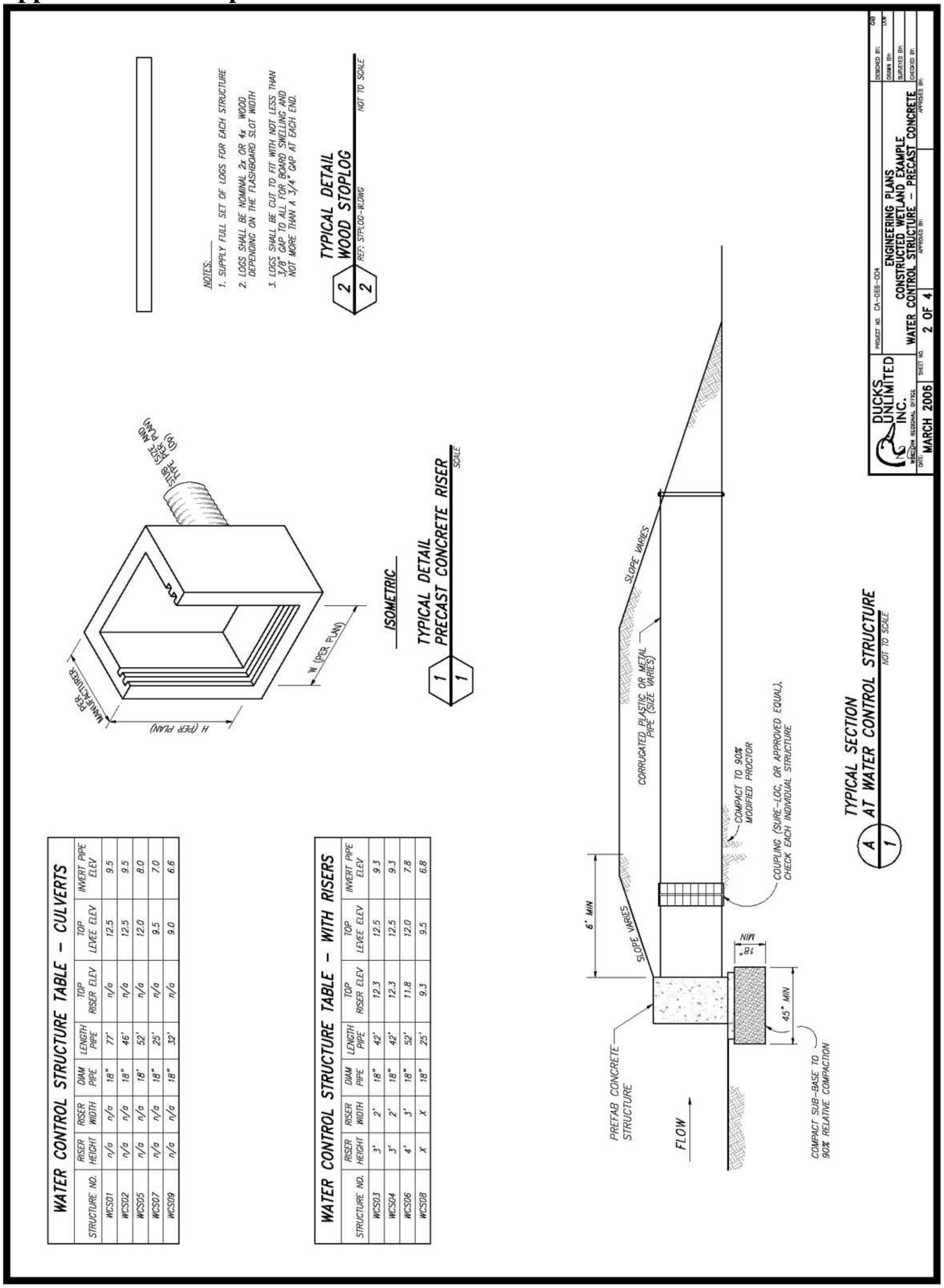


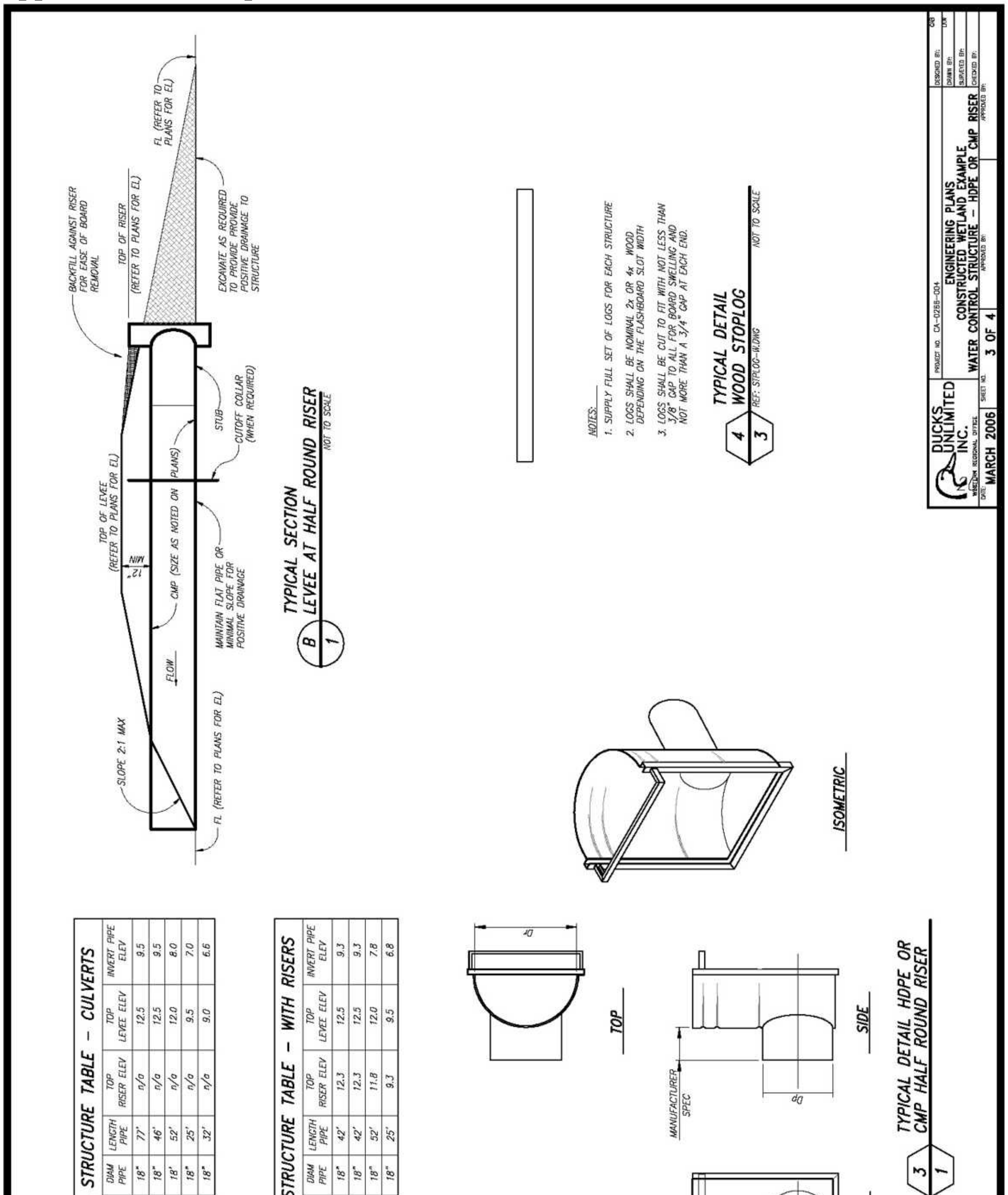
WATER CONTROL STRUCTURE TABLE – CULVERTS

STRUCTURE NO.	RISER HEIGHT	RISER WIDTH	DIAM PIPE	LENGTH PIPE	TOP RISER ELEV	TOP LEVEE ELEV	INVERT PIPE ELEV
WCS01	n/a	n/a	18"	77'	n/a	12.5	9.5
WCS02	n/a	n/a	18"	46'	n/a	12.5	9.5
WCS05	n/a	n/a	18"	52'	n/a	12.0	8.0
WCS07	n/a	n/a	18"	25'	n/a	9.5	7.0
WCS09	n/a	n/a	18"	32'	n/a	9.0	6.6

