Introduction

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A New Technology Emerges

Wastewater professionals have long recognized the cleansing abilities of wetland systems. But until recently, there were limited data available about these systems. Pioneers in this industry designed wetland systems based on ingenuity and limited performance data. Today, due to their efforts, there are many operating constructed treatment wetlands both nationwide and in Colorado. Ingenuity is no longer the key factor to design wetlands – publicly available data is.

In 1999, the Governor’s Office of Energy Management and Conservation (OEMC) recognized the need to collect and disseminate this data and embarked on a program to evaluate and document constructed treatment wetland features and performance in Colorado. The OEMC’s timely implementation of this inventory will help all future builders of constructed treatment wetlands in Colorado and other parts of the country.

In Search Of Excellence – A Comprehensive Approach

The OEMC began this effort by selecting experts from various groups involved with wetlands and wetlands issues. These individuals comprise the OEMC Wetlands Task Force. The Task Force provided expertise and advice to guide the project and establish requirements for evaluating wetland data.

To implement the program, the OEMC requested proposals from qualified firms to locate, catalog and document the efficiency of Colorado's constructed treatment wetlands. From that request, the Task Force and OEMC selected the engineering-biologist team of HDR Engineering, Inc. and ERO Resources. Including both engineers and biologists in the inventory allowed a comprehensive review of the wetland treatment systems – from engineering details to habitat value. The team collected data to assess design features, energy savings, flora and fauna biodiversity, general operational problems, and to develop "lessons learned" from existing treatment wetlands in Colorado (discussed in Chapter 8 of this report). From this inventory, the team created a database compatible with the North American Treatment Wetland Database (NADB).

A Vision For The Future

A future that includes safe water supplies and functioning natural waterways and riparian habitats must also include the wise management of our wastewater. Engineers and government agencies both have visions of using wetlands more often as a natural way not only to maintain the environment, but also to enhance water quality and reduce energy costs. Developing an ideally functioning wetland that incorporates "best practices" from this inventory to guide other wetland designers is one of the OEMC's goals. This project is the stepping-stone to achieve that goal.

Based on this inventory (Phase I), the OEMC plans to develop a demonstration project to incorporate the most effective features of all the wetlands evaluated (Phase II). Phase II will require a partnership between the OEMC, an engineering consultant, and a community, or other group, wishing to build a wastewater treatment facility using wetlands, and potentially the Department of Energy (DOE), US Environmental Protection Agency (EPA) or other regulating agencies. Ideally, the wetlands project will incorporate energy savings, efficiency, improved water quality for stream or river discharge, high-value wildlife habitat, and walking trails for wildlife viewing. Phase II will consider general quality-of-life issues such as buffers between developments or communities to address "smart growth" issues and acquisition of open space. The Request For Proposal (RFP) for Phase II will most likely be released in the late summer or early fall of 2001.

Wetlands – Why Are They So Important?

Natural purification barriers: As natural water purification barriers, wetlands are typically a relatively low cost, low energy method to improve water quality. Because of land development practices during the last few decades, many natural wetlands have been dewatered. This reduction in wetland area has resulted in larger amounts of pollutants such as fecal coliform, total suspended solids, bacteria, viruses, algae and other organic and inorganic matter entering water bodies. This results in increased turbidity, decreased oxygen, and unnatural variations in pH and temperature. Recently, in an effort to counteract these results, a shift towards wetland area protection has occurred as the cleansing capabilities of wetlands have been recognized.

Natural cleansing process: The cleansing processes identified in natural wetlands can be mimicked in constructed treatment wetlands. Constructed treatment wetlands are designed to maximize the natural abilities of wetlands to remove pollutants from a variety of wastewater sources. This study focuses on the use of constructed wetlands for the treatment of municipal wastewater.

Water – A Limited Resource

"When the well's dry, we know the worth of water" – Benjamin Franklin

Earth is often referred to as the water planet because more than 70% of the earth's surface is covered with water. Since this resource is seemingly abundant it is easily taken for granted. This apparent abundance is deceptive, as only 3% of the earth's water is fresh, and two-thirds of that is trapped in glaciers and icecaps. So the issue that must be dealt with is not water supply, but water quality. With a limited amount of fresh water and an increasing global population, wise management of water supplies is essential. It is important for societies to recognize the value of protecting the quality of this limited and valuable resource.

The OEMC recognized this need and embarked upon this project.

Constructed wetlands are a viable treatment alternative for many reasons. Treatment wetlands remove solids, oxygen depleting pollutants, and lower bacterial and viral levels. Unlike traditional treatment methods, wetlands offer many ancillary benefits. These benefits, including wildlife habitat, and aesthetic and educational values, were evaluated, as was the wetland's ability to successfully meet its treatment goals.

Identifying Colorado's Treatment Wetlands

Phase I of the Colorado Constructed Treatment Wetlands Inventory was a reconnaissance effort to locate wetlands in Colorado used to treat point source pollutants. The project team performed a literature review, pursued leads provided by the OEMC and Task Force, and used local community knowledge to identify appropriate wetland sites. From a preliminary list of constructed treatment wetlands, the Task Force developed a final list to include in this study. The criteria used to determine whether a site would be included on the final list are as follows:

- Constructed wetland must be treating a point source.
- Data must be available in order to assess the wetland's wastewater treatment efficiency.

Twenty sites met both of the above criteria. Wetland site locations varied from locations such as Dove Creek to Avondale. While examples of other types of wetlands are included in the study, most of them were not included in the more rigorous analysis. Chapter 6 contains detailed analyses of the sites visited.

So…Are We Meeting Government Standards?

The HDR/ERO team considered both engineering and biological parameters in their wetland evaluations. The team made site visits to the selected wetlands and used a Site Data Sheet (SDS) to provide a consistent method for evaluating each site. The evaluation process allowed for an independent review of both the engineering and biological aspects. The inventory provided a 'snapshot' of how the wetland was performing on the date of the site visit. Water quality records and historical information were gathered during an interview with a wetland contact person; as well as from the Colorado Department of Public Health and Environment's (CDPHE) permit files.

What does this mean? It means information will now be in one location and accessible for comparison. This will allow future wetland designers to determine which practices best meet their goals. Chapter 8 discusses how our findings compared to CDPHE's regulations, as well as "lessons learned."

What's In This Report?

From Local to National – Making the Information Available

In the early 1990's the US EPA sponsored the creation of a database containing design and performance information about constructed treatment wetlands. This information was used to develop design guidelines and to chronicle the successes and failures of wetland systems. Prior to the Colorado Constructed Treatment Wetland Inventory project, only one Colorado wetland was included in the database. A primary goal of this study was to collect data on Colorado's treatment wetlands for entry into the National Database. The team developed the SDS with this goal in mind and designed a database compatible with the NADB to store this information. The information gathered through this inventory is available from the OEMC. Future designers can use the data as a tool for comparative analysis and to help guide them in making design decisions for their wetland.

'Lessons Learned' From Those Involved With Existing Wetlands

Wastewater treatment using constructed wetlands involves different processes than conventional treatment methods. Operators, designers, and local officials must approach the implementation and operation of constructed wetlands with an understanding of the natural treatment processes involved. Information collected from the existing Colorado treatment wetlands details the challenges of designing and operating these systems and chronicles the innovative solutions developed to meet them. The ultimate goal of this project is to disseminate information regarding the use, design, operation, and performance of constructed treatment wetlands in Colorado. This will assist future wetland designers and operators to learn from the past experience of others.

Who's Who In Treatment Wetlands In Colorado

Over the course of this project, the HDR/ERO team developed a contact list. This list is provided at the end of Chapter 8 to facilitate communication between those with knowledge about these systems and those interested in learning more.

Final Report

The Colorado Constructed Treatment Wetlands Inventory report documents experiences with Colorado's treatment wetlands. A description of individual sites is discussed in Chapter 6 and general observations from the project are presented in Chapter 7. The OEMC, Task Force and HDR/ERO team hope this document will serve as a resource for those interested in using constructed wetlands as an effective and low energy method of treating wastewater.

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Treatment Wetlands Overview

Chapter Highlights

- Wetlands are environmentally sensitive areas that are adapted for variable hydrologic conditions.
- Constructed treatment wetlands are used to treat wastewater by mimicking the processes seen in natural wetlands.
- Constructed treatment wetlands are engineered systems that differ from natural systems.
- Free water surface wetlands operate with a water depth of 3” to 18”.
- Subsurface flow wetlands are designed to maintain the entire depth of the water column within the soil media. In a subsurface flow wetland the water level is not visible at the ground.

What Is A Wetland?

What is a wetland? Definitions vary from Oxford Dictionary’s characterization of wetlands as “swamps and other damp areas of land” to Kadlec and Knights “Wetlands are land areas that are wet during part or all of the year because of their location in the landscape.[1]” For the purposes of this report, we define wetlands as environmentally sensitive areas that can be identified by the following attributes:

Anaerobic refers to the absence of oxygen.

Litter layer is a deposit of partially decomposed organic matter.

Soil Type

Wetland soils are inundated by water or are saturated for extended periods and are characterized by a lack of oxygen. Their soils typically contain a high proportion of organic matter as a result of annual vegetation production. This combination of **anaerobic** conditions and a thick **litter layer** provide ideal conditions for chemical and microbial processes.

Hydrologic Characteristics

Wetlands are characterized by a hydrologic regime that provide periods of inundation and saturation. Important aspects of wetland hydrology include the detention time in the wetland, the water depth, the flow velocity through the wetland and the number of days per year in which the wetland is inundated.

Plant Species

Wetlands are home to a diverse group of plants, including emergent, floating and submerged species. Wetland plants are adapted to survive in saturated conditions. While most plants absorb oxygen through their roots, wetland plants can also absorb oxygen through their stems and leaves and transport it to their roots through specialized root cells.

[1]Robert H. Kadlec & Robert L. Knight: *Treatment Wetlands*, Lewis Publishers, Boca Raton, 1996.

Typical Microorganisms

Wetlands provide ideal conditions for a wide variety of microorganisms. These organisms are the 'workhorses' in the wetland treatment processes.

The construction of wetlands to treat wastewater is based on the chemical, biological, and physical processes that occur in natural wetlands. Because the soil or substrate in a wetland is commonly saturated, chemicals that enter the wetland in an oxidized state undergo transformations when exposed to the reduced conditions of the saturated soils. Biological activity in the **biofilm** that attaches to wetland soil and plants accounts for much of the dissemination and transformation of pollutants. Physical entrapment and sedimentation of wastewater solids are also key processes to remove pollutants. As wastewater treatment professionals recognized these processes in natural wetlands, they began to construct treatment wetlands to accomplish the same purposes.

Biofilm is a slime layer where microorganisms live. **Sedimentation** is a physical process by which solids settle to the bottom of a liquid.

Comparison of Natural and Treatment Wetlands

Although constructed treatment wetlands mimic many of the conditions seen in the natural wetland, there are significant differences. The primary goal of a treatment wetland is to improve the quality of the water flowing through it to a level that will meet discharge permit requirements. Since it is usually desirable to accomplish these requirements with minimal cost, energy and maintenance input, modifications to the natural system are necessary. Significant differences between constructed wetlands and natural wetlands are discussed below.

Comparison of Wetlands

Natural Wetland

- Accumulated organic matter
- Natural water source
- Biodiversity
- Microorganisms determined by existing environment

Constructed Wetland

- No or limited organic layer
- Piped water source
- Less biodiversity
- Microorganisms determined by type of wastewater

Soil Type

Some natural wetlands have soils that have formed as the result of many years (often 1000's of years) of accumulated organic matter. These rich soils are home to a wide variety of microorganisms. Soils used in constructed wetlands often lack organic matter and are not well developed. Some constructed wetlands are designed with specific soil properties to maintain a certain flow rate, or to prevent percolation to the groundwater.

Hydrologic Characteristics

Treatment wetlands are generally fed by a piped water source. Since these wetlands are often constructed in upland areas outside of drainages or natural depressions, they do not usually intercept natural surface water drainage during storm or flood events. Because of this their function in floodwater and sediment retention is different from a natural wetland. In addition, unlike natural wetlands, treatment wetlands are often lined with clay or plastic. This prevents groundwater discharge and recharge into the wetland.

Plant Species

Constructed wetlands often support a less diverse plant community than natural wetlands. Constructed wetlands are typically seeded or planted. Since all the plants are usually started at the same time, it is easier for the dominant species to overtake the wetland area before the less dominant species can become established. Since the hydrology in a constructed wetland is generally not as variable as what is experienced in a natural system, conditions in the constructed wetland will always favor a certain plant species.

Typical Microorganisms

The type of wastewater being treated determines the microorganisms that will flourish in the constructed wetland. Typically, the wastewater already contains a community of microorganisms before it is introduced into the wetland. Constructed wetlands are designed to provide an ideal habitat for microbial communities to breakdown key pollutants. Temperature and oxygen levels in wetlands play important roles in microbial processes. Constructed wetlands may be designed so that certain temperatures and dissolved oxygen parameters are maintained.

Common Design Methods

- Historical Data
- Attached growth models
- Areal & Volumetric Loading

Design Methods

The first step in designing a wetland system is to determine the required wetland size needed to reach treatment goals. Since available land is frequently a limiting factor, the area required by wetland systems often establishes the viability of using this option. Currently, there is not a universally accepted design process for sizing wetlands. The following paragraphs describe the most common methods used to size a constructed treatment wetland.

Historical Data

Empirical data collected from pilot scale and fully operational treatment wetlands are used to develop relationships between treatment goals and size requirements. Data stored in the NADB has been used to a limited degree to predict wetland performance. Relationships derived from empirical data may be useful if the designer has reliable data from a wetland with similar operating and climatic characteristics.

Attached Growth Models

This approach makes the assumption that first-order plug flow models used to design traditional wastewater treatment systems can be used to describe wetland treatment processes. This approach also assumes that the reaction of wastewater components can be described by first order reaction kinetics. The general relationship for first-order plug flow models is:

$$C_t = C_o \exp^{-kt}$$

Where: Ct = effluent pollutant concentration at t = t

t = mean hydraulic detention time

k = apparent first-order rate constant

Co = initial pollutant concentration (t = 0).

The apparent first-order rate constant can be adjusted by the following formula to correspond with a desired temperature:

$$k = k_{20}\Theta^{(T-20)}$$

Where: k = apparent first-order reaction rate constant at T degrees (°C)

K20 = apparent first order reaction rate constant at 20°C

Θ = empirical temperature coefficient, and

T = desired temperature (°C).

Several derivations of the plug-flow model have been developed to incorporate different approaches for defining the reaction coefficient and mean hydraulic detention time.

Areal and Volumetric Loading

Relationships are developed between the volume of water or mass of pollutant load introduced to the system to the surface area of the wetland. Areal loading rates can provide an expected effluent concentration for a particular constituent based on performance data from other similar systems. A limitation of this method is the invalid assumption that the influent is applied uniformly over the land area. Typically, wastewater is applied at the head of the wetland cell and allowed to flow across and/or through the wetland structure to the collection pipe at the end of the cell. Additional simplifications in this design method do not account for the water depth or temperature in the wetland.

Design Considerations

Wetland size requirements are determined by using one of the design methods discussed above. Generally, the treatment level needed to satisfy discharge permit requirements will be the driving factor in determining the limiting pollutant for which the wetland should be designed. Some pollutants typically monitored are discussed below.

Biological Oxygen Demand (BOD)

BOD is a measure of the amount of oxygen that a wastewater stream will consume during biological decomposition processes. The amount of oxygen that a wastewater sample will consume in 5 days (BOD_5) is the most commonly used BOD measurement. BOD creating substances can occur in either settleable or soluble forms. The maximum amount of BOD that can be present in discharge from a treatment system is established to prevent oxygen depletion in receiving water bodies.

Total Suspended Solids (TSS)

TSS includes both organic and inorganic particles that settle out of the water column under quiescent conditions. Releasing excess amounts of TSS into a receiving water body creates turbid conditions that can impede respiration and feeding functions of aquatic creatures, as well as cause the formation of "sludge banks."

"Wherever possible, emphasis should be placed on a "low impact" engineering approach. This not only avoids unnecessary expense but can enhance the natural processes involved in the use of wetlands. The design concept should be to have the system fit naturally into the landscape following the topography and minimizing straight dikes and 90° corners. If wetland habitat is a value, then islands with nooks and crannies should be liberally placed in the wetland surface."

[Gearheart et al., 1992]

Nitrogen

Nitrogen can exist in a variety of forms. Organic nitrogen is typically associated with wastewater solids or algae. Much of this nitrogen will undergo decomposition or mineralization within the system. Inorganic nitrogen, in the form of ammonia, nitrate, nitrite, or nitrogen gas is a result of biological nitrification and denitrification reactions. Although nitrogen removal is not a typical parameter included in a discharge permit, wetland design can provide sufficient oxygen, carbon and retention time to remove organic and inorganic nitrogen. Introducing excess nitrogen to a water body can lead to **eutrophic** conditions. Some forms of nitrogen can be toxic to aquatic life.

Eutrophic refers to water rich in nutrients and high in biological activity.

In order to effectively remove nitrogen through nitrification and dentrification, open water zones should be provided in the constructed wetland. Providing a series of vegetated and open water zones provides for the anaerobic and aerobic zones needed for nitrification of ammonia to nitrate, and dentrification of nitrate to nitrogen gas[2].

Phosphorous

Phosphorus is an essential element in the growth of algae and in excessive amounts can lead to noxious algal blooms. The primary mechanisms for removal of phosphorus in wetland systems are chemical precipitation and adsorption by the soil matrix. The degree of phosphorus removal in the wetland is dependent upon the amount of contact that the wastewater has with the soil matrix. Due to this limitation, free water surface wetlands will have less potential for phosphorus removal than subsurface flow systems. Both of these types of systems are described later in this chapter.

Hydrology describes the average behavior of the wastewater as it flows through the wetlands. **Hydraulics** refers to the physical mechanisms used to convey the water through the wetland.

Once the wetland has been sized to remove the regulated pollutant, the designer must determine wetland characteristics. Some issues to consider are discussed below.

Hydrology

Controlling the average behavior of wastewater as it flows through a wetland is key to its long-term success. Flow through a wetland more closely resembles plug-flow than completely mixed flow. Short-circuiting and dead pools need to be minimized in order more closely resemble plug-flow conditions. **Hydraulic residence times** are crucial design elements that assume uniform flow behavior.

Hydraulic residence time refers to the amount of time wastewater is in a wetland system. If the wastewater flows through the wetland too fast, then it may not be adequately treated.

Most treatment wetlands are designed to prevent stormwater runoff from entering the wetland, unless the intent is to treat stormwater runoff. This is achieved by locating the wetland in a highpoint and/or with the use of berms to route stormwater runoff away from the wetland. Flow characteristics through the wetland include:

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[2] *Constructed Wetland Treatment of Municipal Wastewaters*, USEPA Office of Research and Development, Cincinnati, Ohio, EPA /625/R-99/010, September 2000.

- Velocity – this is controlled by selecting a bed slope that provides a sufficient hydraulic gradient through the wetland to achieve the desired velocity.
- Detention Time – the amount of time that it takes a unit of volume to travel from the inlet to the outlet of the wetland is determined by the size, depth, and travel path through the wetland.
- Depth of Flow – a design depth must be chosen to provide adequate storage and appropriate conditions for the wetland plants chosen.
- Travel Path – providing an appropriate length to width ratio will prevent short-circuiting through the system.
- Water Balance – the designer must determine the sources and sinks that will occur in the wetland. Groundwater influences are generally minimized by the use of liners. It is important to determine the contribution that precipitation and evapotranspiration will have on wetland hydrology.