WATER CONTROL STRUCTURE TABLE – WITH RISERS

STRUCTURE NO.	RISER HEIGHT	RISER WIDTH	DIAM PIPE	LENGTH PIPE	TOP RISER ELEV	TOP LEVEE ELEV	INVERT PIPE ELEV
WCS03	3'	2'	18"	42'	12.3	12.5	9.3
WCS04	3'	2'	18"	42'	12.3	12.5	9.3
WCS06	4'	3'	18"	52'	11.8	12.0	7.8
WCS08	X	X	18"	25'	9.3	9.5	6.8

Appendix B – Example Construction Plans



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WCS02	n/a	n/a	18"	46'	n/a	12.5	9.5
WCS05	n/a	n/a	18"	52'	n/a	12.0	8.0
WCS07	n/a	n/a	18"	25'	n/a	9.5	7.0
WCS09	n/a	n/a	18"	32'	n/a	9.0	6.6

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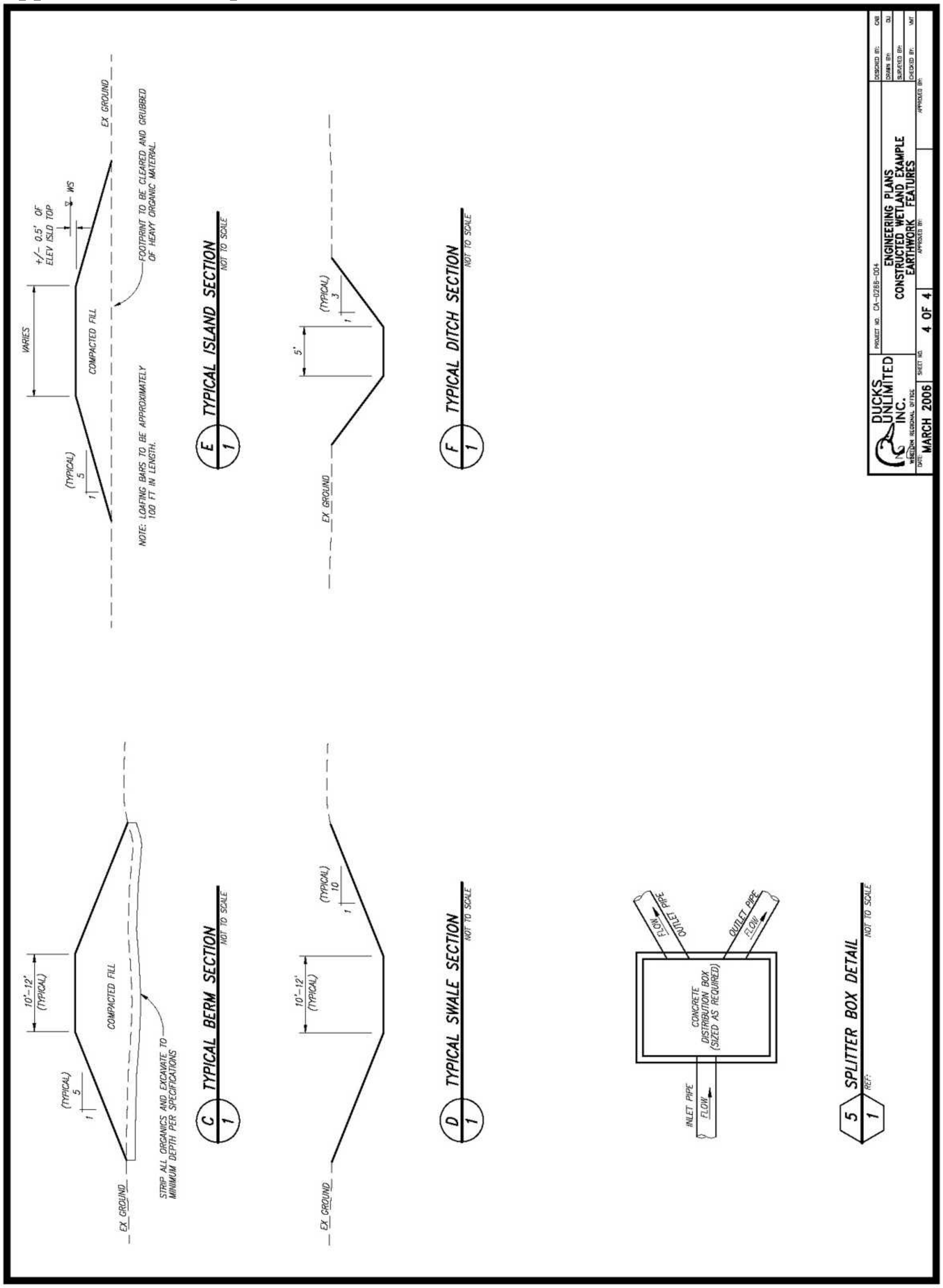
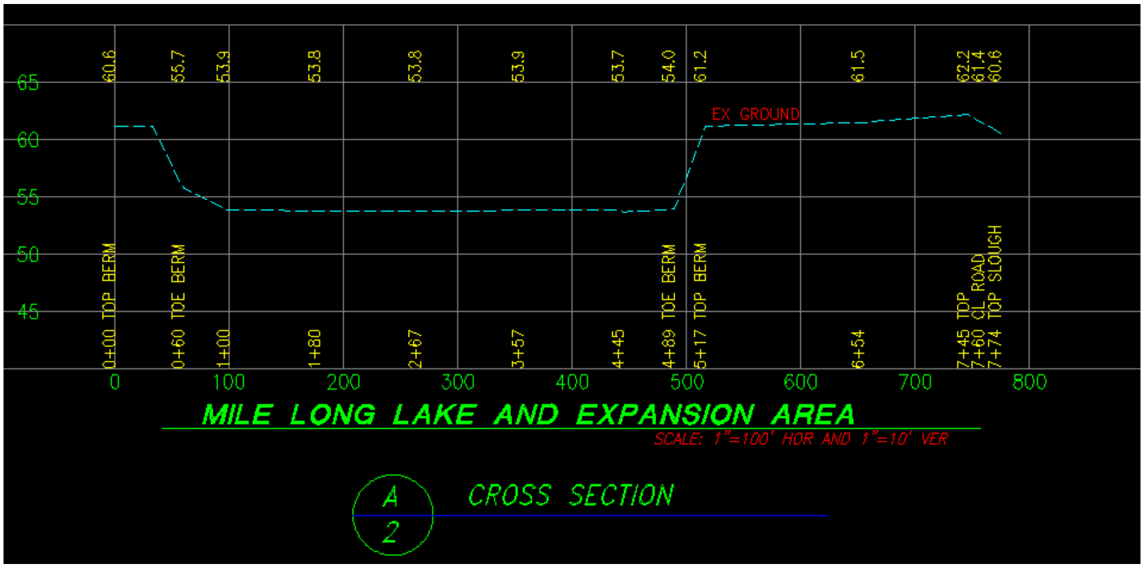
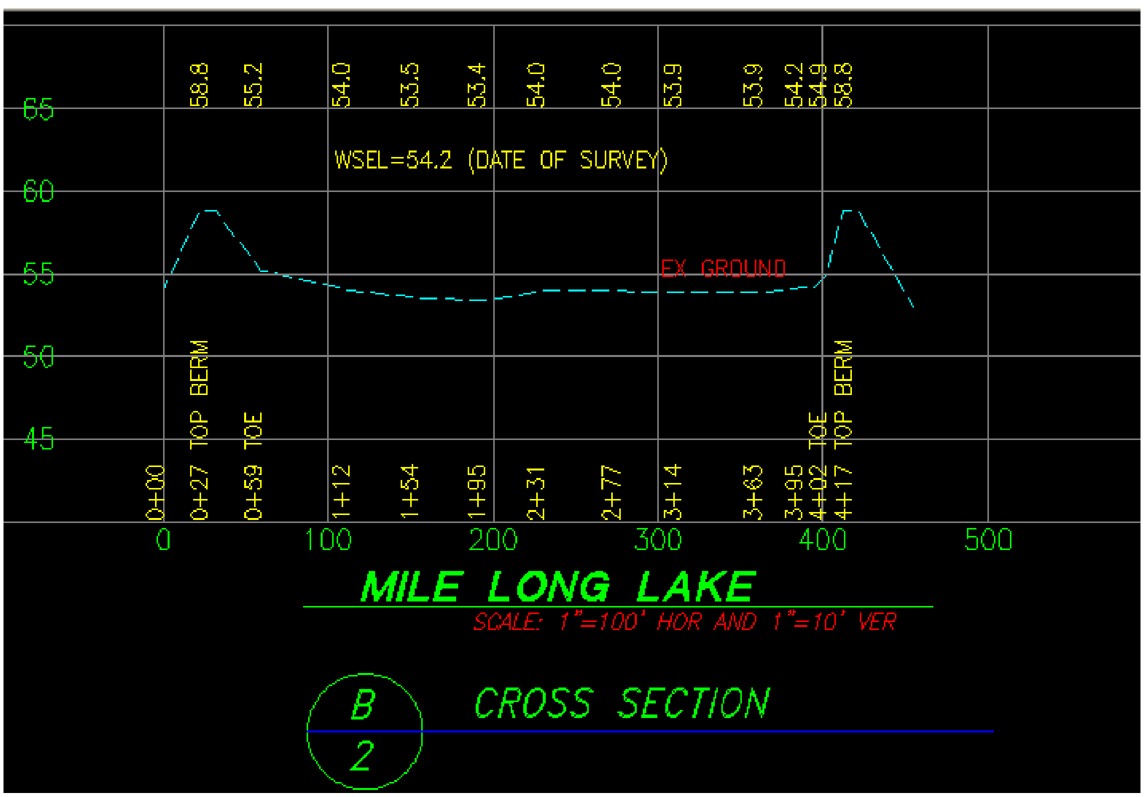


Appendix C – Case Study – Wingsetter Wetland Range





Appendix D - PRINCIPLES OF CENTRAL VALLEY WETLAND MANAGEMENT

Taken from California Department of Fish and Game Handbook POO800X

Wetlands evolved as dynamic ecosystems, constantly changing due to the physical and chemical processes associated with floods, drought, and fire. Today, most of California's rivers have been contained, and the majority of the Central Valley's wetlands seldom experience natural seasonal flooding. Most wetlands are now enclosed by levees and flooded with water from irrigation district conveyance systems, rivers and sloughs, and/or deep wells. Whereas natural wetland hydrology was very dynamic, flooding cycles now used for managed wetlands are often very predictable. It is the task of the modern wetland manager to emulate natural hydrology and re-create a dynamic, productive wetland system. The Central Valley supports the single largest concentration of wintering waterfowl in North America, thus Central Valley wetland managers have an enormous responsibility to provide optimum habitat conditions for wintering waterfowl. However, wetland management can be conducted in such a manner that shorebirds, wading birds, breeding ducks, and other wetland-dependent wildlife also realize maximum benefits.

The management of productive wetland habitat requires dynamic water management, as well as periodic soil and vegetation disturbances. An adequate water conveyance system is essential for meeting water management objectives, thus pumps, delivery ditches, water control structures, and drainage systems must be maintained in functional condition. Discing, mowing, and burning can be used to interrupt the natural succession of wetland habitat and to stabilize the marsh vegetation at a point which is the most productive of those elements required by waterfowl and other wetland-dependent species. The attached wetland habitat management guides showcase a variety of management practices that can be used to produce a diversity of productive wetland habitats.

Seasonal Wetlands (Upper Bench, 0”-16” deep)

Seasonal wetlands are flooded in the fall, with standing water maintained continuously throughout the winter until drawdown occurs in the spring. A variety of annual plants germinate on the exposed mudflats of seasonal wetlands when surface water is drained during spring and summer. These plants are collectively known as "moist-soil plants". Some of these plants produce seeds, browse, and/or tubers that are important foods for waterfowl. A combination of moist-soil plants and robust emergent vegetation (typically cattails and/or tules) usually results from management practices in Central Valley seasonal wetlands. A primary goal of "moist soil management" (seasonal wetland management) is to provide an abundance and diversity of seeds, aquatic invertebrates, and other moist-soil foods for wintering waterfowl. Although agricultural grains (e.g., rice, corn) supplement the diets of waterfowl in winter, these foods lack many of the vitamins, minerals, and proteins essential for survival and subsequent reproductive success. The seeds of moist-soil plants provide waterfowl with the essential nutritional balance lacking in grains. Invertebrates are protein-rich by-products of moist-soil management that serve as an important food source for ducks during late winter and spring. Shorebirds are also highly dependent on seasonal wetlands and the invertebrate foods they supply, particularly during spring migration.

Wildlife Values of Various Moist-soil Plants

The wildlife value of a moist-soil plant species is generally based on its seed production capability, the nutritional quality of its seeds, and the invertebrate habitat the plant provides. Management practices that encourage a diversity of highly valuable moist-soil plants are considered most effective. Watergrass, swamp timothy, and smartweed are the most important moist-soil plants in the Central Valley due to their documented value as a food source for wintering waterfowl. Seeds of these three plants, in aggregate, provide waterfowl and other seed-eating wildlife with a relatively nutritionally balanced diet. However, a variety of other wetland plants are needed to provide additional nutrition, cover, and thermal protection. Some moist-soil plants are not good seed producers or produce seeds with modest nutritional value, but have a complex leaf structure and harbor rich invertebrate communities, thus are valuable to wildlife.

Moist-soil plants with exceptional value to wildlife include watergrass, smartweed, swamp timothy, sprangletop, ammannia, chufa, burhead, beggarticks, annual atriplex, goosefoot, and brass buttons. Spikerush, pricklegrass, alkali heath, alkali weed, bermuda grass, aster, and alkali bulrush are moist-soil plants that are believed to be only moderately valuable to wildlife, but may be important in localized areas. Cocklebur, sweet clover, river bulrush, tuberous bulrush, baltic rush, jointgrass, dock, and salt grass are generally invasive and undesirable wetland plants.

Timing of Drawdown and Soil Disturbance

Important moist-soil waterfowl food plants such as swamp timothy, smartweed, and watergrass are easily propagated on most seasonal wetland sites through effective water management and soil disturbance. The primary factors that affect the type and abundance of moist-soil plants that are found in a seasonal wetland are: 1) the timing of spring drawdown, and 2) the "successional stage" of the wetland (length of time since soil disturbance). The seeds of each plant species germinate best at a specific soil temperature under specific successional conditions. Therefore, as plants compete for dominance, wetland managers can favor specific plants (or groups of plants) by: 1) timing drawdowns to coincide with optimum germination conditions (primarily soil temperature), and 2) discing periodically to maintain the successional stage required by the target vegetation. Although climatic conditions vary by year and location, the drawdown dates listed in the habitat management guides will generally induce germination of the target waterfowl food plant. The management strategies described in these leaflets have been successfully implemented by wetland managers throughout the Central Valley, but are by no means the only way to achieve these desired habitat types. Soil type and water quality also influence plant growth, so modification of these general recommendations may be necessary based on local knowledge and weather patterns for specific sites.

Rate of Drawdown

The rate of pond drawdown affects moist-soil plant composition, seed production, soil salinity levels, and the duration of food availability to waterfowl. Slow drawdowns (2-3 weeks) cause invertebrates to become concentrated in the shallow water and allow waterfowl optimum foraging conditions for a prolonged period. Slow drawdowns also typically result in high vegetation diversity and, if executed during mid- to late spring, may enhance seed production. However, they may concentrate salts near the soil surface in systems with brackish or saline water. Rapid drawdowns (3-5 days) are desirable if a soil-salt problem exists, as was quite often the case in the San Joaquin Valley in the past. Rapid drawdowns may produce extensive stands of waterfowl food plants if timed correctly, but "rob" wildlife of the extended shallow water habitat associated with slow drawdowns. Rapid drawdowns late in the growing season should be followed by a summer irrigation to ensure a good seed crop. Although slow drawdowns are generally better for wildlife, there is no "right" or "wrong" way to drain a seasonal wetland. The rate of drawdown should be based on site-specific knowledge.