Hydraulics

The wetland hydrology will determine many of the controls of the wetland hydraulics. Hydraulics refers to the physical mechanisms used to convey the water through the wetland. Important components of the hydraulic system include:

- Conveyance System – typically a pipe will be used to transport the wastewater from the primary treatment to the wetland.
- Inlet Mechanism – wastewater is introduced to the wetland cells by using slotted pipes at the head of the wetland cells, teed down the length of the cells, or a variety of other methods.
- Depth Control – various mechanisms are used to control water depth in the wetland. Swivel Tees or overflow weirs are commonly used.
- Isolation Devices – it is important to be able to provide flexibility for the flow path in order to allow wetland cells to be taken offline for maintenance. Splitter boxes are typically used to provide the ability to reroute the flow through the wetland.
- Collection Device – after the wastewater has flowed through the wetland it is collected for final discharge from the system. Typical collection mechanisms include drainage channels and buried slotted pipes.

Shape

The designer must develop a wetland shape that provides the surface area requirements and fits into the site topography. Often, existing lagoons are retrofitted to accommodate a wetland system. Providing appropriate length to width (aspect) ratios may also dictate the shape of the wetland. Aspect ratios as high as 10:1 are often recommended in order to prevent short-circuiting of the wastewater as it flows through the system.

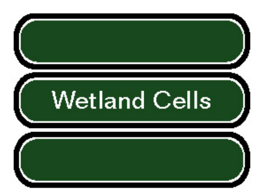
Hydrologic Issues

- Velocity
- Detention time
- Depth of flow
- Travel path
- Water balance

Hydraulic Issues

- Conveyance system
- Inlet mechanism
- Depth control
- Isolation devices
- Collection devices

Shape A



Shape B

Shape Variations

Typically engineered wetland systems, like Shape B, are rectangular and unnatural in shape. Natural shapes with curves and varied edges, like Shape A, allow for more biodiversity than their rectangular counterparts. The shape of the treatment cell does not impact its effectiveness, although it may impact construction costs.

Providing islands and irregular boundaries can enhance the habitat value of a wetland. However, because the construction of a wetland system is generally bid, the needed improvements must be well defined in order to enable the contractor to develop take off quantities. Typically, this forces a more rectangular wetland shape.

> **"Wetlands for water quality are being constructed throughout North America at an accelerating rate. However, many wetland designs do not incorporate ancillary benefits to the extent possible. With thoughtful design, constructed wetlands can provide benefits beyond effective water treatment, such as wildlife enhancement and recreational opportunities. In fact, with the decline of the total area of natural wetlands, constructed treatment wetlands are a viable and cost-efficient way to compensate for the loss of productive wetland habitat."**
> ***(Kadlec and Knight 1996)***

Soil

The wetland soil will provide the media for plant and microbial growth. Depending on the type of wetland designed, the designer may need to specify a particular mix of soil and gravel. The designer may specify that the soil include additives to encourage the growth of wetland plants. A geotechnical study should be performed to determine the suitability of the native soil to support a wetland system.

Plants

Wetlands can be planted, seeded, plugged or left to establish themselves. Designers must specify the type and introduction method that will be used in the wetland.

Ancillary Benefits

The designer can incorporate additional features into the wetland system that do not detract from the primary goal of wastewater treatment. Some of these benefits include aesthetic appeal, educational value, recreational outlets and habitat value. Interpretive centers can be incorporated into the wetland design to provide educational opportunities on such topics as energy conservation, wastewater treatment, wetland ecology, and pollution prevention. If the wetland designer wishes to incorporate these aspects into the wetland design, planning must include a safe means of public access.

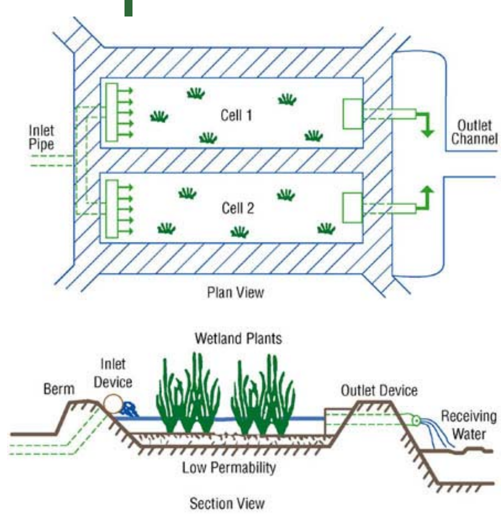
Maintenance

Wetlands will take several years to establish a mature ecosystem. In the design process it is important to determine what methods will be used to harvest vegetation once the litter layer becomes excessive. Potential methods include burning and physical harvesting of wetland biomass. Other maintenance issues include (1) clearing of clogged piping, (2) controlling mosquito and fly populations, and (3) managing nuisance wildlife (i.e. muskrats).

Free Water Surface Flow and Subsurface Flow Wetlands

Two general types of wetlands are typically constructed for wastewater treatment: free water surface flow (FWS) and subsurface flow (SF) wetlands.

In a FWS wetland, water is generally introduced above the ground surface, and flows through the wetlands at depths averaging less than 6 inches, ranging up to 12 inches (Figure 1). FWS wetlands may contain

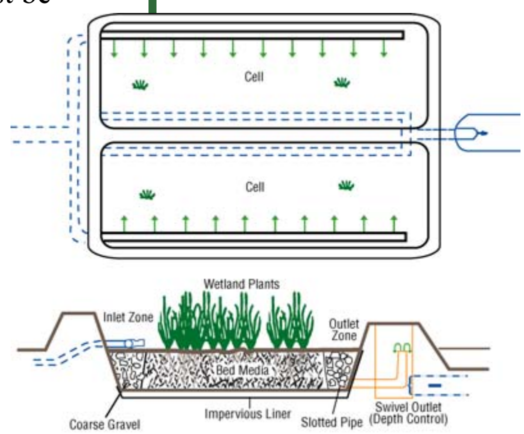


Plan and profile of a typical free water surface wetland.

islands that are at or above the typical water surface, and small, deeper areas, up to 8 feet. However, these deeper areas will not support wetland vegetation.

FWS wetlands are often divided into cells either by earthen berms, concrete, or wood to help direct flow and insure that maximum contact between water and wetland plants. Wetland plants can be established by seeding or transplanting. If a significant source of wetland seed exists nearby, and if the topsoil used in the treatment wetland contains enough propagules, it may be unnecessary to seed or plant the wetlands. Maintenance of a FWS wetland may include periodic burning of the vegetation in the treatment wetland, monitoring and adjusting the water surface elevation, keeping the inflow and outflow structures clear of debris, and sediment removal when necessary.

In a SF wetland, water is introduced into a gravel medium through a perforated pipe or other underground dispersal system. SF wetlands may contain up to 4 feet of gravel, and the water surface elevation is maintained just below the top surface of the gravel. Generally wetland plants must be planted into a SF wetland because the gravel substrate is often not conducive to seed germination and establishment. Maintenance of a SF wetland may include periodic burning of the vegetation in the treatment wetland, monitoring and adjusting the water surface elevation, keeping the inflow, outflow, and dispersion pipes clear of debris, and sediment removal when necessary. SF wetlands are often difficult to maintain because the underground pipes may be subject to clogging and the gravel surrounding the pipes may become clogged with sediment.



Plan and profile of a subsurface flow wetland.

Treatment Wetland Applications

Chapter Highlights

- Societies generate concentrated wastewater that must be treated before it is released back into the environment.
- Constructed wetlands provide wastewater treatment with minimal technical, energy, and chemical inputs.
- Point source and non point source wastewater can be treated in a constructed wetland system.

Municipal Wastewater Treatment

Civilizations have dealt with wastewater for thousands of years. Normal uses of water for hygiene, consumption, and manufacturing generate a pollutant load on the resulting wastewater. In order to prevent contamination of drinking water supplies and the surrounding environment, wastewater must be isolated until pollutant removal is accomplished.

Wastewater treatment has developed in the last century from outhouses and septic systems to piped collection systems that deliver wastewater to centralized treatment facilities. As populations have become denser, wastewater treatment has become a vital, and often expensive, part of a community life style. These centralized collection facilities use a myriad of treatment processes before the reclaimed water is released back into the natural system.

Treatment facilities are designed to fit into the communities that they service. For instance, dense metropolitan areas, in which real estate is at a premium, require facilities that can treat large amounts of wastewater in compact areas. In addition, wastewater from metropolitan areas typically originates from both industrial and domestic sources and may require advanced methods to meet treatment goals. However, in rural areas, land is more available and wastewater is from domestic sources, with minimal industrial inputs. Smaller communities are often constrained by their limited capital and technical resources. In these areas, land intensive treatment options are often desirable. Constructed wetlands, as a component of a treatment process, provide a low energy, low-tech method of removing pollutants.

Constructed wetlands can be used as a treatment component in municipal wastewater treatment facilities. Generally, wetlands are used as a ‘finishing’ component in the treatment process. Some of the benefits of constructed treatment wetlands are discussed in this chapter.

Minimal Energy Consumption

Elevation differences in the wetland can be provided to allow wastewater to flow by gravity through the wetland system. Energy consumption in the treatment system is generally limited to the amount of energy consumed by the primary treatment method.

Fecal coliforms are bacteria that live in the intestinal tract of mammals. The presence of these bacteria in wastewater is an indicator of mammalian waste products.

Chlorine is a low cost chemical that has been proven to provide reliable disinfection. It destroys almost all water borne pathogens, including fecal coliforms.

Minimal Use of Chemicals

The wastewater treatment reactions in a wetland depend on physical, chemical, and microbial processes that occur naturally in the system. Some use of chemicals may be necessary in order to reduce **fecal coliform** levels in the effluent prior to the release of the treated water into a receiving water body. **Chlorine** is a popular form of disinfection used in both natural and conventional treatment systems. The use of **UV or ultraviolet light** in a wetland system provides reliable disinfection without the use of chemicals. In some wetland systems long detention times and exposure to sunlight provide sufficient disinfection, and as a result, additional means of disinfection are unnecessary.

Low Tech

Wetlands are designed to have simple hydraulic and mechanical systems. Since the treatment processes are naturally carried out, operators do not have to monitor the treatment process. The primary tasks of the operator are to keep the hydraulic system running, manage wildlife and the occasional harvesting or burning of excess vegetation.

Ancillary Benefits

Wetlands can be an aesthetic addition to a community. As such they provide open space and associated recreational activities (i.e. hiking, bird watching, etc.). They can also provide valuable habitat for birds, small mammals, and other creatures.

On-site Residential Treatment

Approximately 25 percent of the U.S. population lives in rural areas and relies on decentralized, or on-site, wastewater treatment systems. Isolated communities in the Rocky Mountains face the challenges of wastewater treatment with the added complications of cold weather and rocky soils that are not well suited for traditional **leach fields**. On-site residential treatment is necessary in many remote areas that are unable to connect to centralized sewer systems. In many western slope communities, laying the network of pipelines necessary for a centralized wastewater treatment system is not feasible because of mountainous topography and the need to blast through rock.

Benefits of Constructed Treatment Wetlands

- Low energy consumption
- Minimal chemical usage
- Simple hydraulic systems – easy to operate
- Aesthetically pleasing
- Educational value
- Valuable habitat

UV or ultraviolet light is a type of radiation that acts as a physical (not chemical) disinfectant. UV radiation penetrates the cell walls of bacteria and other water pathogens, and impairs their ability to replicate and in some cases causes the cell to die. This disinfection method is only effective if the UV radiation can reach the wastewater. Typically, UV lights are placed on a rack and then submersed in wastewater. As the wastewater flows through the UV lights, it is disinfected.

A **leach field** is a subsurface system used for final treatment and disposal of septic effluent. Leach fields are composed of a series of narrow, shallow trenches in which perforated pipes are installed and surrounded by gravel. The trenches serve several purposes that include:

- Maintaining the leach field's structure
- Providing partial treatment of wastewater
- Distributing wastewater beneath the soil surface

Another problem associated with lengthy collection systems is the potential for contamination of the watershed due to leaky pipes and fittings.

Acid Mine Drainage Treatment Wetlands

Wetlands have been used to treat runoff from hard rock and coal mines. This runoff is known as Acid Mine Drainage (AMD). The characteristics of AMD depend on the mine type. Generally these sites have high iron, sulfur, and heavy metal contents. When areas are mined, rock that was buried deep in the ground is broken apart and exposed to oxygen. In rock types that are mined for metals or coal, high amounts of sulfur and iron are generally present. When the iron and sulfur are exposed to oxygen, they become oxidized and sulfuric acid is formed. This acid is dangerous because of its low **pH**. Water with a low pH has a greater ability to dissolve heavy metals. Metals that were at one time chemically bonded within the rock change **valence** states and are dissolved by water flowing through the mine. This leads to higher metal concentrations in runoff. The presence of these metals can be very dangerous to humans, wildlife, livestock, and vegetation.

Oxidation-reduction reactions or redox reactions refer to two reactions. The first part of the reaction, called oxidation refers to the loss of an electron by one of the reactants. The second part, reduction, refers to the gain of an electron by one of the reactants. Oxidation and reduction always occur together. The substance that is oxidized is the reducing agent, while the substance that is reduced is the oxidizing agent.

Chemical reactions occur in wetlands that affect metals in a variety of ways. In a natural wetland, **oxidation-reduction (redox)** reactions are important to **metal speciation**. Factors that influence these reactions are saturation, water flow, soil chemistry, and vegetation. Oxidizing conditions may exist near a wetland surface. In this region, metals may be oxidized, forming precipitates, or may **adsorb** on to soil particles. Oxidation reactions occur near the wetland surface and where **hydrophytic** plant's roots affect the soil. Below this, wetlands can isolate metals from oxidizing conditions, keeping metals in a reduced state. Soils are reduced where conditions are permanently saturated and where oxygen is used up at a greater rate than it is replaced. It has been shown that oxygen flows through aqueous solutions 10,000 times more slowly than through porous soil media. Therefore, when soils are saturated, oxygen diffusion is severely restricted and metals are not dissolved in the water.

Adsorption is a process where molecules of gas or liquid "cling" to the surface of a solid. There is no physical or chemical change to either substance.

Absorption is a process where one substance, usually a gas or liquid, is drawn into and fills another. This is accompanied by a physical and/or chemical change of the substance.

An important aspect of oxidation-reduction in dynamic systems, such as mine acids or other

pH is a measure of the acidity of a substance. The pH scale ranges from 1 to 14. A pH of 1 means a substance is very acidic, while a pH of 14 means it is alkaline (basic). Water has a pH of approximately 7 and is considered neutral.

Benefits of Acid Mine Drainage Treatment Wetlands

- **Isolates metals**
- **Neutralizes pH of runoff water before entering**

A valence reflects the combining power of an atom. This is measured by the number of hydrogen atoms with which it can displace or combine.

Metal speciation refers to the variety of metals of one kind that can exist in different valence states.

A hydrophytic plant can also be called a "water-loving" plant. These types of plants have the ability to grow in soil that is saturated by water for extended periods.

sources of AMD is pulses in water levels and flows associated with spring runoff or other flood events. The apparent effect of these events is to damage structures in created wetlands.

There are several studies in Colorado that have examined the treatment of AMD by passive systems, such as bioreactors: Silverton, the Eagle Mine Superfund Site in Minturn (Colorado School of Mines, 1992), and Marshall, Colorado (de Forest, 1985). Few studies have been conducted in natural wetlands in Colorado, and only one study was found that was conducted in a constructed wetland (Idaho Springs). One study on a natural wetland near the Pennsylvania Mine in Peru Creek drainage, near Montezuma, Colorado, involved routing of AMD through an existing wetland (Huskins, 1987). The results of this study showed that the wetland removed iron from the AMD, but because of the low pH, ranging from 3.5 to 4.0 in different depths in the wetland, the ability of iron to co-precipitate other metals was limited. A second study in St. Kevin's Gulch, near Leadville, showed that AMD passing through a wetland showed that iron was removed from the water passing through the wetland, but that zinc was not (Walton-Day, 1996).

Stormwater Wetlands

Constructed wetlands are commonly used to detain and treat stormwater runoff. Stormwater runoff, also known as **non-point source pollution**, may contain a variety of contaminants, chemicals, and nutrients. Stormwater treatment wetlands may treat runoff from residential areas, roads, commercial areas, and parking lots. Typical constituents of stormwater runoff may include BOD, suspended solids, nitrogen, nitrate, and nitrite, phosphorous, copper, lead, zinc, chromium, cadmium, iron, mercury, nickel, phenols, cyanides, soaps, pesticides, herbicides, fertilizers and oil and grease. Treatment wetlands must be designed not only to process all of these, but also to serve as floodwater retention facilities.

In the Denver Metropolitan area, the Urban Drainage and Flood Control District (UDFCD) and others recommend a combination of **sediment detention basins** and wetlands as an efficient means to treat stormwater. In this scenario, sediment detention areas (such as those discussed in Chapter 4) are placed up-gradient of the treatment wetlands, and can either be immediately adjacent to or well away from the wetlands. These sediment basins decrease the sediment load in the wetlands so that the treatment wetlands function more effectively to remove nutrients and chemicals.

Natural wetlands can be used as stormwater treatment areas, but it is important to ensure that the implementation of this form of stormwater treatment complies with all federal and state laws. The U.S. Army Corps of Engineers and the EPA have expressed concerns about using natural wetlands for stormwater treatment.

Non-point source pollution is typically from a variety of sources, while **point source pollution** is from a singular source, such as a pipe or body of water.

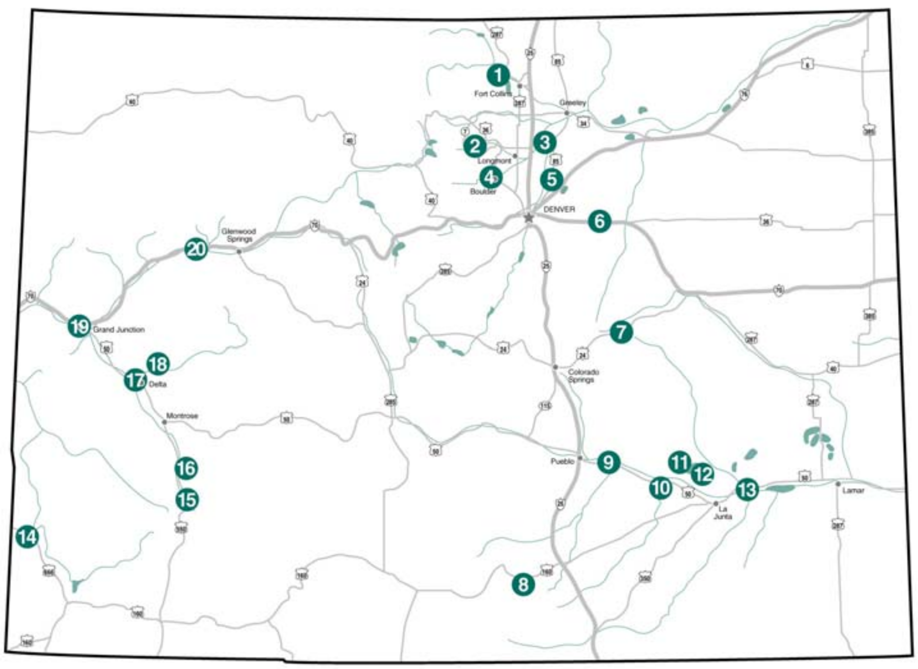
Sediment detention basins are usually large, shallow earthen basins used to separate out solids from wastewater.

Compliance with Regulations

The Colorado Department of Health & Public Environment (CDPHE) is the governing agency for water quality requirements for wastewater treatment facilities that discharge into a receiving body of water. All wastewater treatment facilities must be in compliance with their regulations or a **"notice of non-compliance"** is issued by the CDPHE. If a facility is out of compliance for a longer period of time, the CDPHE will issue a **"cease and desist"** order. At this point, the facility owner may lose their discharge permit and legal action can be taken against them.

What Is Included In This Study

This study focused on constructed wetlands that treat municipal wastewater. Constructed treatment wetlands were identified by Task Force members and consultants through personal knowledge, researching contacts and a literature review. Municipal treatment wetlands have the most data, since discharge permits require the submission of monthly water quality tests. The project team pulled discharge permits from the Colorado Department of Public Health



Colorado Map – Sites Inventoried

and Environment (CDPHE) files in order to get background information and water quality data for each site.

A representative sample of stormwater and other miscellaneous constructed wetlands were also visited. However, since water quality data was not available for these sites, an extensive analysis was not undertaken.