Irrigations

Spring and summer irrigations are very important in Central Valley moist-soil management. Most waterfowl food plants will not attain maximum seed production without at least one irrigation. The San Joaquin Valley receives less rainfall than the Sacramento Valley, and therefore the soils dry out faster and irrigations are more often a necessity. Swamp timothy is the only waterfowl food plant that may be grown successfully without an irrigation in the San Joaquin Valley, however, irrigations greatly enhance seed production if timed correctly. Irrigation schedules for smartweed and watergrass vary with annual weather patterns. These plants can be observed for signs of wilting to determine proper irrigation dates.

Fall Flooding

Early fall flooding (August and September) is particularly important for locally-raised mallards and early migrant pintails and is highly recommended if feasible. Generally, most wetland units should be flooded prior to October 15. This problem is easily solved on those properties which can simply pump groundwater from deep wells to overcome the effects of evapo-transpiration and seepage (percolation).

Water Depth

Water depth is extremely important in Central Valley moist-soil management. Dabbling ducks (e.g. mallards, pintails, green-winged teal) cannot effectively feed on the seeds and invertebrates found on pond-bottoms if the water is deeper than 12 inches. Water depths of 4-10" are preferred for feeding. Therefore, in order to provide feeding habitat for dabbling ducks, shallow water must be maintained! Shallow water habitat management is valuable to many other wildlife species, as well. In Missouri, only 5 of 54 bird species that use seasonal marshes can effectively forage in water deeper than 10 inches. Shorebirds are particularly dependent on shallow water and seldom use habitats in which the water is deeper than 6 inches.

Summer Wetlands

The Central Valley's resident wetland wildlife are highly dependent on semi-permanent and permanent wetlands during the late spring and summer when seasonal wetlands are dry. Basically, the two primary habitat requirements of wetland wildlife during this time period are: 1) sufficient cover and protection from predators, and 2) an abundant food supply of aquatic invertebrates. Such invertebrates are the primary source of dietary protein for ducks and other wetland birds during the breeding season. Most species of wetland wildlife are dependent upon invertebrates as a direct or indirect food source during the spring and summer. For example, breeding ducks and shorebirds eat invertebrates almost exclusively, but herons eat other direct consumers of invertebrates such as fish, reptiles, and amphibians. Both semi-permanent and permanent wetlands provide ample protection from predators, however semi-permanent wetlands usually supply a much greater abundance of invertebrates. Invertebrate populations decline with prolonged flooding, thus a dry period of at least 2 months each year is essential for maintaining abundant populations of invertebrates.

Semi-permanent Wetlands (Upper bench, 1′-2′ deep)

Semi-permanent wetlands, commonly referred to as "brood ponds", are flooded during the spring and summer, but experience a 2-6 month dry period each year. Semi-permanent wetlands provide breeding ducks, ducklings, and other wetland wildlife with protection from predators and abundant invertebrate food supplies. Water depths of 6-12" are necessary to allow wildlife access to invertebrate foods, however deeper areas (e.g. channels, borrow ditches) are also important in that they provide open water. Well managed semi-permanent wetlands require periodic discing to prevent the vegetation from becoming too dense. In order to maximize habitat values without incurring major discing costs, it is recommended that semi-permanent wetlands be relatively small in size (2-10 acres). Various techniques have been developed for integrating semi-permanent wetlands into a moist-soil management program. Specific management practices are described in the attached management guides.

Permanent Marshes (Primary Filter Channel, 4′-6′ deep)

Permanent marshes are wetlands that remain flooded throughout the year. Due to year-round flooding, permanent marshes support a diverse, but usually not abundant, population of invertebrates. However, submerged aquatic vegetation such as sago pondweed, horned pondweed, and water hyssops may occur if adequate water clarity exists. The leaves and/or nutlets of these aquatic plants are commonly consumed by waterfowl, particularly gadwalls, ring-necks, redheads, and canvasbacks. Carp and other rough fish may reduce water clarity and prohibit the growth of these desirable plants. Permanent marshes are important to resident waterfowl in mid- to late summer when local ducks are molting their flight feathers; the deep water and dense cover provide protection from predators.

Habitat Diversity

If a wetland is to be designed to serve the dual benefit of water quality and habitat value, biological goals should be defined during the early project development stages. For instance, is the wetland to attract certain species of wildlife, be used for recreational purposes, or restore specific type(s) of habitat?

Biological diversity is extremely important in establishing a healthy self sustaining ecosystem of high habitat value. It is recommended that constructed wetlands contain a diverse mixture of habitats, including upland, emergent wetland, and open water. The engineering designs should include various water depths and incorporate a variety of engineering features, while the biological sign should incorporate a variety of vegetation and habitat.

It is unlikely that wetland managers will be able to produce a monoculture of any one plant in an established wetland, particularly if pond bottoms are of uneven topography. Furthermore, a wetland with diverse habitats is valuable to a wider variety of waterfowl and other wildlife species and will better resist the devastating effects of plant diseases, insect pests, and bird depredation. Diversified habitats also provide a variety of waterfowl foods throughout the fall and winter. Even though some moist-soil plants are poor seed producers, when flooded they may support excellent assemblages of invertebrates. Waterfowl also utilize other plants (e.g. cattails and "tules") for cover. An ideal Central Valley seasonal wetland is dominated by waterfowl food plants, contains other moist-soil plants, and provides waterfowl with substantial cover.

Vegetation Control

Some plants reduce the value of a wetland to waterfowl if they become overly abundant. Tules and/or cattails can eventually "fill in" a pond and eliminate open water. Dense stands of tules and cattails should not occupy more than 60% of a pond. The primary tools for tule/cattail control are discing, mowing, and burning. Mowing and burning are only effective when followed by discing and 2-3 months of exposure to the sun, which is necessary in order to dry out and kill the tubers and rhizomes. Discing tules and cattails also disturbs the soil and provides favorable conditions for invasion by valuable moist-soil waterfowl food plants.

Discing is typically accomplished with either a "stubble disc" or a "finish disc". The depth of discing varies with soil structure, soil moisture, implement weight, tractor size, and tractor speed. Most stubble discs have blades that range from 26-36" in diameter; these make cuts that are 7-10" deep. Stubble discs are necessary for most types of pond-bottom discing, however, a finish disc and ring-roller can be used afterward to break up dirt clods and make walking easier under flooded conditions. Deep stubble discing can adversely affect the water-holding capacity of a wetland if the disc breaks through the shallow clay pond bottom and into the underlying sandy soil. Although very uncommon, this unfortunate situation can be avoided by contacting the local Natural Resources Conservation Service (NRCS) office prior to initiating a deep-discing or excavation project.

Finish discs, which typically have blades that range from 18-24" in diameter, usually make cuts that are 4-6" deep. Finish discs often suffice for discing low-growing vegetation such as pricklegrass and swamp timothy, but have proven totally ineffective for controlling cattails, tules, river bulrush, baltic rush, or other robust wetland plants.

Summer irrigations occasionally cause watergrass, smartweed, sprangletop, and other valuable moist soil plants to occur in very dense stands. Waterfowl use of these areas may be impeded unless openings are created prior to fall flooding. With the use of a finish disc, managers can create strips, channels, and potholes in the otherwise dense vegetation. The appropriate time to create such openings is in July or August.

Wetland Management - An Art

Wetland management is an art, not a science. Wetland management practices are continually being improved as a result of research and experimental management. The results of these learning efforts are disseminated to interested parties by the agencies and organizations involved in waterfowl management. However, it is to the advantage of all wetland managers to keep accurate records of habitat manipulations (e.g. dates of flooding, irrigation, drawdown, discing). Managers should eventually be able to predict how the vegetation on their property will respond to specific management practices; this in turn will allow them to consistently provide high-quality waterfowl habitat.

Upper Bench, 0″-16″ deep

SEASONAL WETLAND

Target Waterfowl Food Plant: Smartweed

Timing of Spring Drawdown:

March 1 – 20. Sacramento Valley

February 20 - March 10. San Joaquin Valley

Moist-soil Plant Community: In addition to smartweed, other desirable wetland plants that may occur under the following water management and soil disturbance schedule include but are not limited to tule, cattail, spikerush, chufa, fat-hen, alkali bulrush, and watergrass.

Potential Problem Plants: Some wetland plants are undesirable if they become overly abundant or create dense stands. These include but are not limited to tule, cattail, asters, cocklebur, salt grass, bermuda grass, and baltic rush.

Value to Waterfowl: A moist-soil plant community dominated by smartweed, but including various other wetland plants, is an important component of a diversified marsh management program. Also referred to as "redweed", smartweed provides ducks with a quality food source throughout the fall and winter. Smartweed produces seeds that contain balanced proportions of essential vitamins, protein, minerals, and carbohydrates. In addition, it has a complex leaf structure, which supports excellent assemblages of aquatic invertebrates when flooded. Recent research in the Midwest shows high invertebrate abundance and diversity in association with smartweed. Tules, cattails, and other emergent plants add structural diversity to the marsh and provide ducks with cover. Wetland units having dominant stands of smartweed in association with these cover plants become an integral part of the wetland complex and receive heavy usage by dabbling ducks, particularly mallards. Smartweed may also occur in combination with watergrass, which has even greater seed value.

Management Strategy: Two important factors that influence smartweed growth are: (1) the timing of spring drawdown, and (2) the stage of succession (number of years since the area was last disturbed through discing or plowing). Smartweed requires cool soil temperatures and relatively high soil moisture for germination, and therefore, is usually found in wetlands that undergo early spring drawdowns. Smartweed can be maintained in seasonal wetlands for several years if water management coincides with its growth requirements. Periodic soil disturbance is usually essential to the maintenance of smartweed stands. Smartweed is considered a "pioneer" or "invader" plant species because it colonizes recently disturbed wetland sites. Eventually, competition from other wetland plants, particularly cattails and tules, will eliminate smartweed from the community. Discing should occur when smartweed abundance decreases substantially.

Establishment: Smartweed seeds are present in the soils of most wetlands, ricefields, and set-aside lands, which eliminates the need for any type of planting. If undesirable vegetation is dominant, the area must be disced, preferably during summer. Discing reduces plant competition and prepares the seedbed for improved smartweed production the following spring. Discing dense stands of cattails and tules in early summer is the most effective way to reduce competition and create conditions suitable for smartweed colonization. This method exposes cattail/rule rhizomes and tubers to the sun and kills them, thus preventing their re-growth during fall flooding. Water should be maintained on these areas throughout the winter. Smartweed will usually "invade" the disced areas if an early spring drawdown occurs.

Spring Drawdown: Managers must do everything possible within the constraints imposed by water districts to maintain water until the early-spring drawdown that will typically encourage smartweed development. Coincidentally, the retention of pond water through February assures the availability of protein-rich invertebrates to pre-breeding ducks. Appropriate drawdown dates are listed above. Smartweed seeds should begin to germinate within 2 weeks of drawdown. Rapid drawdowns (3-5 days) typically produce extensive stands of moist-soil vegetation, consisting of relatively few plant species. Slow drawdowns (2-3 weeks) maximize the foraging opportunity for waterfowl and other wetland birds and result in greater diversity of vegetation. Invertebrates, in particular, become concentrated and readily available to ducks.

Irrigation: An irrigation will be needed if smartweed plants show signs of stunting (i.e. halted growth and "yellowing"). This usually occurs 4-6 weeks after germination when plants are generally 3-12" high. Irrigation should occur as soon as possible, but may be delayed until mid-summer if water availability is a problem. A second irrigation is necessary if plants appear stunted before seed development occurs. Summer irrigations encourage the expansion of cattail and tule stands, as well as sprangletop and watergrass development. Smartweed may achieve full development without an irrigation, particularly if a high water table is present, late rains occur, or water seeps in from surrounding wetlands or ricefields.

Fall Flooding: Flooding should coincide with the arrival of migratory waterfowl. Pintails begin arriving in the Central Valley in mid-August, and peak numbers of wintering waterfowl are usually present during December and January. The flooding of individual units should be staggered to match the habitat requirements of arriving waterfowl, if possible. For example, fall flooding should begin on sites suitable for pintails, such as areas dominated by swamp timothy. Smartweed units are typically used by mallards, many of which are raised locally, therefore flooding can occur anytime between August and October. The timing of water delivery plays a major role in the determination of flooding schedules, however. Many marsh managers simply execute their fall flooding when irrigation districts make water available. Marsh units should be gradually flooded to allow ducks maximum accessibility to seeds and invertebrates.

Discing: Periodic soil disturbance is vital to most marsh management programs, particularly those involving smartweed production. It reduces potential problem plants and creates conditions suitable
for smartweed establishment. Discing should be employed when it is obvious that smartweed is no longer dominant and is being replaced by undesirable species. This normally occurs 3-6 years after establishment. However, discing the entire field at one time would eliminate all food and cover from the area for one season and should be discouraged. This practice would also return the marsh to a monoculture of smartweed the following year. Marsh plant diversity is desirable, and discing 30-40% of the pond bottom in a random pattern will create a "mosaic" of smartweed and dense emergent vegetation. Following discing, smartweed will colonize areas previously occupied by cattails, tules and other non-target species.

Note: Occasionally, stands of smartweed develop a fungal infection called "smut", which reduces seed production. Little is known about smut, although it appears most prevalent when too much water is applied during the growing season. Managers should not be overly concerned with the disease because it usually only affects a portion of the smartweed seed source, and not the invertebrate habitat the plant provides. However, the threat of the disease further emphasizes the need for habitat diversity. If, in a given year, a smartweed seed crop fails in a diverse wetland complex, other waterfowl food plants will help supply necessary seeds for wintering waterfowl.

Target Waterfowl Food Plant: Swamp timothy

Timing of Spring Drawdown:

April 15 – 30. Sacramento Valley
March 20 - April 10. San Joaquin Valley

Drawdown should be slightly later on sites with sandy soils.

Moist-soil Plant Community: In addition to swamp timothy, other desirable wetland plants that may occur under the following water management and soil disturbance schedule include but are not limited to tules, cattails, pricklegrass, watergrass, beggarticks, fat-hen, and alkali bulrush.

Potential Problem Plants: Some wetland plants are undesirable if they become overly abundant or create dense stands. These include but are not limited to tale, cattail, cocklebur, salt grass, bermuda grass, aster, dock, jointgrass, and baltic rush.

Value to Waterfowl: A moist-soil plant community dominated by swamp timothy, but including various other wetland plants, can be an important component of a diversified marsh management program. Seasonal wetlands dominated by swamp timothy are very attractive to wintering waterfowl. Swamp timothy is a low-growing (2-10"), seed-producing, moist-soil plant that provides sheet-water habitats when flooded. Water should be maintained at depths of 4-12" to allow optimum foraging conditions for dabbling ducks. This plant is naturally occurring on bare, poorly drained sites, but can be grown under a variety of circumstances. Conditions that favor swamp timothy germination and growth were examined in the 1970s and propagation techniques have been refined in recent years. Many San Joaquin Valley wetlands that were once dominated by jointgrass and other low-quality moist-soil plants now support excellent stands of swamp timothy.

Pintails and green-winged teal, in particular, prefer wetland habitats dominated by swamp timothy. Swamp timothy seeds are important to ducks arriving in early fall (August and September) as they facilitate the accumulation of fat reserves and the restoration of nutrients expended during molt and migration. As wetland seed resources are depleted during winter, many invertebrate populations reach maximum densities and are readily available in the shallow water of swamp timothy stands. Studies indicate that midge larvae (the worm-like larvae of the midge fly) are heavily utilized by dabbling ducks in swamp timothy habitats during late winter. In addition, these shallow, open-water habitats provide excellent sites for loafing and courtship.