Sites Inventoried

The map to the left shows locations of constructed treatment wetlands that were inventoried. Further details on each site can be found in Chapter 6.

1. **Rocky Mountain Shambhala Center**
2. **Highlands Presbyterian Camp**
3. **Platteville**
4. **Valmont Power Plant**
5. **Brighton**
6. **Bennett**
7. **Calhan**
8. **La Veta**
9. **Avondale**
10. **Manzanola**
11. **Crowley County Correctional Facility**
12. **Crowley**
13. **Las Animas**
14. **Dove Creek**
15. **Ouray**
16. **Ridgeway State Park**
17. **Delta**
18. **Horizon Nursing Home**
19. **Island Acres Silt Park**
20. **Silt**

Evaluation Criteria

> **Chapter Highlights**
>
> Wetlands were evaluated from both engineering and biological perspectives.
>
> The engineering analysis took into account hydraulic design and energy consumption.
>
> The bottom line for treatment wetlands is 'do they consistently meet discharge permit requirements?'
>
> The Montana Standardization was used by project biologists to compare the value of the constructed wetlands to resources found in natural wetlands.
>
> Ancillary benefits at a wetland system may include educational, aesthetic and recreational components.

Evaluation of a Wetland

The Task Force members' varied backgrounds and the project team's technical expertise provided many perspectives on wetlands. The project team and the Task Force members selected standard criteria in order to provide a consistent framework for evaluating each wetland system. These criteria considered significant components of the wetland system.

The project team included both engineers and biologists in order to provide discipline-independent evaluations of the 'quality' of the wetland system. From an engineering perspective, a highly effective wetland system is one that can consistently meet its discharge requirements with minimal operational, maintenance, and energy requirements.

Biologists evaluated each wetland's value from an ecological perspective. From a biological viewpoint, higher quality wetlands provide habitat value and biological diversity, similar to natural systems.

Engineering Analysis

Team engineers catalogued the engineering related design components. These components include:

Hydrology

The hydrology in a constructed wetland system is determined by design rather than by climatic and groundwater influences. The general types of constructed wetlands are free water surface and subsurface flow wetlands. In a free water surface wetland, the water level is maintained above the ground level. In a subsurface wetland the water level is maintained below the surface of the ground. (See Chapter 2 for further details).

Hydraulics

The hydraulics will determine how wastewater is introduced into and conveyed through the wetland system. These system components include inlet piping systems, mechanisms to control the water depth in the wetland cells, and systems to collect and discharge the treated effluent at the end of the wetland cell.

Soil

Soils provide two main functions in a wetland system: to provide a consistent hydraulic conductivity and detention time for design flows, and to maintain and encourage plant growth. Soil may be native or a commercial mix containing soil amendments. The specified soil mix may consist of a specific particle size and type. Inorganic media may be used in place of organic soil to prevent the introduction of **noxious weeds**.

A noxious weed is a species of plant considered undesirable in a specific ecosystem. These plants tend to dominate an area and can cause liner punctures, plugging of flow, excessive shading, excessive water and nutrient consumption, and can minimize biological diversity in wetland systems.

Water Quality

Water quality requirements are the first concern when selecting a treatment method. Pollutants in the wastewater may limit the type of treatment that a community can implement. The focus of this study was small-flow municipal treatment facilities with fairly typical domestic and commercial waste. These communities did not have special conditions that would warrant a highly technical removal process.

The ultimate efficacy of the wetland is judged by its ability to meet permit requirements. Included in the Colorado Department of Public Health and Environment (CDPHE) permit files are the monthly Discharge Monitoring Reports (DMR’s) that facilities must submit to ensure that they are meeting permit requirements. This water quality data provides a historical perspective of how the system is functioning. Since data are generally not available for water going into the wetland system, the water quality data are a measure of the effectiveness of the entire treatment system. These records were used to:

- Evaluate the long term performance of the system,
- Determine how the system effectiveness was altered by adding a wetland, when sufficient data were available from both before and after wetland implementation,
- Determine if the wetland system was consistently meeting discharge effluent requirements.

Energy Analysis

A primary focus of this inventory was to determine the energy savings experienced by using a constructed treatment wetland instead of conventional treatment methods. This discussion presents typical energy requirements for a selection of treatment methods.

A wide number of treatment methods will be able to meet the requirements to cleanse the effluent from theses typical systems. Financing often determines the selection of the most appropriate treatment method. Financing includes such things as operation, maintenance, capital costs, and energy expenditures. With rising energy costs, this component may become a predominant factor in selecting a treatment method.

Every treatment process uses the same amount of energy to physically remove, chemically breakdown, and biologically decompose pollutants per unit quantity. The significant difference between conventional treatment processes and natural treatment processes is the energy source. Conventional treatment systems use electricity and fuel to mechanically remove pollutants, speed-up biological processes, and act as catalysts in chemical processes. Natural systems rely on energy from the sun, gravity, and naturally occurring carbon sources to provide the energy necessary for physical, biological and chemical removal processes to take place.

A study undertaken by Middlebrooks, et al.[1], compared electrical and fuel energy requirements of conventional and land treatment alternatives. The following table shows typical energy requirements of six common treatment systems for a small treatment facility (0.5 mgd capacity).

Energy Requirements: 0.5 mgd System Capacity	
Treatment Type	Kilowatt Hours per Year
Trickling filter	106,500
Rotating biological contact facility (RBC)	111,000
Activated sludge with digestion	222,400
Activated sludge with sludge incineration	248,500
Activated sludge with advanced treatment	1,029,400

A wetland system generally has four components: preliminary treatment (bar racks), primary treatment (generally lagoon systems or septic tanks), the wetland, and finally disinfection. Some typical energy expenditures might include:

- Lift stations
- Grinders
- Aerators in the lagoon
- Automatic sampling and flow measurement devices
- Disinfection system (UV system, chlorine meters, etc.).

Since, the wetland cells themselves do not typically require external energy inputs, the energy efficiency of a system using wetlands will be greatly affected by the other treatment components.

How Much Energy Do We Normally Use?

We all use energy and rely on it for a large part of our lives. But do we know how much we use? A typical house uses approximately 8,760 KW/year. For a small community of less than 6500 people, you would need approximately 12 times that amount to fuel a trickling filter treatment system, and 117 times that much to operate an advanced treatment activated sludge facility.

As future reserves of energy are depleted, we need to look for alternative, low-cost methods to clean our water. Wetlands offer a viable, low-cost, low-energy alternative to traditional methods.

[1] Middlebrooks, E.J., Middlebrooks, C.H., Reynolds, J.H., Watters, G.Z., Reed, S.C., and George, D.B. *Wastewater Stabilization Lagoon Design, Performance and Upgrading*. Macmillan Publishing Co., Inc., New York, NY. 1982.

Design

Each site was evaluated for design goals and methodology. Since the wetlands in this study are used for treatment, the primary design goal was treatment of the wastewater to meet permit effluent requirements. The area needed to reach these effluent requirements determines the size of the wetland. The shape of the wetland is not as critical to the treatment functionality. The majority of wetlands inventoried were rectangular. Although rectangular wetlands are perceived to be easier to design and build, wetlands with irregular borders provide additional benefits without detracting from the treatment capabilities of the wetland itself.

The hydrology of a wetland system is the single most important design issue when creating a wetland. Free water surface wetlands are designed to allow the water to pond at the surface of the wetland cells to a depth ranging from six inches to several feet. In subsurface wetlands, the water level flows through the wetland media several inches below the surface of the wetland. The level of saturation in the wetland is vital for maintaining plant health. Allowing conditions in the wetland to become too dry or the water level to become too high will seriously impact the wetland plants. During site visits, the water depth and ability to change the water level was recorded.

The hydraulics of the system include the methods of conveying water into, through, and out of the wetland system. For each site the conveyance methods and operational experiences were recorded.

Biological Perspective

Wetlands function in treating wastewater through biological and chemical processes. Water cleansing depends on reduction/oxidation, or redox chemical reactions, in which metabolism by soil microorganisms and vegetation play a role. A healthy vegetative and microbial community is vital to the functioning of treatment wetlands. The biological health of a treatment wetland also plays an important role in its capacity to provide wildlife habitat and vegetative and landscape diversity.

To gain a biological perspective of treatment wetlands included in the study, researchers selected several key parameters, including vegetative cover, the number of plant communities in each cell, the amount of open water or bare soil, the vegetative structural diversity, wildlife habitat, and the presence of noxious weeds. These are all parameters that make a treatment system more valuable from a biological perspective and in turn, an aesthetic and socioeconomic perspective.

Montana Standardization

For each treatment wetland, project biologists evaluated wetland functions using the Montana Wetland Field Evaluation Form and Instructions (Montana Department of Transportation 1996). The "Montana Method" is an evaluation method that combines the U.S. Fish and Wildlife Service classification system (Cowardin et al. 1979) with a hydrogeomorphic (HGM) approach (Brinson

"Energy consumption is a major factor in the operation of wastewater treatment facilities. Many of the plans for water pollution management in the United States were developed before the cost of energy and the limitations of energy resources became serious concerns for the nation. As wastewater treatment facilities are built or updated to incorporate current treatment technology and to meet regulatory performance standards, energy must be a major consideration in designing and planning facilities."

Reed, Sherwood C., Crites, Ronald W., and Middlebrooks, E.Joe. *Natural Systems for Waste Management and Treatment*. McGraw-Hill, Inc., Inc., New York, NY, 1995.

1993). The Montana Method provides a landscape context to the U.S. Fish and Wildlife Service classification. It is a rapid functional assessment process designed primarily to address wetland resources. The Montana Method, along with other standard methods of assessing wetland function and values, is designed to assess natural wetlands. Because treatment wetlands differ from natural wetlands, some of the function and value parameters were not included in the study, such as flood attenuation and storage, groundwater recharge and discharge, sediment/shoreline stabilization, recreation/education potential, and dynamic surface water storage. Also, project biologists did not complete Section 15A of the field evaluation form—*Habitat for Federally-Listed, Proposed, or Candidate Threatened or Endangered Plants or Animals* and *Section 15B—Habitat for Plants or Animals Rated S1, S2, or S3 by the Natural Heritage Program*. No federally listed, state listed, or Forest Service listed plant species are likely to occur in the treatment wetlands.

For each wetland, a function and value summary was prepared. The Montana Method provides a rating of low, moderate, high, or not applicable based on observations and responses to questions. Functional units were calculated without the use of area calculations. Additional site-specific information (vegetation, soils, and hydrology) was collected as part of the wetland assessment process.

The following is a brief description of the functions and values assessed (Montana Department of Transportation 1996).

Wildlife Habitat

General wildlife habitat potential of the assessment area based on perceived use by aquatic, semi-aquatic, and non-aquatic wildlife groups and habitat diversity as determined by the variety of wetland types.

Fish/Aquatic Habitat

Potential for the presence of fish in the assessment area is based on the known or suspected presence of native or introduced fish and the depth and duration of surface water at the site.

Sediment/Nutrient/Toxicant Retention and Removal

The ability of the assessment area to retain sediment and retain and remove nutrients and toxicants was based on the site's proximity to sediment/nutrient/toxicant sources; transport potential of these constituents to the assessment area via surface water; potential for the site to detain and retain the constituents; and potential of the site to filter and/or process (uptake) the constituents.

Production Export/Food Chain Support

The potential of the assessment area to produce and export food/nutrients for living organisms was evaluated. Production export typically refers to the flushing of relatively large amounts of organic material from the wetland to downstream habitats or adjacent deeper waters (Adamus, et al., 1991).

"Our hunch is that, at least in surface flow wetlands, habitat quality and water treatment function are closely related, in that many of the same things that enhance habitat quality also tend to improve water treatment function."

Sartoris, James J. and Thullen, Joan S., "Developing a habitat-driven approach to CWWT design." Proceedings from Engineering Approaches to Ecosystem Restoration ASCE Conference, March 22-27, 1998, Denver, Colorado.

Uniqueness

Includes the general uniqueness of the assessment area relative to the abundance of similar sites occurring in the same major watershed basin, the replacement potential and habitat diversity of the assessment area, and the degree of human disturbance in the assessment area.

Human Use and Aesthetics

The primary goal of treatment wetlands is to treat wastewater. Wetland treatment systems have unique properties that differ from those of most conventional treatment methods. These unique properties provide ancillary benefits that can be enjoyed by the local community. Constructed treatment wetland sites offer educational experiences to schoolchildren, groups and individuals. These sites are ideal settings for viewing wildlife, discussing wastewater treatment processes, and educating the public on the importance of wetlands in the water cycle. Constructed wetlands are also an attractive addition to the community. In contrast to conventional treatment systems, constructed wetlands provide aesthetic benefits and do not detract from the scenic beauty of many remote areas and often add to beauty of overused and overbuilt areas. The Colorado inventory identified constructed treatment wetlands that were along trails, used as a water feature at a park entrance, and part of scenic vistas. Each site was inventoried to record ways that the local community profited from these ancillary benefits.

Operation and Maintenance

Wetland systems are often touted as a low maintenance solution to wastewater treatment. However, like most any **treatment train** an operator is necessary to ensure that the system remains functional. In this inventory, the operator for each system was interviewed to determine the level of effort necessary to successfully operate each system. Maintenance issues included clearing pipes to prevent clogging, seasonal burning or harvesting of the wetland plants, repair of berms, and general problem solving. Wetland system operators must have proper licensing, take water quality samples, and submit reports to the CDPHE to ensure compliance with discharge permits.

A treatment train is a series of processes that make up a treatment system. System components are selected to achieve a desired level of treatment.

Overall Component of the Community

The system was evaluated for its overall function as a component of the community. The following questions were asked at each inventoried wetland:

- Does the wetland treatment system detract from scenic vistas?
- Is the system publicly supported?
- Are recreational opportunities, such as running trails, provided?
- Are educational groups hosted?
- Is the wetland facility a source of pride for the community?

Data Management

Chapter Highlights

A standardized methodology was adopted to insure consistent data collection and storage.
Data collected were stored in a database that is compatible with the North American Constructed Wetland Database.

Site Data Sheets were designed with guidance from the Task Force members. These Site Data Sheets were used during site visits to provide a consistent means of evaluating each wetland.

Before any data were collected, the Task Force members and project team assembled a standardized method for data collection and storage. The data management system included standardized methods to analyze the evaluation criteria, a Site Data Sheet to consistently record data and the development of a database for storing the final data.

Database

In the early 1990's the USEPA funded the development of the North American Constructed Wetlands Database (NADB). The NADB contains the most comprehensive inventory of treatment wetland performance and design data currently available. This inventory contains information for both natural and constructed wetlands used to treat wastewater in the United States and Canada. Version 1 of the NADB contained information on 179 sites. Version 2 of the NADB was updated to a total of 257 sites. Currently, the database is being updated by Humboldt State University and will be provided in a web-based interface.

The NADB is divided into the following twelve database files:

Sites

Fields are provided to record general site information, such as EPA region, state, and community. A checklist is included to indicate the inclusion or exclusion of parameters that are recorded in following database files.

Systems

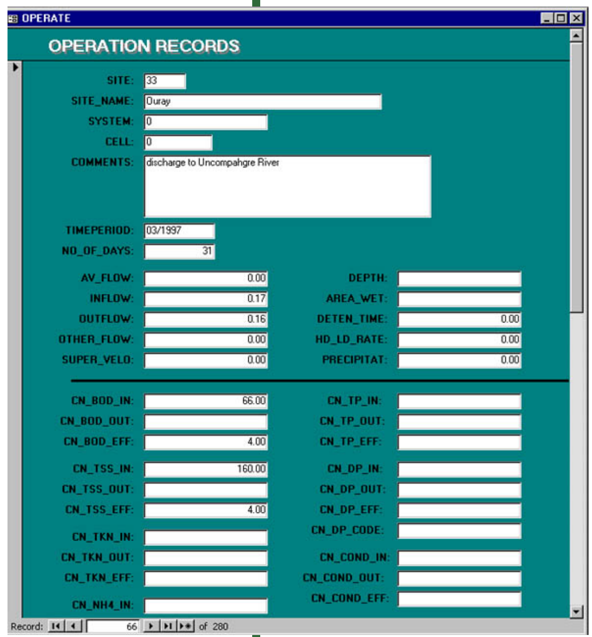
This section contains an overall description of the wetland site, including such items and contributing population, number of cells, area, costs and waste source.

Cells

The wetland system is subdivided into cells. This file records information for each cell, such as area, length and width, vegetation type, slope, island, deep zones and water depth.

Permits

This field allows the entry of permit limitations. Entries can be made for 36 parameters, including permitted flow, BOD, COD, TSS TDS, temperature, nitrogen, phosphorous, total coliforms, and pH.



People

Information is recorded for contact people, with address, phone and fax information. The contact persons role in the wetland is also included.

Literature

Citations are recorded for any publications that have been written about the site.

Operations

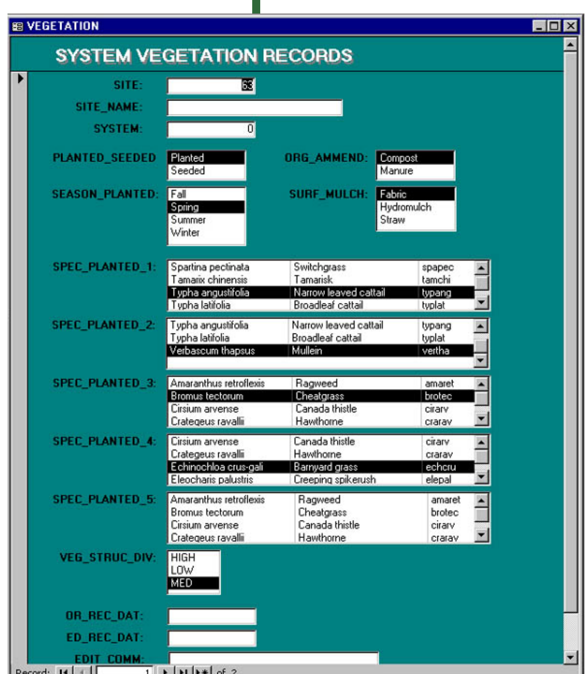
This database file contains the operational data for each site. Available performance data for influent and effluent water quality are recorded here. A screen capture of this form is shown to the right.

Vegetation

Data can be entered for each cell of the wetland system to indicate plant groups and subgroups. Space is also available to enter decomposition rates, basal area, chlorophyll a, diversity and density. The graphic to the right is a screen capture of the database form used to enter system vegetation records.

Wildlife

Information can be entered for amphibians, benthos, mammals and avifauna. Topics available include birth and death rates, egg clutch size, breeding pair density, and population net growth.



Metals / Organics

The NADB contains metals and organics data collected from 26 sites. Samples were taken from the surface water, sediments, and tissue.

Biomonitoring

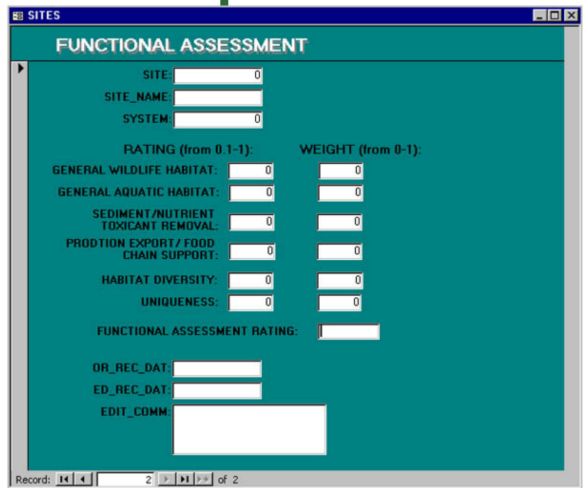
This database file contains data used to determine the effects of treatment wetlands on “whole-effluent” toxicity. Whole-effluent toxicity is determined by conducting tests on organisms to determine acute and chronic toxicity.

Human Use

Data on the human uses of treatment wetlands is recorded in this field. Parameters recorded in this field include money spent, type of activity, and number of human uses per year.

The NADB provides a structure to record all available treatment wetland data. The categories available in this database are extensive. The majority of wetlands will have data available for only a portion of the developed fields.

A primary goal of the Colorado Constructed Treatment Wetland Inventory was the inclusion data on Colorado treatment wetlands into the NADB. To this end, data collected in this study were entered into a database that is compatible with the NADB.


SITES

FUNCTIONAL ASSESSMENT

SITE: 0
SITE_NAME:
SYSTEM: 0

	RATING (from 0.1-1):	WEIGHT (from 0-1):
GENERAL WILDLIFE HABITAT:	0	0
GENERAL AQUATIC HABITAT:	0	0
SEDIMENT/NUTRIENT TOXICANT REMOVAL:	0	0
PRODTION EXPORT/ FOOD CHAIN SUPPORT:	0	0
HABITAT DIVERSITY:	0	0
UNIQUENESS:	0	0

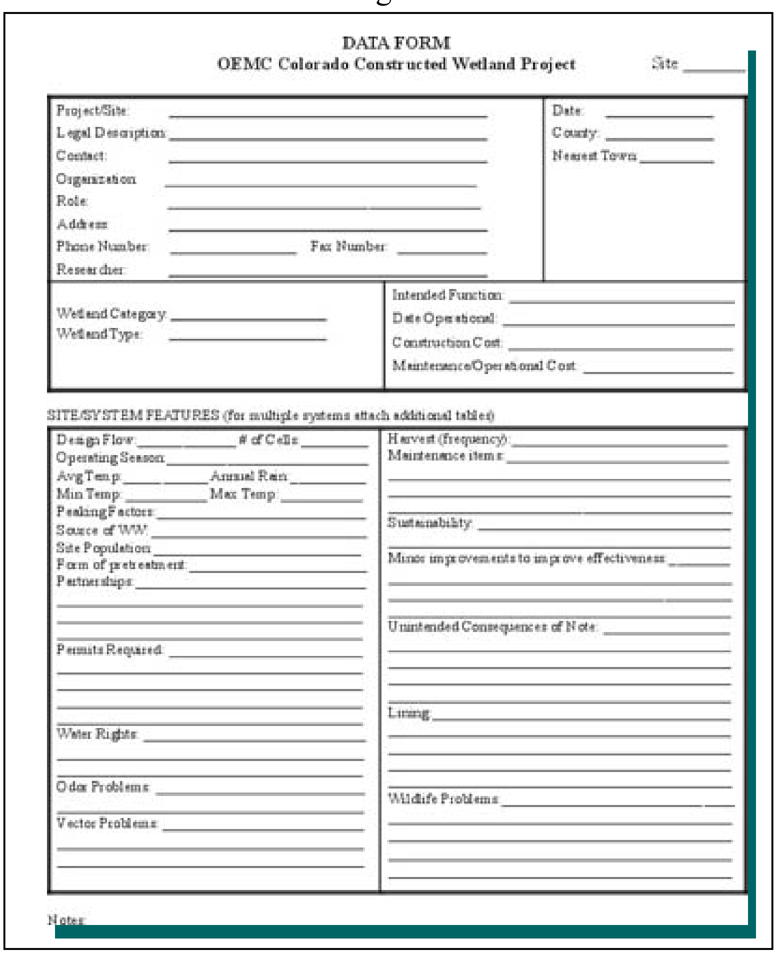
FUNCTIONAL ASSESSMENT RATING:

OR_REC_DAT:
ED_REC_DAT:
EDIT_COMM:

Record: 2 of 2

Site Data Sheets

The project team designed site Data Sheets (SDS), with guidance from the Task Force members. Each section in the SDS was designed to coordinate with tables in the NADB. Site visits were structured around the collection of data on the SDS. The SDS served as a checklist to insure a consistent evaluation of each wetland. Field notes were recorded on the SDS for downloading into the database.


DATA FORM
OEMC Colorado Constructed Wetland Project

Site: ______

Project/Site: ______
Legal Description: ______
Contact: ______
Organization: ______
Role: ______
Address: ______
Phone Number: ______ Fax Number: ______
Researcher: ______

Date: ______
County: ______
Nearest Town: ______

Wetland Category: ______
Wetland Type: ______

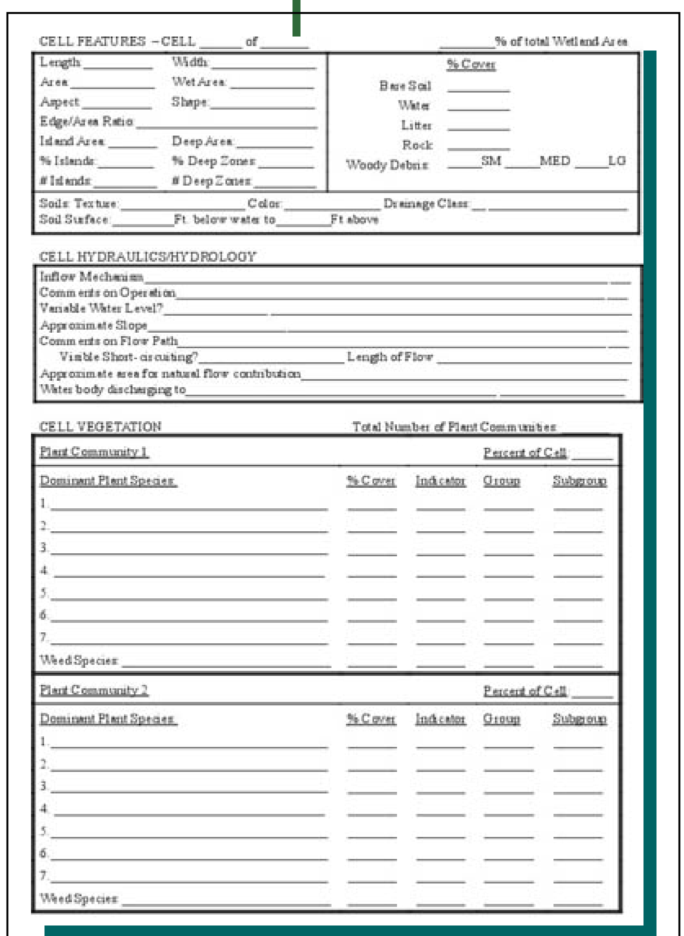
Intended Function: ______
Date Operational: ______
Construction Cost: ______
Maintenance/Operational Cost: ______

SITE/SYSTEM FEATURES (for multiple systems attach additional tables)

Design Flow: ______ # of Cells: ______
Operating Season: ______
Avg Temp: ______ Annual Rain: ______
Min Temp: ______ Max Temp: ______
Peaking Factors: ______
Source of WW: ______
Site Population: ______
Form of pretreatment: ______
Partnerships: ______
Permits Required: ______
Water Rights: ______
Odor Problems: ______
Vector Problems: ______

Harvest (frequency): ______
Maintenance items: ______
Sustainability: ______
Minor improvements to improve effectiveness: ______
Unintended Consequences of Note: ______
Lining: ______
Wildlife Problems: ______

Notes:


CELL FEATURES – CELL ______ of ______ ______% of total Wetland Area

Length: ______ Width: ______
Area: ______ Wet Area: ______
Aspect: ______ Shape: ______
Edge/Area Ratio: ______
Island Area: ______ Deep Area: ______
% Islands: ______ % Deep Zones: ______
# Islands: ______ # Deep Zones: ______

% Cover
Bare Soil ______
Water ______
Litter ______
Rock ______
Woody Debris: ______ SM ______ MED ______ LG

Soils: Texture: ______ Color: ______ Drainage Class: ______
Soil Surface: ______ Ft. below water to ______ Ft above

CELL HYDRAULICS/HYDROLOGY

Inflow Mechanism ______
Comments on Operation ______
Variable Water Level? ______
Approximate Slope ______
Comments on Flow Path ______
Visible Short-circuiting? ______ Length of Flow ______
Approximate area for natural flow contribution ______
Water body discharging to ______

CELL VEGETATION Total Number of Plant Communities ______

Plant Community 1 Percent of Cell ______

Dominant Plant Species	% Cover	Indicator	Group	Subgroup
1.				
2.				
3.				
4.				
5.				
6.				
7.				
Weed Species				

Plant Community 2 Percent of Cell ______

Dominant Plant Species	% Cover	Indicator	Group	Subgroup
1.				
2.				
3.				
4.				
5.				
6.				
7.				
Weed Species				

WETLAND VEGETATION INFORMATION

Planted or Seeded: Planted - Seeded	
Species Planted:	
Time of Year:	
Surface Mulch: Straw - Fabric - Hydromulch	
Organic Amendment: Compost - Manure	
Vegetative Structural Diversity: _____Low _____Med _____High	
Wildlife Habitat Value: _____Low _____Med _____High	

WILDLIFE SPECIES

Species Observed	Species For which Habitat Available

WETLAND BIODIVERSITY FUNCTIONAL ASSESSMENT

Function and Value Variables	Functional Points (0.1 – 1)	Possible Points
General Wildlife Habitat		
General Fish/aquatic Habitat		
Sediment / Nutrient Toxicant Removal		
Production Export / Food Chain Support		
Habitat Diversity		
Uniqueness		
Total Points		
Overall Rating (1-4)		

HUMAN USE

Use Category_____________ Use Days_____________ $ Spent_____________
Aesthetic Value: _____________ Low _____________ Med_____________ High
Educational Use: _____________ Low _____________ Med_____________ High

LITERATURE

Year and Citation_____________

Notes

SITE FEATURE EFFECTIVENESS

Highly Effective Features	Sporadically Effective	Rarely Effective Features	Ineffective Features

OVERALL EFFECTIVENESS/COMMENTS_____________

ENERGY CONSERVATION

KW used (from billing records)	Amount and Type of Energy Conserved
Construction	
Maintenance and operations	

WATER QUALITY DATA COLLECTED

To be included in attached file
BOD
COD
TSS
TKN
N_NH4
N_NO3
N_TOT
P_DSV
P_TOT
DO
F_COLIF
E_COLI
TDS
TURB
PH

Notes

Chapter 6

Site Visits

Site Locations

The Project Team visited 20 constructed wetlands permitted to treat municipal wastewater. A site data sheet was completed for each of these sites.

Biologists and Engineers documented treatment and habitat values for each site.

The Project Team also visited 8 miscellaneous wetlands used for stormwater treatment, educational purposes, and on-site residential wastewater treatment. A commentary is provided for these sites.

General Approach

Sites identified by the Task Force members and project team to fit project criteria were visited during the summer and early fall of 2000. Project inventory consisted of collecting available data and observing site conditions on the date visited.

Each wetland visited was evaluated with the same criteria. Site Data Sheets (SDS's), as discussed in Chapter 5, served as checklists to ensure each subject was covered, as well as a data log to record field notes. A team of at least one engineer and one biologist evaluated each site.

Engineering Analysis

Team engineers catalogued the engineering related design components. Operators and design engineers were interviewed to gather site specific data.

Biological Perspective

Project biologist used the Montana Method, as discussed in Chapter 4, to evaluate the wetland. This method develops a score for each wetland based on its value to the natural ecosystem.

Overall Site Comments

The primary function of each treatment wetland was to provide sufficient removal of pollutants from the wastewater to meet discharge permit requirements. The bottom line for each site was 'did it meet its discharge permit requirements?' From an engineering perspective, the wetland was determined to be successful if it was able to consistently meet permit limitations.

Biologists determined the level to which the wetland functioned as an environmental element by using the Montana Method to rank each site. A table is provided for each site with scores allocated for each assessment category. An overall score was compiled for each site.

Site Visits

A write-up is provided for each site visited. A description of the facility and details of the engineering and biological evaluations are discussed.

10-acre facultative lagoon system, prior to wetland cells

Avondale Facility Statistics	
Nearest Town:	Avondale
County:	Pueblo
River Basin:	Middle Arkansas
Receiving Water Body:	Green Arroyo
Year Online:	1996
Population:	1,000
Elevation (feet):	4560
Design Flow (mgd):	0.110
Average Flow (mgd):	0.080
Size (acres):	0.87

Portion of wetland cell with some plant die-off

Wetland cell

Facility Description

The Avondale Wastewater treatment facility is a minor municipal lagoon system. The facility consists of a continuous influent flow measuring device and recorder, a lagoon system, three wetland cells, a chlorine contact chamber, and a continuous effluent flow measuring device and recorder.

The permitted design capacity of the Avondale Wastewater Facility is 0.1146 million gallons per day for hydraulic flow (30-day average) and 211lbs. BOD_5 per day for organic loading (30-day average).

Lagoons

The Avondale lagoon system consists of 2 unaerated cells. Some of the system features are detailed in the table below.

Lagoon Information		
Cell No.:	1	2
Surface Area (sq. ft.)	217,800	217,800
Avg. Depth (ft)	5	5
Avg. Volume (Million gallons)	7.5	7.5
Detention time (days)	90	90
Aerator size (hp)	NA	NA

Background Information

On April 30, 1993 the Water Quality Control Division issued a Notice of Violation and Cease and Desist Order (NOVCDO) to the District as a result of non-compliance with the permit for the Wastewater Treatment Facility. On February 1, 1995, the NOVCDO was amended requiring the District to complete construction of a facility upgrade and planting of the wetland portion of the facility. The deadline established for completion of construction and planting was November 30, 1995. In late November 1995, the District notified CDPHE that the upgrade was completed except for the wetland planting which would be delayed until spring, 1996. This system has continued to have problems meeting permit limitation, even after the wetland implementation. At the time of the site visit, this facility was not discharging.

Energy Analysis

The Avondale system is an unaerated facultative lagoon system. Energy consumption at this site is negligible.

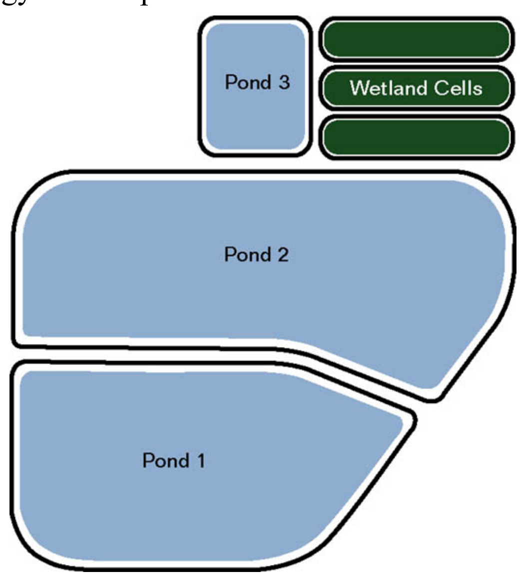
Wetland Design

Design Methods

The FWS wetlands were sized using first order plug flow kinetics for BOD removal. The average loading for each wetland cell was calculated to be 11.2 acre per mgd, with a detention time of 4.1 days. The summer loading rate was calculated to be 28.3 acre per mgd, with a detention time of 3.4 days.

Objectives

The FWS wetland cells were added to polish the effluent from the lagoon system. Compliance issues were a result of algae carryover from the lagoon system.



Size

The individual area for the three wetland cells is approximately 12,750 ft^2 for a total area of 38,250 ft^2.

Shape

As the schematic to the right shows, Avondale constructed wetland cells are flat and rectangular, with an area of approximately 0.3 acres each.

Hydraulics

Wetland cells are lined with 3" of bentonite clay to prevent groundwater influences. The inlet mechanism into the wetland cells consists of slotted pipes buried in a gravel bed with particle sizes ranging from 3" to 6". Plugging of the outlet was noted to be a problem. At the time of the site visit the outlet was not functioning. This system does not have a mechanism for varying water elevation in the wetland.

At the time of the site visit the wetland system was not discharging. The operator was able to bypass the wetland system if the lagoon effluent met discharge requirements. Otherwise, the wetland system operated as an evaporative cell.

Treatment Goals

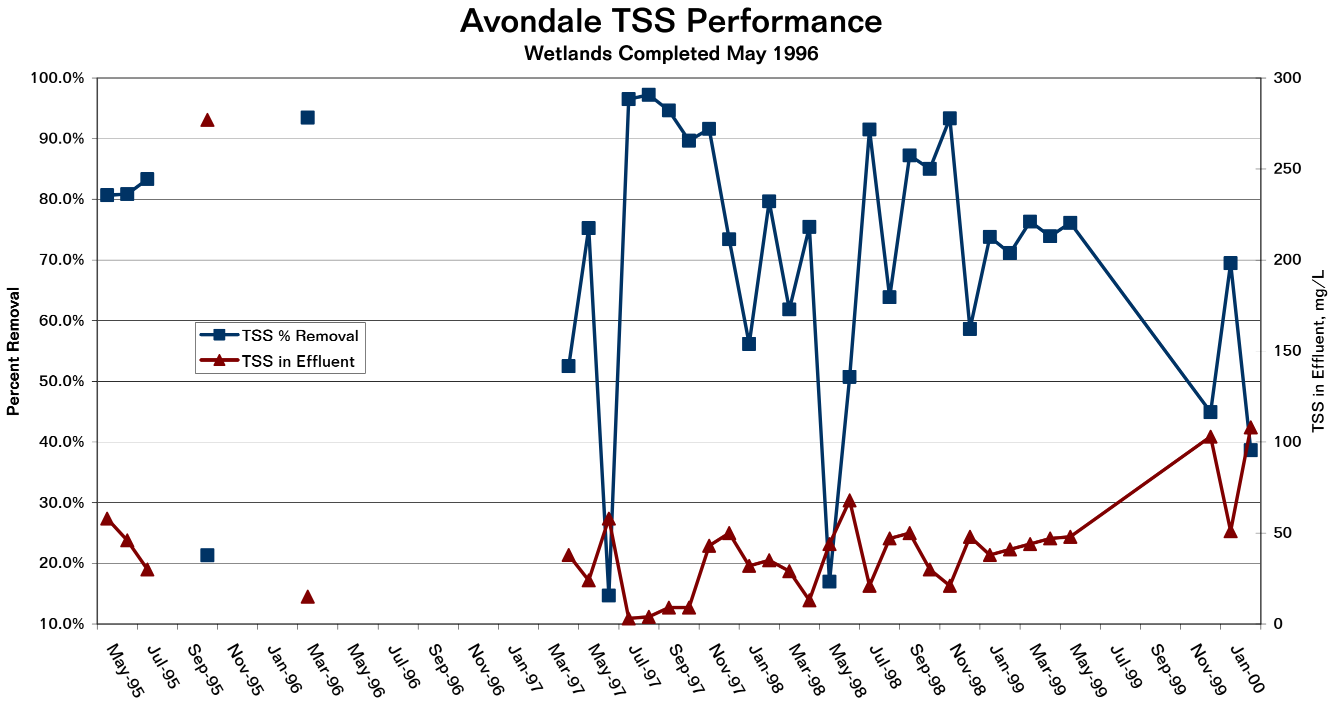
Permitted Discharge Limitations	
Oil and Grease:	10 mg/l (Daily Max)
$CBOD_5$:	25 mg/l (30-day avg)
BOD_5 Removal:	85%
TSS:	105 mg/l (30-day avg)
PH, su (min – max)	6.5 – 9.0 (Daily Max)
Chlorine Residual:	0.5 mg/l (Daily Max)
Fecal Coliform Bacteria:	6,000 organisms per 100 ml (Daily Max)

Water Quality Data

Water quality data were obtained from CDPHE permit files. The data indicate that the wetlands have not been able to consistently meet permit.