Management Strategy: Swamp timothy is a drought-adapted plant that germinates with a mid-spring drawdown and will achieve seed production without summer irrigation. Swamp timothy management is commonly practiced on areas that lack a reliable source of summer water, but growth and seed formation may be enhanced through irrigation. However, summer irrigations and periodic discing have differing effects on swamp timothy stands at different locations in the Central Valley. For example, irrigations enhance plant growth and seed production in the San Joaquin Valley, but apparently have little impact on seed production in the western Sacramento Valley. The periodic discing of pond bottoms (every 3-7 years) has also resulted in increased plant vigor and seed production in the San Joaquin Valley, although managers in the western Sacramento Valley have maintained productive timothy stands for many years without discing. In general, if the vigor of timothy stands declines significantly over time, regardless of location, discing is strongly recommended.

Establishment: Swamp timothy seeds are present in most Central Valley wetland soils, thus planting is generally unnecessary. Discing may be required to position seeds near the surface if recent soil disturbance has not occurred. Impounding water throughout the fall and winter will create ideal conditions for germination the following spring.

Spring Drawdown: Managers must do everything possible within the constraints imposed by water districts to maintain water until the mid-spring drawdown that will typically encourage swamp timothy development. Coincidentally, the retention of pond water through March assures the availability of protein-rich invertebrates to pre-breeding and breeding ducks. Appropriate drawdown dates are listed above. Swamp timothy seeds should begin to germinate within 2 weeks of drawdown. Rapid drawdowns (3-5 days) typically produce extensive stands of moist-soil vegetation, consisting of relatively few plant species. Slow drawdowns (2-3 weeks) maximize the foraging opportunity for waterfowl and other wetland birds and result in greater diversity of vegetation. Invertebrates, in particular, become concentrated and readily available to ducks.

Irrigations: A shallow "flash" irrigation may be given to swamp timothy stands approximately one month after germination. Extreme care must be taken in this process, however. Maturing plants will not survive flooding which overtops them for more than 10 days, nor will they tolerate flooding once they have produced a seed head. Rainfall may eliminate the need for irrigation in the Sacramento Valley, however San Joaquin Valley wetlands usually require at least one irrigation for optimal swamp timothy development.

Fall Flooding: Flooding should coincide with the arrival of migratory waterfowl. Pintails begin arriving in the Central Valley in mid-August, and peak numbers of wintering waterfowl are usually present during December and January. The flooding of individual units should be staggered to match the habitat requirements of arriving waterfowl, if possible. For example, fall flooding should begin on sites suitable for pintails, such as areas dominated by swamp timothy. The timing of water delivery plays a major role in the determination of flooding schedules, however. Many marsh managers simply execute their fall flooding when irrigation districts make water available. Marsh units should be gradually flooded to allow ducks maximum accessibility to seeds and invertebrates.

Notes: Proper water manipulation may be needed for 1-3 years after initial discing to achieve a robust stand of swamp timothy. If at least a few plants produce a seed crop the first year, ground cover will increase each of the following years due to increased seed production and distribution. Swamp timothy ponds should have 10-35% cattail or tule interspersion to provide cover for loafing waterfowl.

Target Waterfowl Food Plant: Watergrass

Timing of Spring Drawdown:

May 1 – 31. Sacramento Valley

April 15 - May 15. San Joaquin Valley

Moist-soil Plant Community: In addition to watergrass, other desirable wetland plants that may occur under the following water management and soil disturbance schedule include, but are not limited to tules, cattails, sprangletop, ammannia, fat-hen, beggarticks, and smartweed.

Potential Problem Plants: Some wetland plants are undesirable if they become overly abundant or create dense stands. These include but are not limited to tule, cattail, cocklebur, salt grass, bermuda grass, dock, jointgrass, and baltic rush.

Value to Waterfowl: A moist-soil plant community dominated by watergrass is an important component of a diversified marsh management program. Watergrass, also referred to as millet, is an important and very abundant waterfowl food plant in the Central Valley. It is highly attractive to pintails, mallards, and other dabbling ducks, presumably due to its combination of seed production, invertebrate habitat, and thermal cover. Watergrass is a weed that grows in dense stands and may produce in excess of 2,000 lb. of seed/acre. It has substantial stem mass, which provides ducks with thermal cover and protection from predators. Through flooding and waterfowl activity, the stems eventually become matted and serve as excellent substrate for invertebrate production.

Watergrass seeds provide greater balance in nutritive quality than the high-energy, low-protein cereal grains, (e.g. corn, rice). They are especially high in essential minerals. Marsh units dominated by watergrass typically receive heavy duck usage throughout the season.

Sprangletop seeds provide waterfowl with a lesser, but still valuable, food source. Ammannia is a plant species that benefits waterfowl, but does not occur in great abundance.

Management Strategy: Watergrass requires more water than other waterfowl food plants, but is an easily propagated wetland plant species. Although an initial seeding may be required, a stand can be sustained for several years with proper water management, which involves late-spring drawdowns and summer irrigations. Unlike other waterfowl food plants, watergrass is commonly propagated in a monoculture. These watergrass units resemble unharvested rice fields in appearance. This management practice maximizes food production at the expense of habitat diversity. However, units can be strategically located so that diverse wetland habitats are nearby. Watergrass is also produced in conjunction with other moist-soil plants in diverse wetland units.

Watergrass and rice have very similar growth requirements. Maximum growth occurs during hot days and warm nights. The establishment (i.e. aerial seeding) of rice can even be used as a local estimate for determining the proper drawdown date for watergrass. Watergrass seed maturation takes approximately 45-80 days, but less time may be required under ideal soil and temperature conditions. Although crops can be established as late as August, seed production is limited due to the cold nights at the end of the growing season. Sprangletop germination generally occurs with late June or July drawdowns. Watergrass grows best in heavy clay or loam soils and will tolerate mildly saline conditions.

Establishment: The introduction of watergrass to a seasonal wetland through seeding usually promotes rapid establishment. Optimal establishment occurs either by: 1) discing, broadcasting the seed, treating the soil with a cultipacker (ring-roller), then flooding for 3-5 days, or 2) through aerial application on saturated soils. The subsequent drawdown should be executed within the time frame in which watergrass locally germinates best (listed under "Timing of Spring Drawdown"). Seeds should begin to germinate within 2 weeks. If germination has not occurred 3 weeks after drawdown, an irrigation will be needed. Irrigation schedules are listed below. Discing prior to seeding reduces plant competition and need not occur if the ground is sparsely vegetated. It may be necessary to repeat the discing process several times to remove dense or robust vegetation. It is important to remember that watergrass is a weed and that drilling or covering the seed is unnecessary. The seed will not germinate if it is buried too deeply in the soil. "Rice cleanings" can be obtained from rice mills and should be applied at 50-1001b./acre. Though only 10-40% watergrass seed, these have proven quite satisfactory. "Pure" watergrass can be purchased from seed distributors and only requires 15-40 lb./acre.

Spring Drawdown: Managers must do everything possible within the constraints imposed by water districts to maintain water until the late-spring drawdown that will typically encourage watergrass development. Coincidentally, the retention of pond water through April assures the availability of protein-rich invertebrates to breeding ducks. Appropriate drawdown dates are listed above. Watergrass seeds should begin to germinate within 2 weeks of drawdown. Rapid drawdowns (3-5 days) typically produce extensive stands of moist-soil vegetation, consisting of relatively few plant species. Slow drawdowns (2-3 weeks) maximize the foraging opportunity for waterfowl and other wetland birds and result in greater diversity of vegetation. Invertebrates, in particular, become concentrated and readily available to ducks.