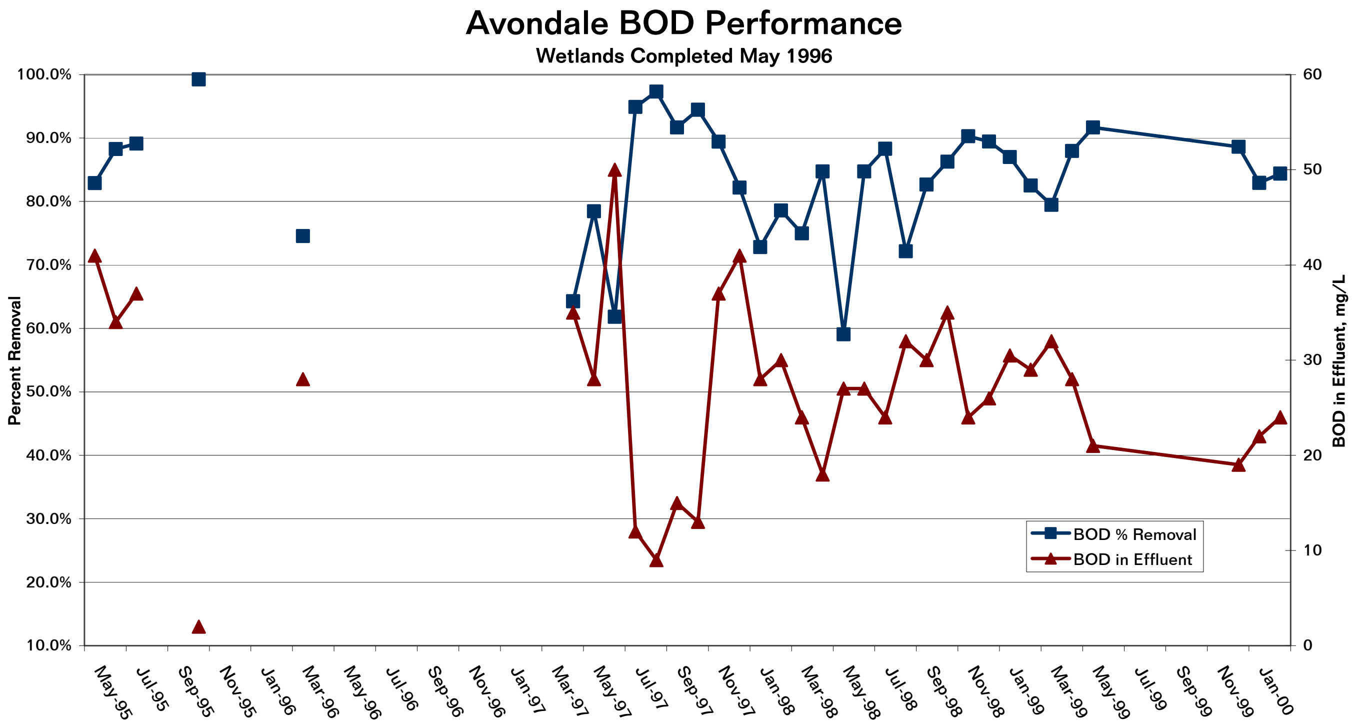
TSS Data

Some general observations can be made by reviewing the plotted 30-day average TSS data. The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. In the months before the wetland was implemented, there was no discharge from the treatment facility. Since no discharge was occurring, data for this period were not reported. Trends in the TSS data indicate that TSS in the effluent has consistently been below permit limitations. The most current data indicate that TSS in the effluent has been increasing, while percent removal in the system has been decreasing.



The discharge permit limitation for TSS in the effluent is 105 mg/l for the 30-day average. Monthly reports submitted to the CDPHE record an average daily TSS in the influent, since the wetlands have been operating, of 165 mg/l. The average TSS in the effluent is recorded to be 40 mg/l. This removal clearly meets the discharge requirements of 105 mg/l.

BOD Data

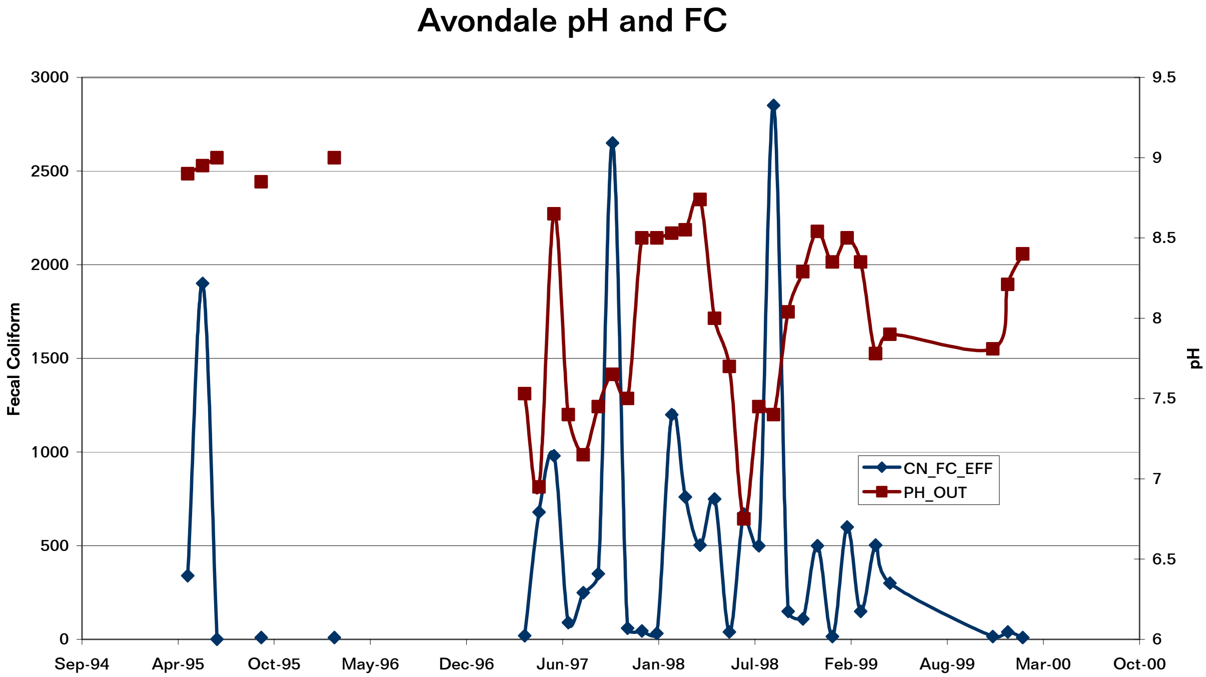


The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The data previous to the wetland implementation is scant, as discharge was not occurring during this period. The permit for this system changed from reporting BOD5 to reporting CBOD5. Tests indicate that there is little difference between the two at this system. The data from this system indicates that CBOD values have exceeded permit limitations. The average CBOD in the influent, since wetland implementation, has been 185 mg/l, with an average effluent amount of 27 mg/l. This average value is slightly higher than the permitted value of 25 mg/l. The percent removal in the system recorded an average value, during this same period, of 83 percent. This removal is slightly lower than the permitted removal of 85 percent.

pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent, no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Previous to the wetland implementation, data indicate that average pH values in the effluent were close to the maximum daily allowable of 9. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.

Fecal Coliform in the effluent is consistently well below the permit limitations of 6,000 organisms per 100ml.



General Ecological Setting

The Avondale wetland is located on the north side of the Town of Avondale, on a terrace above the Arkansas River.

Cell Vegetation

Three cells with similar vegetation communities are present at the Avondale site. Cell 1 is composed of 80 percent water, 10 percent litter, and 10 percent vegetation. The vegetation community is dominated by cattail (*Typha latifolia*), duckweed (*Lemna minor*), and algae, with common reedgrass present but not dominant. Tamarisk (*Tamarix chinensis*) and Russian olive (*Eleagnus angustifolia*) are present on the edges of the cell. Cell 2 is 75 percent open water, 5 percent litter, and 20 percent vegetation. The plant community in cell 2 is composed of cattail, duckweed, and barnyard grass (*Echinochloa crus-galli*). Cell 3 is 50 percent open water and 50 percent vegetation. The vegetation community is dominated by cattail, duckweed, common reedgrass (*Phragmites australis*), barnyard grass, and algae.

Planting/Seeding

The wetland was planted with cattail, giant burreed, water lily, dwarf bamboo, duckweed, and yellow water iris. Most planted/seeded species have not survived. The water lily, bamboo, and water iris are not specifically adapted to this area, and probably could not compete with species such as cattail.

Weeds

Tamarisk and Russian olive are present on the edges of cell 1. Tamarisk is a facultative phreatophyte, i.e., it can draw water from underground sources but once established it can survive without access to ground water. It consumes large quantities of water, possibly more than woody native plant species that occupy similar habitats. Tamarisk is a maintenance concern and commonly is controlled in riparian areas and wetlands because of its potential to displace native vegetation and its lower value as wildlife habitat. Russian olive is an introduced ornamental shade tree than can invade waterways and becomes a serious weed problem (Whitson 1996). It provides little value as wildlife habitat.

Wildlife

The Avondale wetland provides habitat for muskrat and snapping turtle. Muskrats have been problematic, causing vegetation damage and clogging outflows. This site contains some structural diversity such as open water mixed with cattail stands; however, some of the open water may be a result of a recent die–off. Also, it should be noted that large areas of open water that lack vegetative cover have lower habitat value.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high. General wildlife habitat and production export/food chain support rated moderate. Habitat diversity and uniqueness of the constructed wetland rated low. This wetland received 40 percent of the total possible functional points.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.4 (mod.)	1
General Fish/Aquatic Habitat	0.0	1
Production Export/Food Chain Support	0.6 (mod.)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.4 (48%)	5
Wetland Category (I, II, III, or IV)	III	

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. At the time of the site visit, the aesthetic value of this wetland was low because of recent vegetation die offs. However it has potential to have moderate aesthetic value with viable vegetation.

Maintenance Issues

Wetlands would benefit from either lowering the water level or raising the soil surface. The overall system performance could be improved by incorporating a mechanism to allow the water level in the wetland to be lowered.

Overall Site Comments

The wetlands at this site have not functioned as intended. It is possible that the shallow lagoons are not achieving the treatment anticipated and are therefore overloading the wetland system.

Aerated lagoons

Wetland cells

Wetland trench – not yet planted

Bennett Facility Statistics	
Nearest Town:	**Bennett**
County:	**Adams**
River Basin:	**Middle South Platte**
Receiving Water Body:	**Unnamed drainage – tributary to Lost Creek**
Year Operational:	**Pilot scale studies**
Population:	**2200**
Elevation (feet):	**5490**
Design Flow (mgd):	**0.42**
Average Flow (mgd):	**0.08**
Size (acres):	**2**

Facility Description

The Bennett system is minor municipal aerated lagoon system. The facility consists of two aerated lagoons, one polishing pond, and a chlorine contact basin.

The permitted design capacity of the Bennett system is 0.42 million gallons per day for hydraulic flow (30-day average).

The Town is conducting a reuse pilot study using the facility effluent in constructed wetlands. These studies include the use of solar powered motors and pumps, and aerators. An ion generator is being used to kill both bacteria and algae. Independent testing and subsequent trials indicate that ion generator disinfection method will meet CDPHE requirements. Bennett plans to reuse its effluent by supporting a retail nursery, irrigation for parks and a ball field, and the incorporation of hot houses for commercial crops.

Background Information

On July 29, 1993 the Town of Bennett was issued a Notice of Violation and Cease and Desist Order for exceeding permitted BOD5 effluent limits. The plant was originally designed to operate as a three-pond system. This proved to be too expensive to operate and the plant was cut back to one pond. Pond 1 was curtained off to provide a primary pond, with floating aerators, a secondary pond with floating aerators, and a covered polishing pond. Design based on population growth that did not occur. The main problem has been abnormally heavy algae growth.

The town is conducting a reuse pilot study using constructed wetlands. At this time, the wetlands are not a part of the treatment process.

The facility consists of a three-cell lagoon system: cell 1 is operated as a complete mix lagoon, cell 2 is operated as a partial mix lagoon, and cell3 functions as a polishing pond, and a chlorine contact basin.

Energy Analysis:

The site uses 4 – 7.5 hp aerators running full-time. This results in an annual energy consumption of 196,000 kw/year. The Town is currently experimenting with low energy processes to reduce the energy consumption. These processes include solar-powered aerators, and ion-generators to assist with disinfection.

Construction Cost

The Town of Bennett was able to retrofit existing ponds with minimal construction. One of the original lagoons was converted to a wetland area. Earthwork was provided to divide the lagoon into 4 connected cells. It was estimated that the cost to implement the wetland was around $150,000.

Design

Design Methods

The Bennett wetlands were designed to fit into the existing site. An abandoned lagoon was retrofit to incorporate the subsurface portion of the wetland. A ditch along the perimeter of the site serves as a subsurface wetland.

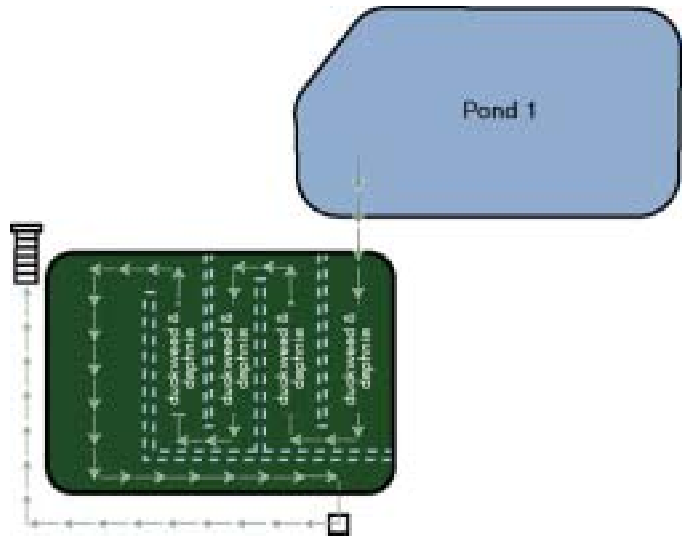
Objectives

The Bennett wastewater treatment plant is has been updated in recent years to consistently meet effluent permit requirements. The implementation of the wetland cells have the primary goal of further cleansing the water, providing wetland plants for reuse and experimental area for testing low energy treatment methods.

Size

An existing lagoon has been retrofit to include a constructed wetland system. The lagoon is approximately 1.8 acres. A cattail and gravel trench has been constructed to transport the effluent from the wetland system to the chlorine contact basin. This trench is approximately 20 feet wide and approximately 700 feet long.

Shape



Berms have been constructed to divide the lagoon into five cells that are connected by a serpentine flow path. The cattail and gravel trench that runs along the perimeter of the FWS wetland cells is designed as a subsurface component of this system.

Hydraulics

The wetland system has been designed to include operating flexibility. Splitter boxes are provided to allow the bypass of the wetland system. The first portion of the wetland receives flow by gravity from the lagoon system. The inlet pipe from the splitter box discharges directly into the wetland. After winding through the serpentine wetland system, flow collects at a holding cell along the western side of the wetland. A pump is used to lift the water to the gravel and cattail trench. The water flows by gravity in this trench along the perimeter of the wetland cells. At the end of the trench, the flow can be directed into a greenhouse or directly into the chlorine contact chamber.

Water Quality Data

At the time of this study, the Bennett system was not a component of the permitted treatment facility. No monthly discharge testing records are available for this wetland system.

General Ecological Setting

The four Bennett constructed wetland cells are flat and rectangular. Three of the cells have an area of approximately 0.10 acre each, and cell 4 is approximately 0.20 acre. The wetland currently is not discharging. The Bennett treatment wetland is located in an upland agricultural area on the north side of the Town of Bennett.

Cell Vegetation

Each cell at the Bennett site has a slightly different vegetation composition, and a different ratio of vegetation to water. Cell 1 is composed of 98 percent water and 2 percent vegetation. Two vegetation communities are present in cell 1. Vegetation community 1, which comprises 60 percent of cell vegetation, is dominated by cattail (*Typha latifolia*) and softstem bulrush (*Scirpus tabernamontanae*). The remaining 40 percent is composed of barnyard grass (*Echinochloa crus-galli*), curly dock (*Rumex crispus*) and pinkweed (*Polygonum pensylvanica*). Cell 2 is 3 percent open water and 97 percent vegetated. There is a single plant community, which is dominated by duckweed (*Lemna minor*), cattail, and softstem bulrush. Cell 3 is similar to cell 2 and has the same vegetation-to-water ratio. Vegetation community 1, which comprises 65 percent of cell vegetation, is dominated by cattail and softstem bulrush. The remaining 35 percent is composed of pinkweed, barnyard grass, and curly dock. Cell 4, which is twice the size of cells 1, 2, and 3, is 97 percent vegetation and 3 percent water. It has a single vegetation community, which is dominated by duckweed, cattail, and softstem bulrush.

Planting/Seeding

In the Spring of 1999 seedlings were planted. No surface mulch was added. Duckweed and Daphnia were introduced to the system 3 to 4 years ago.

Weeds

No noxious weeds were found on the site.

Maintenance Issues

A portion of the Bennett system will serve as a nursery for wetland plants. This area will be harvested as needed.

Wildlife

The Bennett wetland provides habitat for red winged black birds and waterfowl. Red winged black birds were observed during the site visit. The wetland has some structural diversity because it contains both shallow water and areas of emergent vegetation. However, its value is limited because only a small portion of the wetland is vegetated; open water comprises most of the wetland cells.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high. General wildlife habitat and production export/food chain support rated moderate. Habitat diversity and uniqueness of the constructed wetland rated moderate to low. This wetland received 43 percent of the total possible functional points, and was classified as a category III wetland.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.5 (mod.)	1
General Fish/Aquatic Habitat	0.0	1
Production Export/Food Chain Support	0.7 (mod.)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.6 (52%)	5
Wetland Category (I, II, III, or IV)	III	

Human Use

The wastewater wetland is part of a restricted public access area. This wetland has low to moderate aesthetic value because it is dominated mainly by open water. This facility has been included in a ‘smart growth’ study being conducted by the OEMC due to the alternative energy methods being.

Overall Site Comments

At the time of the site visit, the wetland was still being constructed. The use of a both surface and subsurface flow wetland components is a unique treatment design.

Aerated lagoon #1

Aerated lagoon #2

Subsurface Flow Wetland Cell

Hi-Land Acres Facility Statistics	
Nearest Town:	**Brighton**
County:	**Adams**
River Basin:	**Upper South Platte**
Receiving Water Body:	**Todd Creek**
Year Operational:	**1998**
Population:	**300**
Elevation (feet):	**5144**
Design Flow (mgd):	**0.055**
Average Flow (mgd):	**0.022**
Size (acres):	**0.21**

Facility Description

The Hi-Land Acres Water and Sanitation District wastewater treatment facility is a minor municipal lagoon system. The facility consists of two completely mixed aerated lagoons and one settling pond followed by a subsurface flow treatment wetland and gas chlorination. The influent flow is measured by a 6-inch Parshall flume with a continuous recorder and totalizer. The effluent flow is measured by a 90° v-notched weir with a continuous recorder and totalizer.

The two aerated cells are equipped with four aspirating aerators, that apply approximately 27 percent more energy than is recommended in the 1983 USEPA design manual for complete mix aerated lagoon systems. The goal of using high energy mechanical mixers coupled with long residence times is to achieve complete nitrification.

Effluent from the aerated cells flows into a quiescent pond. Suspended solids, particularly algae, will settle out in the settling pond. The wetland cell will then intercept most of the remaining suspended solids before discharge to the chlorine facility and ultimately final discharge to the receiving water body.

Lagoons

The Hi-Land Acres lagoon system consists of 2 completely mixed aerated cells followed by 1 settling cell. Some features of the lagoon system are detailed in the table below.

Lagoon Information			
Cell No.:	**1**	**2**	**3**
Surface Area (sq. ft.)	**9,840**	**9,840**	**9,753**
Avg. Depth (ft)	**12**	**12**	**8**
Avg. Volume (Million gallons)	**0.40**	**0.40**	**0.23**
Detention time (days)	**6.6**	**6.6**	**4.0**
Aerator size (hp)	**30**	**30**	**NA**

Background Information

The Hi-Land Acres District has operated a wastewater treatment facility since 1964. Numerous violations of the permit effluent parameters during the period from 1987 to 1992 have been recorded. In the fall of 1995 the system was in “Significant Noncompliance” due to exceeding effluent limitations for BOD_5 and TSS. In addition, the facility has had a history of numerous pH violations. The District undertook several system modifications to improve the effluent quality. In November of 1998, the aerated lagoon was divided into two smaller cells to reduce the hydraulic retention time. Pontoon supported aspirating mechanical aerators replaced the failing synthetic membrane diffusers. In addition new outlet control structures were added to allow flexibility in the operating water level in each lagoon cell. The subsurface wetland system was added to polish the lagoon effluent prior to chlorine disinfection and final discharge to Todd Creek.

Energy Analysis

The Hi-Land Acres system utilizes 4-7.5 hp motors in its aerated lagoon system. The aerators are operated full-time with 39 hp per million gallons of mixing power. This results electrical consumption of 640 kW per day.

Construction, Maintenance and Operational Cost

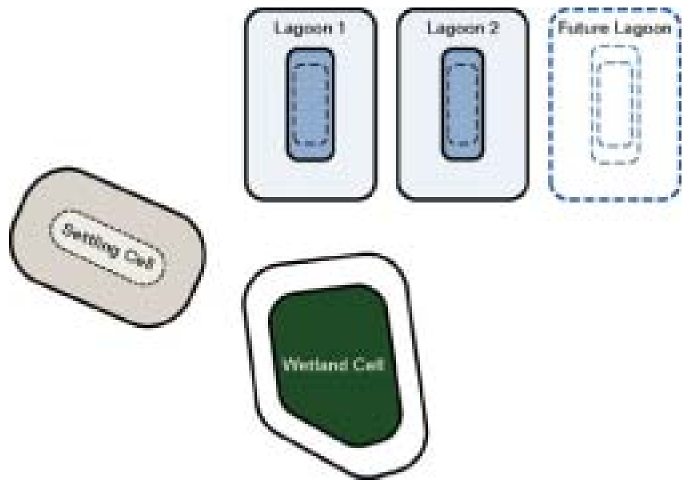
The approximate construction costs for this system were $250,000. The wetland was installed in an abandoned lagoon, so earthwork was minimized. Annual maintenance and operational costs are approximately $20,000.

Design Methods

The subsurface wetland system was designed to remove suspended solids and algae from the lagoon effluent prior to discharge into Todd Creek. A hydraulic residence time of 36 hours at design flows was used to size the wetland system.

Size

The wetland area is approximately 9,148 ft2. The depth of the media in the wetland cell is 4.5 feet with a porosity of 28%. This provides a water volume in the cell of approximately 1,525 cubic yards.



Shape

The subsurface flow wetland was installed by retrofitting an abandoned lagoon. The overall shape of the wetland is roughly square, with a length to width ratio of 1:1.

Hydraulics

The wetland consists of shallow earthen basin filled with ¾ - inch gravel placed to a depth of 3.5 feet. Lagoon effluent is distributed through the wetland area by a perforated pipe buried in the gravel media. The wetland effluent discharges through a perforated pipe buried in the gravel media into an outlet control structure. Aluminum stop logs in the outlet control structure form a weir to control the water surface elevation in the wetland. Stop logs can be inserted or removed to vary the water surface elevation and hydraulic retention time in the wetland.

Effectiveness

The lagoon/wetland system has shown promising results. Tests taken show that the wetland removes 53 percent of the BOD and 58 percent of the TSS remaining in the lagoon system effluent.

Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.02 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**1,500 organisms per 100 ml (Daily Max)**

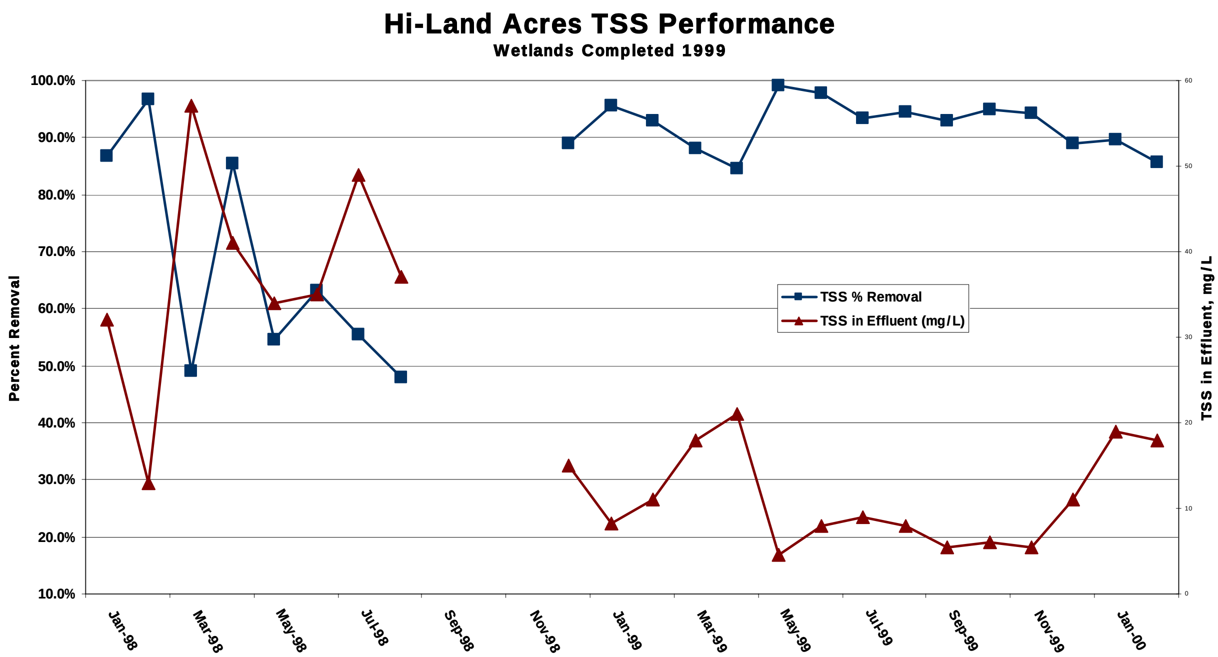
Water Quality Data

Water quality data was obtained from CDPHE permit files. The data indicate that within a year of implementing the wetlands, permit limitations have been consistently met.

TSS Data

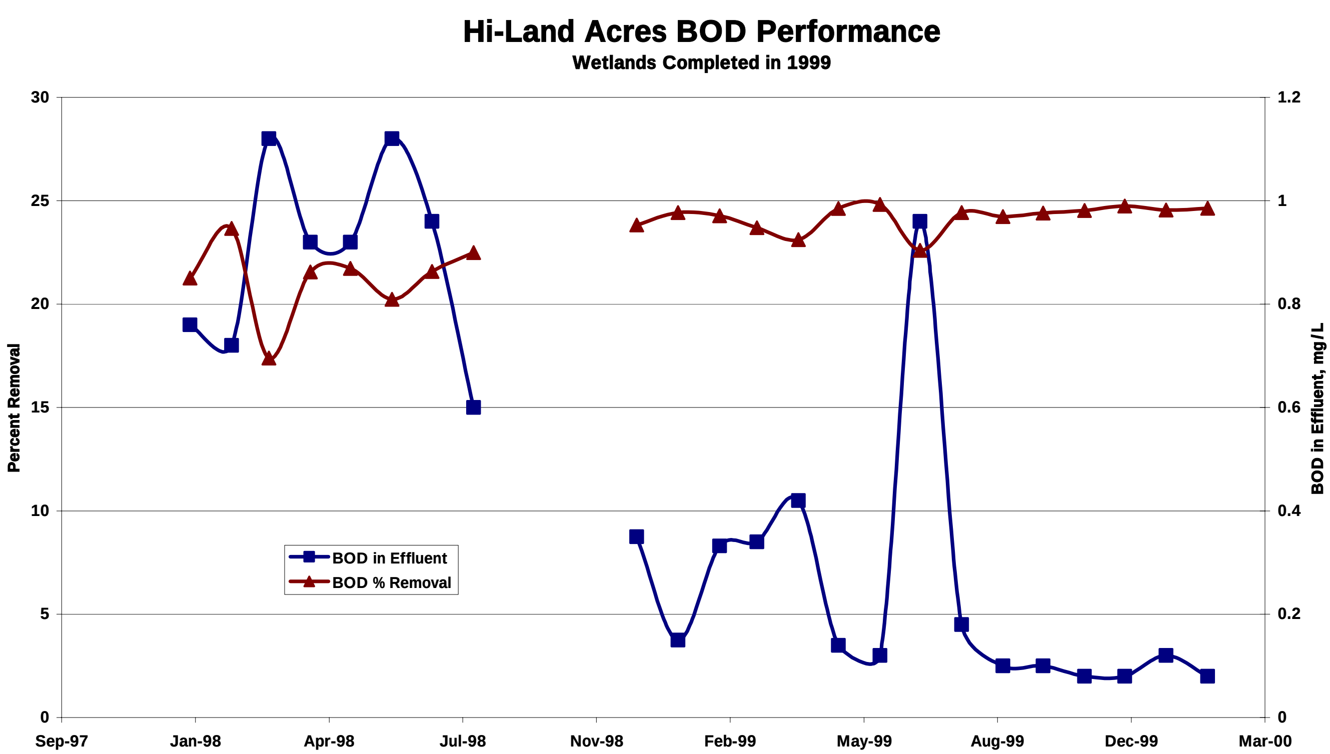
Some general observations can be made by reviewing the plotted 30-day average TSS data. The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. In the months before the wetland was implemented, there was no discharge from the treatment facility. Since no discharge was occurring, data for this period were not reported. Trends in the TSS data indicate that TSS in the effluent has consistently been below permit limitations.

The discharge permit limitation for TSS in the effluent is for the 30-day average. Monthly reports submitted to the CDPHE, since the wetlands have been operating, record an average daily TSS in the influent of 172 mg/l. The average TSS in the effluent during this same time period is recorded to be 11mg/l. The removal clearly meets the discharge requirements of 105mg/l.



BOD Data

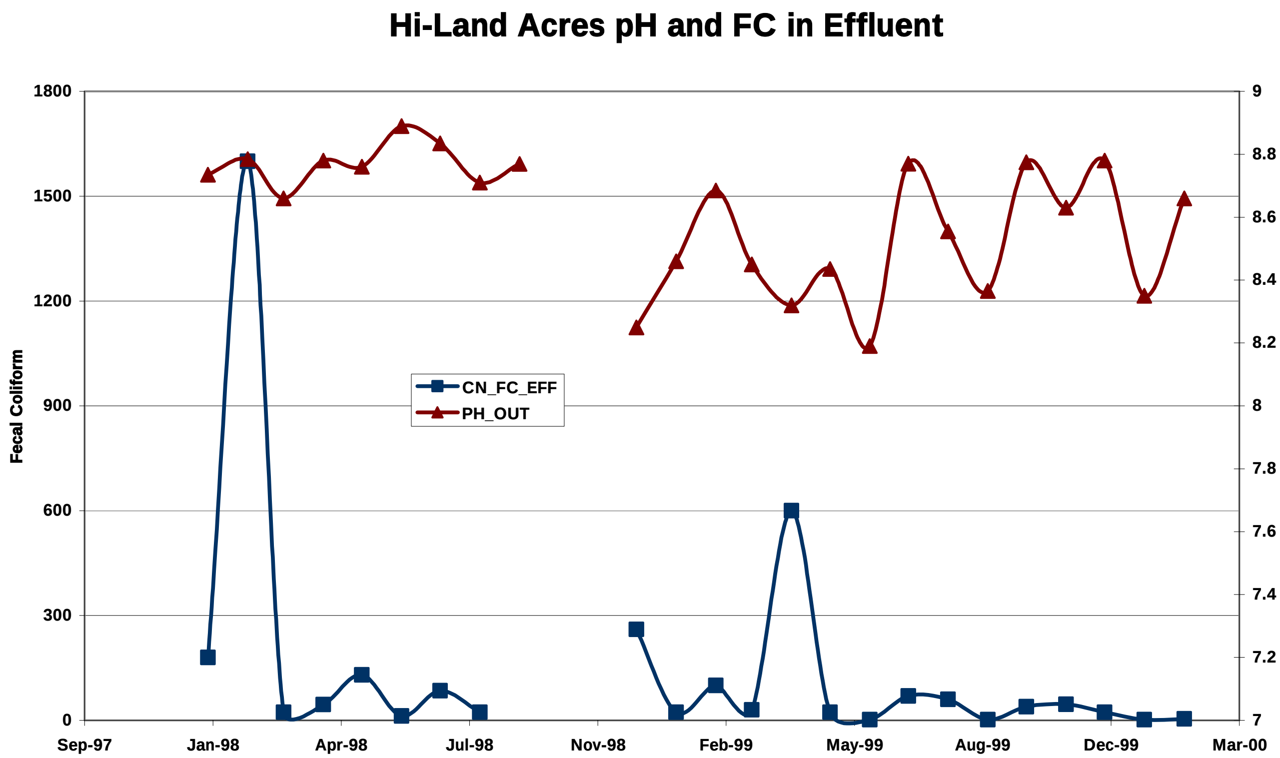
The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. Since the wetland implementation, BOD in the effluent and percent removal have visibly improved. The average BOD in the influent has been 194 mg/l, since wetland implementation has been, with an average effluent amount of 6 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent, no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Previous to the wetland implementation, data indicate that average pH values in the effluent were close to the maximum daily allowable of 9. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.

Fecal Coliform in the effluent is consistently well below the permit limitations of 6000 organisms per 100ml.



General Ecological Setting

Highland Acres is sited along Todd Creek, a tributary to the South Platte River in Adams County. The wastewater treatment lagoons and subsurface wetland are in an upland area where rolling hills are dominated by shortgrass prairie and other introduced grass and weed species. Todd Creek is about 300 yards downslope of the treatment facility, and it supports a narrow riparian corridor with scattered plains cottonwood trees and other shrubs.

Cell Vegetation

The Highland Acres wetland consists of one square cell, approximately ¼ acre, with two plant communities. Plant community 1, which represents 90 percent of the total cell area, is dominated by prickly lettuce (*Lactuca seriola*) and ragweed (*Amaranthus retroflexis*). Plant community 2, which represents 10 percent of the total cell area, is dominated by cattail (*Typha latifolia*) and lady's thumb (*Polygonum persicaria*)

Planting/Seeding

No wetland planting or seeding was performed at the site. Plant establishment relied on plant colonization from adjoining areas.

Weeds

A small stand of Canada thistle (*Cirsium arvense*) is located in the wetland area. Canada thistle, a State Noxious Weed, is particularly invasive in areas of recent disturbance, and spreads quickly. It prevents the establishment of or displaces native species and has low value as wildlife habitat.

Maintenance Issues

Deepening the lagoons and covering the sedimentation lagoon with a floating cover to prevent algae growth could improve wetland effectiveness.

Wildlife

Vegetative diversity and subsequent wildlife habitat value are low. Much of the subsurface wetland has not been colonized by vegetation or has been colonized by weeds only. Gravel may limit the establishment of vegetation valuable to wildlife, as. From a landscape perspective, the treatment wetland does not provide unique functions and value for wildlife, although the lagoons provide small areas of open water, which is uncommon in the area.

Wetland Biodiversity Functional Assessment

The general wildlife habitat, habitat diversity, and uniqueness of the Highland Acres constructed wetland rated low. Sediment/nutrient toxicant removal was rated moderate. Total functional points were 15 percent of the total possible, and the wetland was rated in category IV, the lowest value rating.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	**0.1 (low)**	**1**
General Fish / Aquatic Habitat	**NA**	**1**
Production Export / Food Chain Support	**0.1 (low)**	**1**
Habitat Diversity	**0.1 (low)**	**1**
Uniqueness	**0.1 (low)**	**1**
Total Points	**0.9 (18%)**	**5**

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
Wetland Category (I, II, III, or IV)	**IV**	

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has low aesthetic value because areas of bare gravel and weedy species dominate it.

The Hi-Land Acres wetland system was the subject of a paper presented at the October 2000 Water Environment Federation Annual Conference[1].

Overall Site Comments

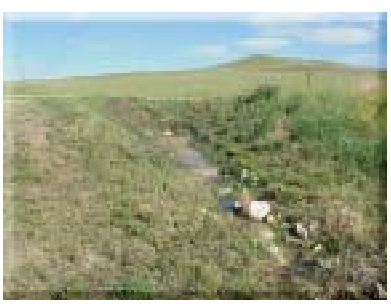
While this site functions quite effectively in its intended wastewater treatment function, a large portion of the site has not developed wetland vegetation. The sewage lagoons at the site provide open water habitat for wildlife, but the treatment wetland provides only limited habitat.

[1] Lutz, Michael P., Perasso, Paul M., Yamamoto, Tom, and Watson, Roger. “Nitrification and Denitrification in Aerated Lagoons Coupled with Artificial Wetlands”, presented at WEFTEC 2000.

Aerated Lagoons

Ponding water in wetland

Plant diversity in wetland



Receiving water body

Calhan Facility Statistics	
Nearest Town:	Calhan
County:	El Paso
River Basin:	Lower Arkansas
Receiving Water Body:	Tributary to Big Sandy Creek
Year On-line:	1996
Population:	850
Elevation (feet):	6541
Design Flow (mgd):	0.080
Average Flow (mgd):	0.065
Size (acres):	0.31

Facility Description

The Calhan wastewater treatment facility is a minor municipal aerated lagoon system. This system consists of two complete-mix, mechanically aerated lagoons, one facultative lagoon, and an artificial wetland. Subsurface wetlands were included in this wastewater treatment facility to remove suspended solids from lagoon effluent and to prevent algal blooms in the flood control reservoirs that receive effluent from this facility.

Lagoons

Some features of the Calhan lagoon system are detailed in the table below.

Lagoon Information			
Cell No.:	1	2	3
Surface Area (sq. ft.)	11,800	11,800	11,800
Avg. Depth (ft)	12	12	12
Avg. Volume (Million gallons)	0.536	0.536	0.536
Detention time (days)	6.7	6.7	6.7
Aerator size (hp)	14	14	NA

Background Information

The Calhan wastewater treatment facility is a new system. Constructed treatment wetlands were included as a component of the aerated lagoon system in order to provide final polishing before discharge from the site. The wetland cells were designed to be subsurface flow systems. At the time of the site visit, the water was flowing at about 3” above the gravel surface.

Energy Analysis:

Energy consumption at this site is minimal. The aerated lagoons operate 2-7.5 hp aerators.

Wetland Design

Design Methods

The wetland size was based on regression analysis of 14 full scale systems. In addition, design data from the Las Animas study[1] were used as a guide. Based on this empirical data, a gravel size of ¾” and a void space in the soil media of 28% were used. In addition, it was determined from this data, that a hydraulic retention time of 2.1 days would be sufficient to meet design requirements.

Objectives

This system was designed to reduce TSS in the lagoon effluent. Effluent from the lagoon was determined to range from 30 to 60 mg/l, with a peak effluent TSS of 250 mg/l in summer months, due to algal carryover. The wetland cells were designed to have 36-inch deep beds in consideration of freezing temperatures.

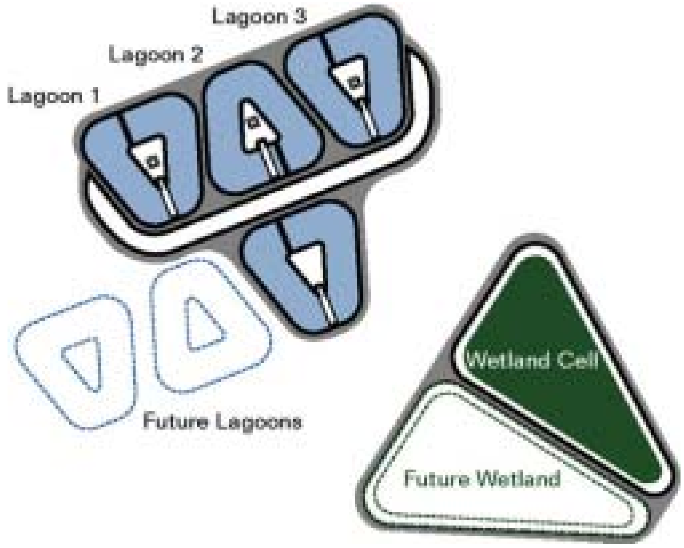
[1] “Subsurface Flow Wetlands – A Performance Evaluation”, Water Environment Research, Vol.67, No.2.