Irrigation: Watergrass and other millets are water-dependent plants that require one or two summer irrigations for seed development to occur. Watergrass plants typically show signs of "redness" when soil moisture becomes limiting and the plants are "stressed". Plants will usually be 3-6" high when this condition occurs. At this point the marsh manager may elect to employ either of two strategies. They are as follows:

a) Irrigate Immediately: This method is the most reliable way to produce a highly productive stand of watergrass. The first irrigation should occur when the majority of the plants are turning red, which is generally 4-6 weeks after drawdown. A subsequent irrigation is crucial if plants show redness again. This procedure generally produces a robust stand of

watergrass with good seed development. Although ducks may initially have problems utilizing excessively tall
watergrass, weather and feeding activity eventually create openings and facilitate access. Stems serve as an excellent substrate for invertebrates when they become "matted" in the water, therefore, tall watergrass provides good invertebrate habitat.

b) Delay Irrigation Until August: If irrigation water is unavailable until August or if a more open and shorter watergrass stand is desired, then irrigation can be delayed until August. However, under this scenario, high soil moisture must be maintained throughout the remainder of the growing season. This can be accomplished through repeated irrigations or continuous flooding. Early fall flooding (August) can serve as this irrigation. This form of watergrass management is not normally recommended because vegetation response is variable and, therefore, seed production is unreliable.

Fall Flooding: Flooding should coincide with the arrival of migratory waterfowl. Pintails begin arriving in the Central Valley in mid-August, and peak numbers of wintering waterfowl are usually present during December and January. Watergrass units should be flooded between August and October, but the delayed flooding (late November - early December) of an individual unit can make a "new" food source available to wintering waterfowl. The timing of water delivery plays a major role in the determination of flooding schedules, however. Many marsh managers simply execute their fall flooding when irrigation districts make water available. Marsh units should be gradually flooded to allow ducks maximum accessibility to seeds and invertebrates.

Filter Channel, 2'-4' deep

PERMANENT MARSH

A permanent marsh is a wetland impoundment that incorporates a permanent, year-round flooding regime with dense emergent vegetation, aquatic vegetation, open water, and possibly small islands. These marshes provide critical habitat for wetland wildlife, particularly during the summer when seasonal wetlands are dry. Hardstem bulrush (tules) and cattails are characteristic of permanent marshes. Ideally, these plants cover approximately 50% of the water surface area and the open water area supports extensive beds of submerged aquatic vegetation. Proper management of a permanent marsh satisfies brood-rearing habitat requirements for ducks, therefore, a "brood pond" that is flooded throughout the year in most years will be considered a permanent marsh. Permanent marsh management does not allow for the production of "moist-soil" waterfowl food plants (e.g. watergrass, smartweed, swamp timothy), but does provide waterfowl with a diverse source of invertebrates and aquatic plants.

Value to Waterfowl: Ducks utilize these habitats throughout their annual cycle, but are most dependent upon them during the breeding season and flightless molting period (late spring and summer months). Permanent marshes provide ducks with habitat for brood-rearing, molting (feather replacement), loafing, foraging, and protection from predators. Nesting sites may be available for over-water nesters, such as redheads. Ideally, the pond bottom is uneven, which allows for a diversity of vegetation and optimal foraging depths for various waterfowl and other wetland birds. These habitats are crucial to breeding ducks, wading birds, pheasants, shorebirds, and certain fur-bearing mammals and songbirds due to the lack of summer wetland habitat in the Central Valley. Winter waterfowl use is primarily by gadwalls, mallards, and wood ducks, although permanent marshes are usually attractive loafing sites for a variety of waterfowl.. Sago pondweed is a preferred food of many dabbling and diving ducks and typically exists in permanent marshes.

The Central Valley breeding duck population is much larger than it was believed to be in the 1950s, however the factor that ultimately limits the population may be the availability of high quality brood-rearing habitat. Permanent marshes are more productive than the relatively sterile ricefields that breeding ducks use extensively in the Sacramento Valley, thus marsh managers can benefit breeding ducks by establishing permanent marsh habitat whenever practical. Although permanent marshes are typically thought of as brood-rearing habitat, they also serve as molting habitat. Ideal molting habitat is also relatively scarce in the Central Valley. The vast permanent and semi-permanent tule marshes of the Klamath Basin and southern Oregon support large congregations of flightless molting ducks during late summer. Mallards that breed in the Central Valley are known to migrate northward in search of suitable molting habitat and it is possible that other species do as well.

Management Strategy: Permanent marshes are usually maintained at constant water depths, with the circulation of water an important factor in maintaining marsh productivity. Circulation can be achieved with water controls set to provide a "slow flow-through" to offset the effect of evapo-transpiration. Complete drawdown should occur every 5-7 years to recycle nutrients and control dense emergent vegetation. Overall pond vegetation will increase annually and should be reduced by discing when coverage exceeds 80% of the pond.

Establishment: The construction of a permanent marsh involves establishing uneven topography on the pond bottoms, creating small islands, and the placement of a water distribution and drainage system that allows adequate circulation and complete drainage. Different plants will become established at different water depths.

- **Size and Location:** Permanent marshes can be of any size, but should be near suitable nesting habitat for ducks to utilize it as brood-rearing habitat. The creation of numerous ponds 5-25 acres in size, scattered throughout a block of wetland habitat generally produces optimum benefits for breeding waterfowl. Generally, such ponds should total no more than 10% of the overall marsh area. The amount and location of permanent marshes on surrounding lands should be taken into consideration when designing a wetland complex.

- **Gradient:** Pond bottoms of uneven topography tend to develop an interspersion of emergent cover and open water. A water regime that involves the maintenance of water throughout the summer months results in the growth of dense emergent vegetation. Emergent vegetation will become established rapidly in areas where the water depth is less than 2.5 feet. Deeper areas will remain open. Thus, it is important to design a pattern of channels, potholes, and small islands that create a mosaic of open water, dense emergent vegetation, and loafing sites. Potholes and channels should be interconnected and sloped from the inlet to the outlet. This design allows for complete drainage of the pond, which is occasionally necessary for habitat revitalization and the maintenance of water control structures.

- **Vegetation:** Tules and/or cattails are generally the dominant vegetation in a permanent marsh. Submerged, emergent and floating aquatic vegetation, such as sago pondweed, arrowhead, and duckweed are also common. The position of cover and open water in a permanent marsh is not critical, but consideration should be given to the fact that vegetation serves to protect duck broods from predators. Trees are not generally encouraged in brood-rearing areas because they provide a perch for avian predators, such as hawks and owls. Most managers maintain permanent marshes for the purpose of raising ducks broods. Thus, if it is the manager's intent to maximize duck brood survival, then the establishment of nearby trees is not recommended. However, trees provide outstanding habitat in seasonal wetlands for many species of wintering waterfowl, particularly mallards and wood ducks.

- **Islands:** The presence of islands in a permanent marsh increases the benefits to waterfowl and other wildlife. They are not essential, but provide additional habitat diversity. Islands can provide important loafing habitats during the wintering, molting, and brood-rearing periods. Ducks prefer barren loafing areas in the fall; thus a late summer burn can be used to provide them with a "clean" site. Winter rains and pond edge moisture will ensure that cover is available for duck broods the following spring. Historically, small mounds were naturally created by physical processes such as erosion and silt deposition and were probably low and gently sloping. Man-made mounds should emulate these natural formations. Gentle slopes will also result in a large "band" of vegetation around the island, creating more emergent cover and diversity.

BROOD POND

Flooding Schedule

Fall Flooding: October 1 preferred

Summer Drawdown: July 15 - August 1

A semi-permanent marsh is a wetland impoundment that incorporates a semi-permanent flooding regime with dense emergent vegetation, aquatic vegetation, moist-soil plants, open water, and possibly small islands. In the Central Valley, they are typically flooded from fall until mid-summer to meet the brood-rearing habitat requirements of local waterfowl. For this reason, semi-permanent marshes are often referred to as **"brood ponds"**. They provide critical habitat for wetland wildlife, particularly during the summer when seasonal wetlands are dry. Hardstem bulrush (tules) and cattails are characteristic of brood ponds. Brood pond management limits the growth of "moist-soil" waterfowl food plants (e.g. smartweed, swamp timothy), but creates valuable escape cover for duck broods. Brood ponds also provide ducks with a diverse food source of invertebrates and aquatic plants.

Value to Waterfowl: Ducks utilize brood ponds throughout much of their annual cycle, but are most dependent upon them during the late spring and summer when aquatic invertebrates are their primary food source and relatively few wetland areas are flooded. Invertebrates, which are high in protein, are readily available to ducks in both seasonal and semi-permanent marshes during drawdowns. Seasonal wetlands in the Central Valley are typically dry and of little value to ducks during the summer. Although permanent marshes are flooded during the summer, invertebrates are not highly available to ducks in these deep-water marshes. Research has shown that while gadwall hens and their broods utilize permanent marshes extensively, hen mallards with broods prefer shallow seasonal or semi-permanent wetlands over permanent marshes when both habitat types are available. Thus, brood ponds (especially during drawdown) and other semi-permanent wetlands appear to be the preferred feeding habitat for Central Valley mallards during the summer.

Brood ponds typically support vigorous stands of cattails and/or tules. The maintenance of a productive brood pond generally requires periodic vegetation manipulation, however. Studies have shown that wetlands exhibiting the "hemi-marsh" 50:50 cover to open water ratio are ideal habitats for breeding ducks. Frequent discing will accomplish nutrient cycling and ensure that the marsh remains in a productive state. Brood ponds also provide excellent loafing habitat for wintering waterfowl, particularly mallards and wood ducks.

Management Strategy: Brood ponds should be flooded continuously from the fall until at least July 15, but preferably August 1. The presence of summer water encourages cattail and/or tule growth in shallow areas, which provides ideal escape cover for duck broods. Discing, mowing, and

burning are methods that can be used to maintain brood ponds in the 50:50 "hemi-marsh" state. Moderate production of moist-soil vegetation may occur (e.g. watergrass), although seed development is hindered by the short period between drawdown and fall flooding, as well as competition from dense emergent vegetation.

In the Central Valley, many wetlands that remain flooded during the spring and summer months are enrolled in the USDA Water Bank Program. Landowners receive annual payments for this provision of brood habitat and may only begin draining these units on established dates between June 15 and July 15. The flightless molting period and part of the brood-rearing period may occur after some Water Bank units have been drained, thus the maintenance of water beyond the contractual calendar date may provide increased benefits to brood-rearing and molting ducks. The timing of fall flooding is not crucial because seasonal wetlands provide the majority of the habitat for early migrant waterfowl. Flooding of brood ponds should occur after maintenance work (i.e. discing, mowing) has been completed.

Note: The presence of summer water benefits ducks and other wetland wildlife, but also may produce mosquitoes. Landowners should check with their local mosquito abatement district for guidelines.

__Complete Constructed Wetland__

SEASONAL WETLAND - SUMMER WATER COMBINATION

Most wetland impoundments have borrow ditches on the "inside" or "pond" side of exterior levees. Borrow areas are created during levee construction and are generally 12-24" lower than the average elevation of the pond bottom. A marsh management practice that is becoming increasingly popular in the Central Valley involves the maintenance of summer water in the borrow areas or channels that exist within otherwise drained seasonal wetlands. These flooded borrow areas/channels typically comprise less than 5% of a wetland impoundment, but can be extremely productive habitats. Without impairing the capability of a wetland unit to produce large quantities of "moist-soil" waterfowl food plants, marsh managers can provide critical summer habitat for wetland-dependent wildlife in the low areas of their seasonal wetlands. These wet summer habitats may be drained in August or maintained throughout the year. Such wetlands may be extremely important summer feeding areas for breeding and post-breeding ducks, ducklings, pheasants, wading birds, and shorebirds. These feather-edged habitats offer more upland/wetland interface, and thus a more productive feeding habitat, than do typical "brood ponds" which are generally flooded "levee-to-levee".

Value to Waterfowl: Ducks utilize these flooded borrow areas/channels during the late spring and summer when aquatic invertebrates are their primary food source and relatively few wetland areas are flooded. Invertebrates, which are high in protein, are readily available to ducks in seasonal marshes during spring drawdowns. However, seasonal wetlands in the Central Valley are typically dry and of little value to ducks during the summer. Although permanent marshes are flooded during the summer, invertebrates are not highly available to ducks in these deep-water marshes. Research has shown that while gadwall hens and their broods utilize permanent marshes extensively, hen mallards with broods prefer shallow seasonal or semipermanent wetlands over permanent marshes when both habitat types are available. Thus, flooded borrow areas/channels within seasonal marshes and "brood ponds" would appear to be the preferred feeding habitat for Central Valley mallards during the summer.

Flooded borrow areas/channels provide some escape cover for duck broods, but function primarily as invertebrate-rich feeding areas for duck broods and other wetland wildlife. Ideally, brood ponds should be located nearby to provide ducks with optimum cover. Although these wet summer habitats are important to duckling survival, they may also be extremely important to the survival of young pheasants. Pheasant chicks are completely dependent on insects as a food source during their first 2 weeks of life; the "feather-edges" of these semi-permanent wetlands support good insect populations.

Management Strategy: The management of a seasonal wetland in combination with a flooded borrow area/channel component involves flooding the entire pond during the fall and draining the majority of the pond during the spring, while maintaining water in borrow areas/channels until at least July 15. However, managers are encouraged to maintain water in borrow areas/channels throughout the entire year at stable levels. This practice is compatible with the interests of mosquito abatement districts because a mosquito fish population can be established and continuously maintained. These wetland areas generally encompass such small acreage that the amount of water required to maintain them is minimal. In addition to providing mosquito fish, these sites also provide a brood stock of midges. This management practice is thought to increase the production of midge larvae substantially in the pond during the following winter. The worm-like larvae of the midge fly is a major invertebrate food source for pintails and green-winged teal.

Channels or borrow areas may be constructed in wetlands that do not have existing topographic diversity. The depth of these channels may range from 6"-36". Although inexpensive to construct, shallow channels (6"-12") typically require periodic maintenance (e.g. discing) due to the invasion of tules and/or cattails that results from the presence of summer water. Deep (30"-36") channels prohibit tule/cattail growth and require minimal maintenance, but the cost of excavation can be extremely high. Generally, shallow channels are more productive than deeper areas, but either can greatly enhance the value of a seasonal wetland.

Appendix E – Contacts

Natural Resources Conservation Service

Modesto Service Center
3800 Cornucopia Way Ste E
Modesto, CA 95358-9494
(209) 491-9320
Contact: Michael E. McElhiney, District Conservationist
(209) 491-9320 ext. 102

Resource Conservation District

Modesto Service Center
3800 Cornucopia Way Ste E
Modesto, CA 95358-9494
(209) 491-9320

Regional Conservation District

West Stanislaus RCD
220 N El Circulo Ave
Patterson, CA 95363-2521
(209) 892-3026

East San Joaquin Water Quality Coalition

Parry Klassen
Coalition for Urban/Rural Environmental Stewardship (CURES)
(559) 325-9855

Stanislaus County Farm Bureau

Wayne Zipser
(209) 522-7278
www.esjcoalition.org

Appendix F – Additional Resources on Constructed Wetland Design

Ducks Unlimited, Inc. 2006. *A Landowner's Guide to Best Management Practices – Conservation Measures to Treat Agricultural Runoff.* Prepared for Coalition for Urban/Rural Environmental Stewardship.

Hammer, Donald A. 1999. Constructed Wetlands for Wastewater Treatment Municipal, Industrial, and Agricultural. Lewis Publishers.

Prepared by: Humboldt State University, CH2M-Hill, and PBS&J. 1999. *Free Water Surface Wetlands for Wastewater Treatment A Technology Assessment*. June 1999. Prepared for: U.S. Environmental Protection Agency, U.S. Department of the Interior, City of Phoenix. Accessed: http://www.epa.gov/owow/wetlands/watershed/cwetlands.html

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Kadlec, Robert H. and Knight, Robert L. 1996. Treatment Wetlands. New York. Lewis Publishers.

Prepared by: Luise Davis. *A Handbook of Constructed Wetlands a Guide to creating wetlands for: Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage, Stormwater in the Mid-Atlantic Region.* Prepared for: Natural Resources Conservation Service and the Environmental Protection Agency-Region III. Vol 1. Accessed: http://www.epa.gov/owow/wetlands/watershed/cwetlands.html

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