Size

The subsurface wetland system consists of two cells with a surface area of 0.31 acres each. The depth of the soil media is 3feet. 1500 cubic yards of ¾ -inch rock provide a void space of 28%.

Shape

The wetlands are roughly triangular, with the inlet wider than the outlet width.



Hydraulics

Slotted pipe is used to convey water from the lagoons to the wetland cells. A 2’x4’ water level control is used at this site. No lining was used since the natural soils are clayey. It is noted that the system has settled about 8” to 1’ into the clay. This system was designed as a subsurface flow system, but due to settling of the system and possibly plugging, the system operates as a free water surface wetland.

Treatment Goals

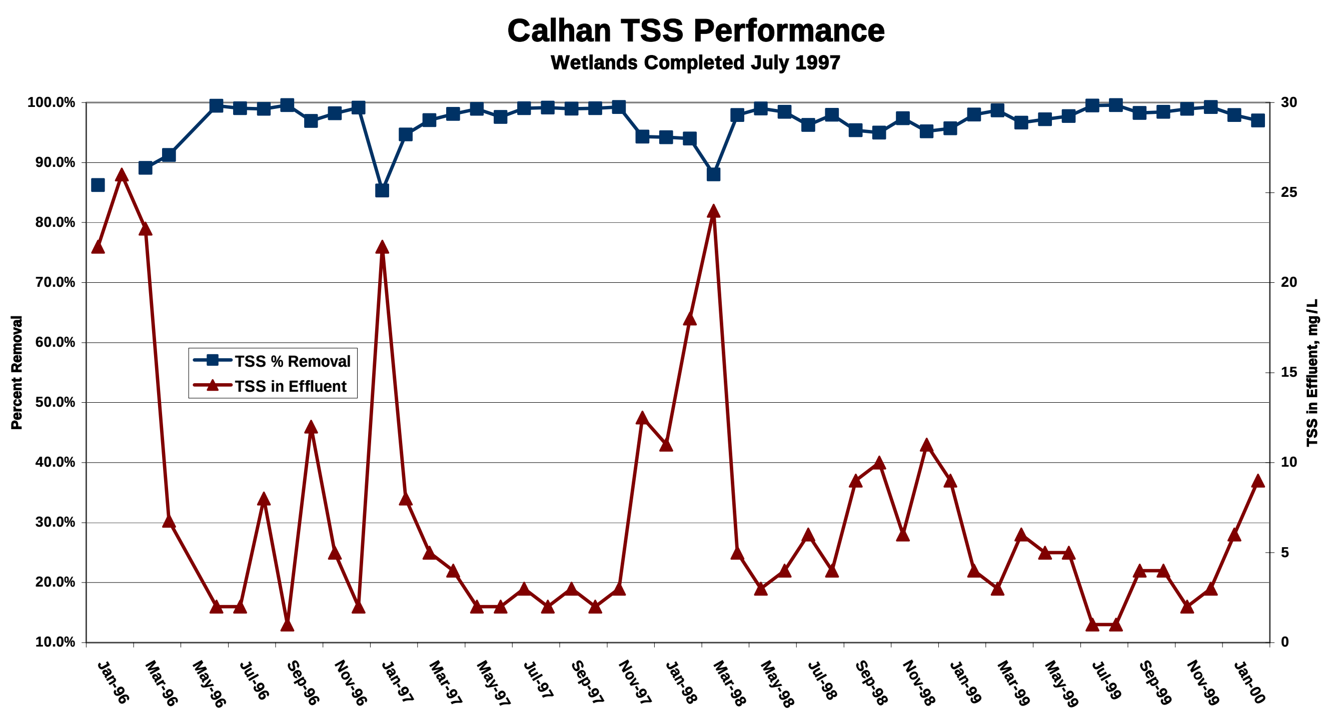
Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
$CBOD_5$:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**2,000 organisms per 100 ml (Daily Max)**

Water Quality Data

Water quality data were obtained from CDPHE permit files. Since the wetland implementation in 1997, the Calhan Wastewater Treatment Facility has consistently met its discharge permit requirements.

TSS Data

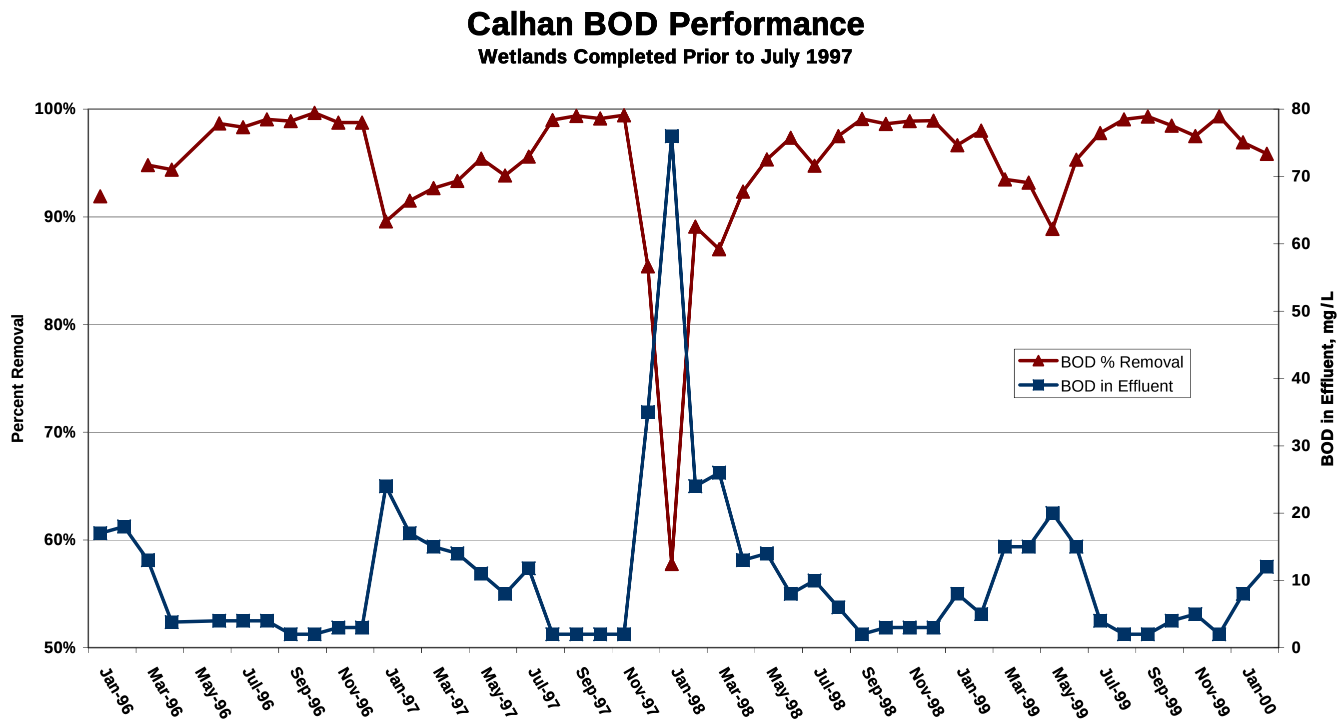
The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. Some general observations can be made by reviewing the plotted 30-day average TSS data. Since the wetland system has come online, the average monthly TSS in the influent to the facility has been 241 mg/l



and the average monthly TSS in the effluent has been 6 mg/l. Peaks in the system correlate with the annual Watermelon Festival, which brings large crowds to the area.

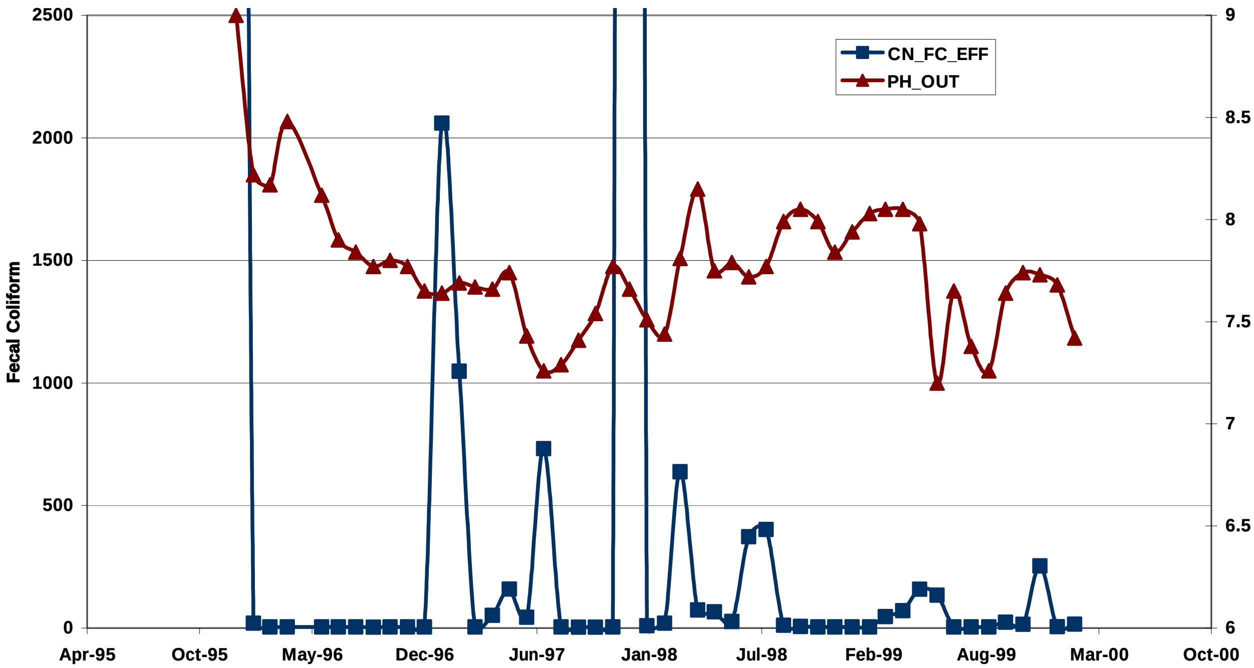
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly BOD in the influent has been 245 mg/l and the average BOD in the effluent has been 11 mg/l.



pH and Fecal Coliform

Data for these two categories has been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9. Previous to the wetland implementation, the fecal coliform values fluctuated considerably. Since the wetland implementation, the fecal coliform values have consistently met permit requirements.



General Ecological Setting

The Calhan constructed wetland cell is flat and rectangular. It has an area of approximately 0.7 acre. The wetland discharges to an unnamed tributary to Big Sandy Creek. The wetland is located northeast of the town of Calhan in a rangeland area.

Cell Vegetation

The Calhan wetland is comprised of a single wetland cell with two plant communities. The cell is composed of 30 percent water, 20 percent rock, and 50 percent vegetation. Plant community 1, which is 60 percent of the vegetated wetland area, is dominated by cattail (*Typha latifolia*), duckweed (*Lemna minor*), and barnyard grass (*Echinochloa crus-galli*), with a few foxtail barley (*Hordeum jubatum*. Plant community 2, which comprises 40 percent of the vegetated area, is dominated by pinkweed (*Polygonum pensylvanica*), curly dock (*Rumex crispus*), and Canada thistle (*Cirsium arvense*), with plains cottonwood (*Populus deltoides*), crack willow (*Salix fragilis*), and prickly lettuce (*Lactuca seriola*) present but not dominant.

Planting/Seeding

Cattails were planted at the site.

Weeds

Canada thistle is present in plant community 2. A State Noxious Weed, Canada thistle is particularly invasive in areas of recent disturbance, and spreads quickly. It prevents the establishment of, or displaces, native species and has low value as wildlife habitat.

Wildlife

The Calhan wetland provides habitat for muskrat, deer, pronghorn, songbirds, waterfowl, and mudpuppies. Teal, red winged black birds, and killdeer were observed during the site visit. This wetland has fairly high structural diversity, because it contains areas of open water, two plant communities, and areas of open gravel. The diversity is maintained in part because the water surface elevation is not consistent.

No muskrats have invaded the wetland area, although muskrats have been observed in the adjacent receiving pond. A fence is provided to prevent intrusion by antelope and cows from the adjacent ranch.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high. General wildlife habitat and production export/food chain support rated moderate. Habitat diversity and uniqueness of the constructed wetland rated moderate to low. This wetland received 43 percent of the possible functional points. It rated as a category III wetland.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	**0.5 (mod.)**	**1**
General Fish / Aquatic Habitat	**0.0**	**1**
Production Export / Food Chain Support	**0.7 (mod.)**	**1**
Habitat Diversity	**0.2 (low)**	**1**
Uniqueness	**0.2 (low)**	**1**
Total Points	**2.6 (52%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

The wastewater wetland is part of a restricted public access area. The site has been used for educational purposes during field trips by local 4th graders. This wetland has high aesthetic value because it is well maintained and because of its situation on the landscape. The outflow from the wetland flows through a draw, supporting riparian vegetation, then into a stock pond, both the draw and the stock pond provide valuable habitat.

Maintenance Issues

The site will be harvested for the first time this year. The primary maintenance issue noted is the weed control.

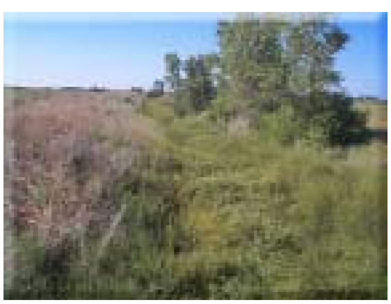
Overall Site Comments

This wetland is functioning well, and provides a mosaic of vegetation types, open water, and bare areas. The draw and stockpond into which water from this wetland flows add greatly to the biological and aesthetic value of this treatment wetland. Even though this system does not operate as designed, it does consistently meet its permit requirements.

Aerators on lagoon

Influent pipe to wetland

Wetland cell along barrier



Receiving stream

Crowley Facility Statistics	
Nearest Town:	Crowley
County:	Crowley
River Basin:	Lower Arkansas
Receiving Water Body:	Crowley Drain Canal
Year Online:	1996
Population:	1200
Elevation (feet):	4354
Design Flow (mgd):	0.170
Average Flow (mgd):	0.126
Size (acres):	3.04

Facility Description

The Town of Crowley wastewater facility is a minor municipal lagoon system. 85 percent of the wastewater flow is attributed to the nearby prison and 15 percent is attributed to the Town of Crowley. The facility consists of three aerated lagoons, a polishing pond, two constructed wetland cells, and a chlorine contact chamber. The influent flow is measured by two ultrasonic meters with a totalizer. The effluent flow is measured by a 45° v-notch weir. This facility services a nearby correctional facility.

Lagoons

The Crowley lagoons are configured as follows:

Lagoon Information				
Cell No.:	**1**	**2**	**3**	**4**
Surface Area (sq. ft.)	**43,950**	**38,050**	**20,580**	**23,270**
Avg. Depth (ft)	**5.5**	**5.5**	**5.3**	**5.1**
Avg. Volume (Million gallons)	**1.57**	**1.313**	**0.658**	**0.723**
Detention time (days)	**9.2**	**7.7**	**3.9**	**4.3**
Aerator size (hp)	**36**	**10**	**5**	**NA**

Background Information

This surface flow wetland system was constructed in 1994. The incorporation of the constructed wetland treatment component was undertaken to polish lagoon systems effluent to remove particulate matter, primarily algae, and the organic load associated with the discharge of this particulate matter.

Energy Analysis

The aerators on the lagoons consume the majority of the energy at this site. The site has a total of 6 – 5hp aerators and 8 – 3hp aerators.

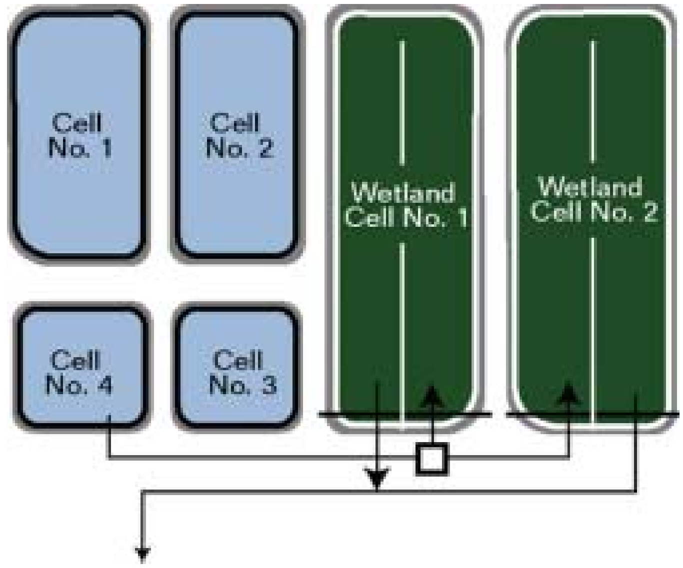
Wetland Design

Design Methods

A review of literature indicates that the two most significant design parameters with regard to TSS control are hydraulic residence time and aspect ratio. The design of the wetland was based on a hrt of 6 days under summer operating conditions and a minimum aspect ratio of 10:1. BOD removal predicted by first order, plug flow, reaction kinetics model developed by Reed, Middlebrooks and Crites. A hydraulic loading rate of 1.228 gpd/ft2 was selected. A common range for secondary and tertiary treatment is 15 to 25 acres / mgd. The wetland area provided is 3.042 acres, or a winter loading of 18.8 acres/mgd and a summer loading of 20.2 acres /mgd.

Objectives

The wetland component was designed to remove BOD from the lagoon effluent as a result of algal carryover.



Size

The cells have a total surface area of 132,500 square feet.

Shape

The wetland cells are rectangular, with a serpentine flow pattern.

Hydraulics

Perforated irrigation pipe is used to introduce the wastewater into the wetland system. The flow path through the cells is serpentine in order to provide the maximum hydraulic residence time in the system and to minimize short-circuiting. The barrier walls between the wetland cells are constructed of timber. This material poses a problem during burn-off of the wetland cells.

Construction, Maintenance and Operational Cost

The approximate construction costs for this system were $350,000.

Treatment Goals

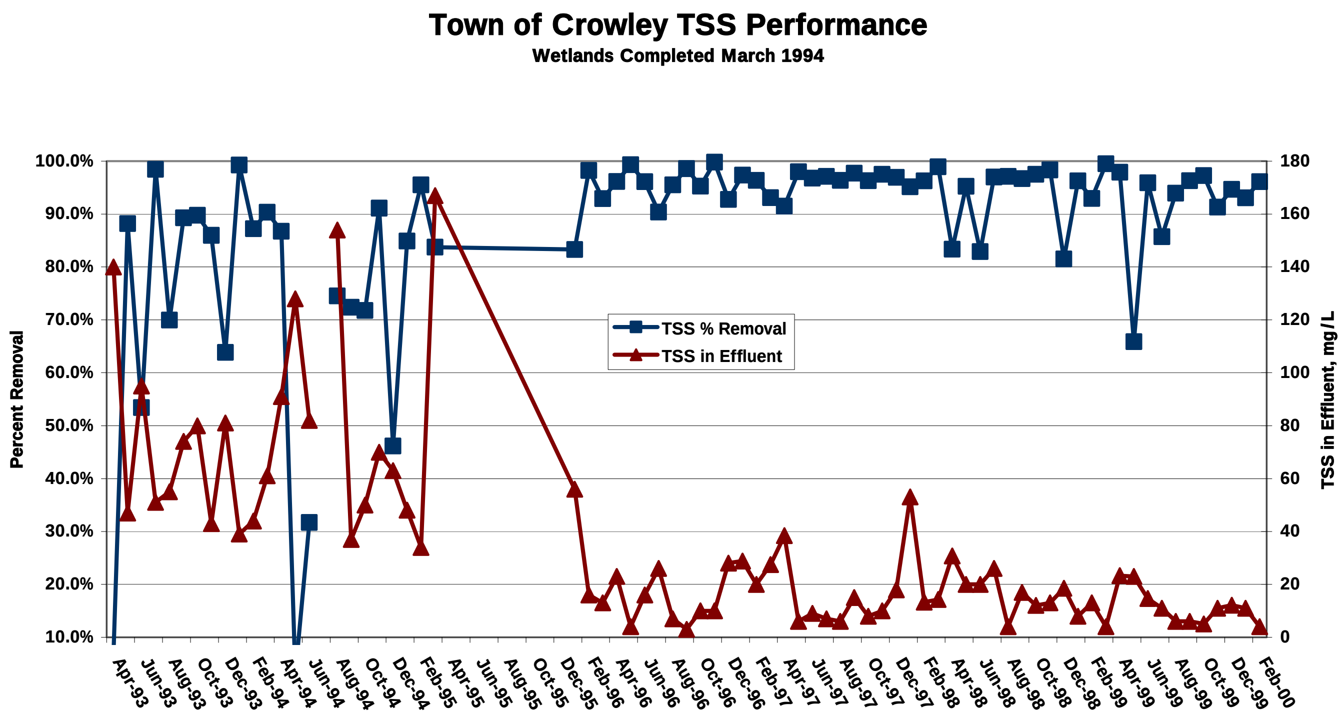
Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**2,000 organisms per 100 ml (Daily Max)**

Water Quality Data

Water quality data was obtained from CDPHE permit files

TSS Data

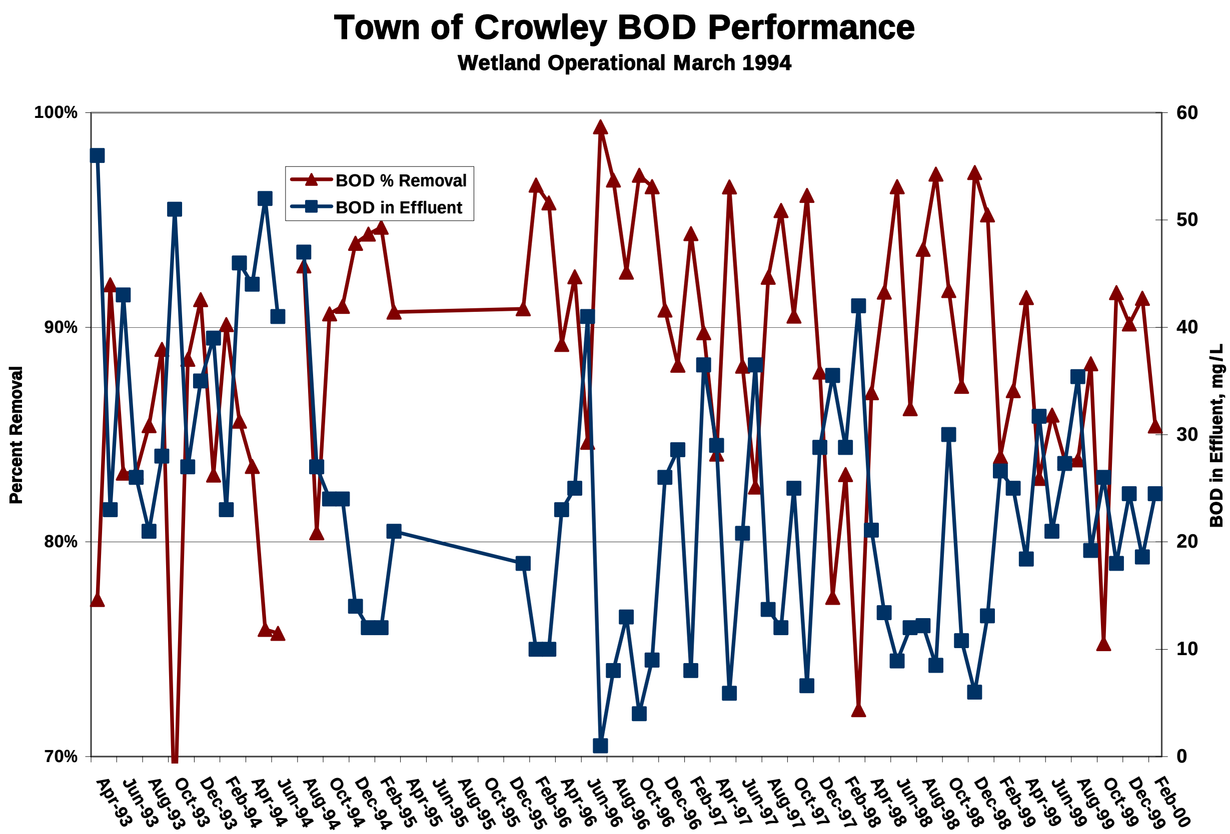
The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. Trends in the TSS data indicate that TSS in the effluent has consistently been below permit limitations.



The average daily TSS in the influent, since the wetlands have been operating, has been 489 mg/l. The average TSS in the effluent is recorded to be 29 mg/l. This removal clearly meets the discharge requirements of 75 mg/l.

BOD Data

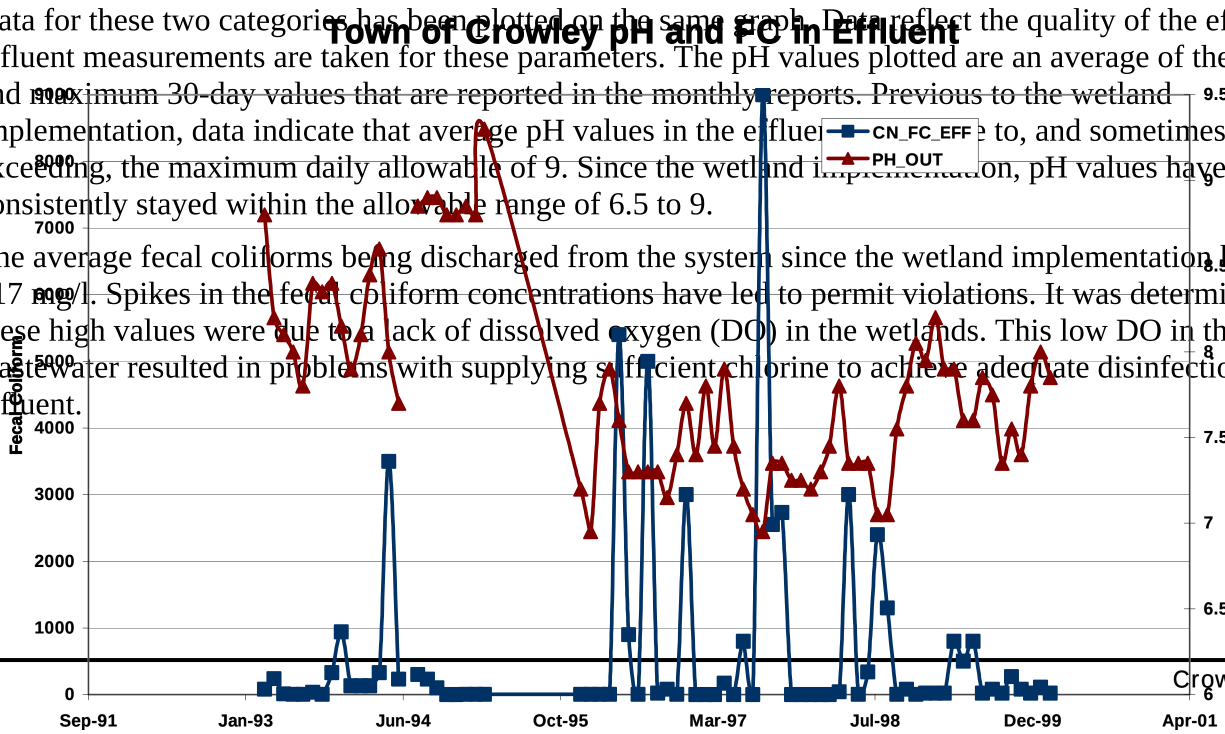
The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. Average monthly influent BOD has been 220 mg/l, the average monthly effluent from the system has been 22 mg/l. This clearly meets discharge requirements of 30 mg/l.



pH and Fecal Coliform

Data for these two categories has been plotted on the same graph. Data reflect the quality of the effluent, no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Previous to the wetland implementation, data indicate that average pH values in the effluent were close to, and sometimes exceeding, the maximum daily allowable of 9. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.

The average fecal coliforms being discharged from the system since the wetland implementation have been 717 mg/l. Spikes in the fecal coliform concentrations have led to permit violations. It was determined that these high values were due to a lack of dissolved oxygen (DO) in the wetlands. This low DO in the wastewater resulted in problems with supplying sufficient chlorine to achieve adequate disinfection of the effluent.



General Ecological Setting

The Crowley treatment wetland is located along a ditch that empties into the Arkansas River. The cells are flat, rectangular, and are 99 percent vegetated and 1 percent open water. This wetland is located in an agricultural area southeast of the Town of Crowley.

Cell Vegetation

The Crowley site consists of two identical cells, which total 0.46 acres. The two cells support identical plant communities dominated by cattail (98 percent—*Typha latifolia*) and duckweed (3 percent—*Lemna minor*). The soil surface is inundated from 0 to 1 foot.

Planting/Seeding

Cattails were transplanted from a nearby ditch.

Weeds

No noxious weeds were found on the project site.

Wildlife

The Crowley constructed wetland provides habitat for muskrat, songbirds, and waterfowl. Several bird species, including swallows, killdeer, curlew, mallard, red wing blackbird, and avocet, were observed during the site visit. The vegetation in this wetland is not structurally diverse, and probably is of limited value to wildlife. Red winged black birds probably nest in the wetland, but the wetland does not provide unique, diverse habitat for wildlife.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high. General wildlife habitat and production export/food chain support rated moderate. Habitat diversity and uniqueness of the constructed wetland rated moderate to low. This wetland received 42 percent of the total possible functional points and was rated functionally as a category III wetland.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.4 (mod.)	1
General Fish / Aquatic Habitat	0.0	1
Production Export / Food Chain Support	0.7 (mod.)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.5 (50%)	5

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has moderate aesthetic value. It is dominated by a uniform stand of cattail.

Maintenance Issues

The walls dividing cells in this wetland are wood. When cell vegetation is periodically burned, the wood walls catch on fire, which must be suppressed. If concrete walls were constructed to divide the wetland cells, this concern would be remedied.

This site was noted to have a sulfuric odor. This is due to a high influent wastewater sulfate content, apparently due to the quality of the domestic water supply. In the presence of low dissolved oxygen conditions (such as those noted in the wetlands), sulfur reducing bacteria convert sulfate to sulfide, which results in hydrogen sulfide. In addition to an odor problem, the presence of hydrogen sulfide can exert a chlorine demand that may cause problems with providing sufficient disinfection.

Pipes in the wetland require frequent ‘roto-rooting’ to clear-out an unidentified fibrous plant growth.

Overall Site Comments

This site functions quite effectively in its intended wastewater treatment function, and has healthy vegetation cover. No major maintenance issues were noted.

Lagoon

Mechanical fine screen (ROTOMAT) headworks facility

Wetland cell

Effluent from wetland cells

Crowley County Correctional Facility Statistics	
Nearest Town:	Olney Springs
County:	Crowley
River Basin:	Lower Arkansas
Receiving Water Body:	Arkansas River
Year Online:	1998
Population:	600 inmates
Elevation (feet):	4354
Design Flow (mgd):	0.150
Average Flow (mgd):	0.110
Size (acres):	3.3

Facility Description

This facility is a minor municipal lagoon system. The facility consists of a mechanical fine screen (ROTOMAT) headworks facility, two aerated lagoons, a polishing pond, two constructed wetlands, and a chlorine contact chamber. The influent flow is measured by a continuous recorder and totalizer. The effluent flow is measured by a continuous recorder and totalizer.

Lagoons

The Crowley Correctional Facility lagoon system consists of 2 aerated cells, and one polishing pond. Some of the lagoon system features are detailed in the table below.

Lagoon Information			
Cell No.:	**1**	**2**	**3**
Surface Area (sq. ft.)	**36,875**	**36,875**	**10,625**
Avg. Depth (ft)	**10**	**10**	**10**
Avg. Volume (Million gallons)	**1.9**	**1.9**	**0.4**
Detention time (days)	**12.6**	**12.6**	**2.7**
Aerator size (hp)	**60**	**15**	**NA**

Background Information

The wetland system is an original component of this wastewater treatment facility. It was modeled after the successful lagoon-wetland system used at the nearby Town of Crowley.

Energy Analysis

Utility bills for this system run approximately $1000 per month. Energy at this site is used primarily on the lagoon aerators and the rotomat.

Wetland Design

Design Methods

This system was modeled after the Town of Crowley wetland system. Sizing requirements were determined by using CDPHE standards of 10-50 acres per mgd of influent. The surface loading for this system is 22 acres / mgd

Objectives

The wetlands are intended to polish the lagoon effluent. The removal of TSS is the primary design goal.

Size

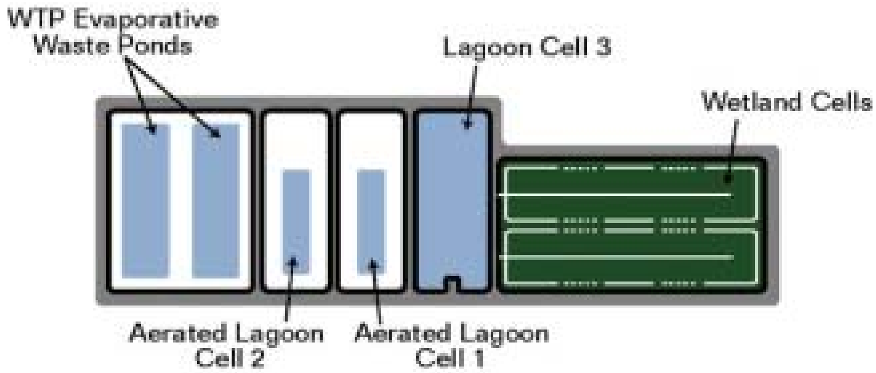
The wetland system is comprised of four surface flow cells. Each wetland cell is 600'long by 60' wide.

Shape

The rectangular wetland cells have aspect ratios of 10:1. The flow path is serpentine to minimize short-circuiting and maximize the aspect ratio.

Hydraulics

This system is a surface flow wetland. Water in wetlands is running at a depth of about 3”. The flow follows a serpentine pattern. The hydraulic residence time in the system is 7.2 days, with a volume of 1.08 million gallons. A buried 30 mil PVC liner eliminates groundwater influences.



Treatment Goals

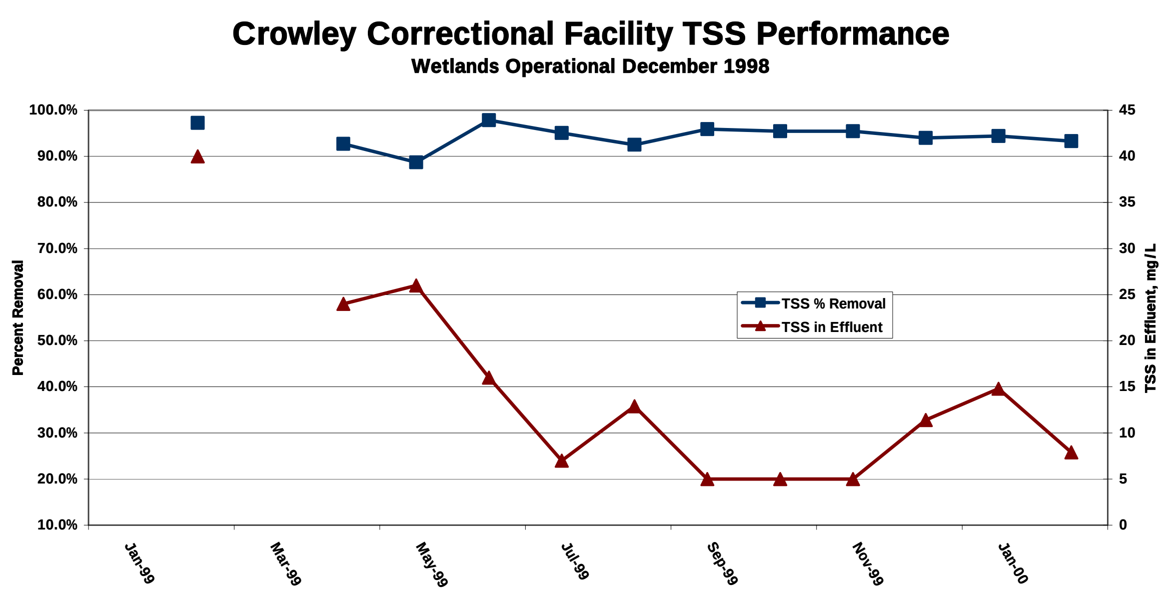
Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.0 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

The Discharge Monitoring Report (DMR) forms documented numerous exceedances of the hydraulic and organic capacities. In part, this was a result of the mass loading not being calculated correctly. Reported TSS influent values are higher than what is normally seen at this type of facility. This may be due to sampling procedures.

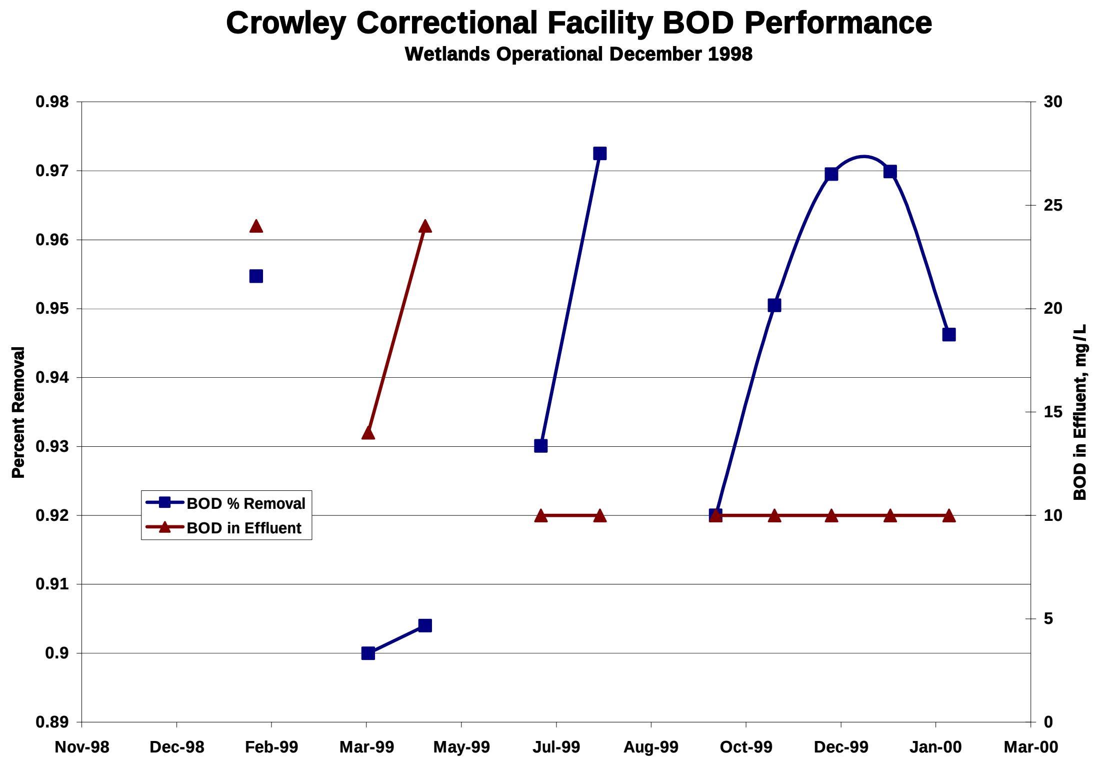
TSS Data

Some general observations can be made by reviewing the plotted 30-day average TSS data. The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. In the months before the wetland was implemented, there was no discharge from the treatment facility. Since no discharge was occurring, data for this period were not reported. Trends in the TSS data indicate that TSS in the effluent has consistently been below permit limitations. Average influent TSS is 333 mg/l and average effluent is 15 mg/l.



BOD Data

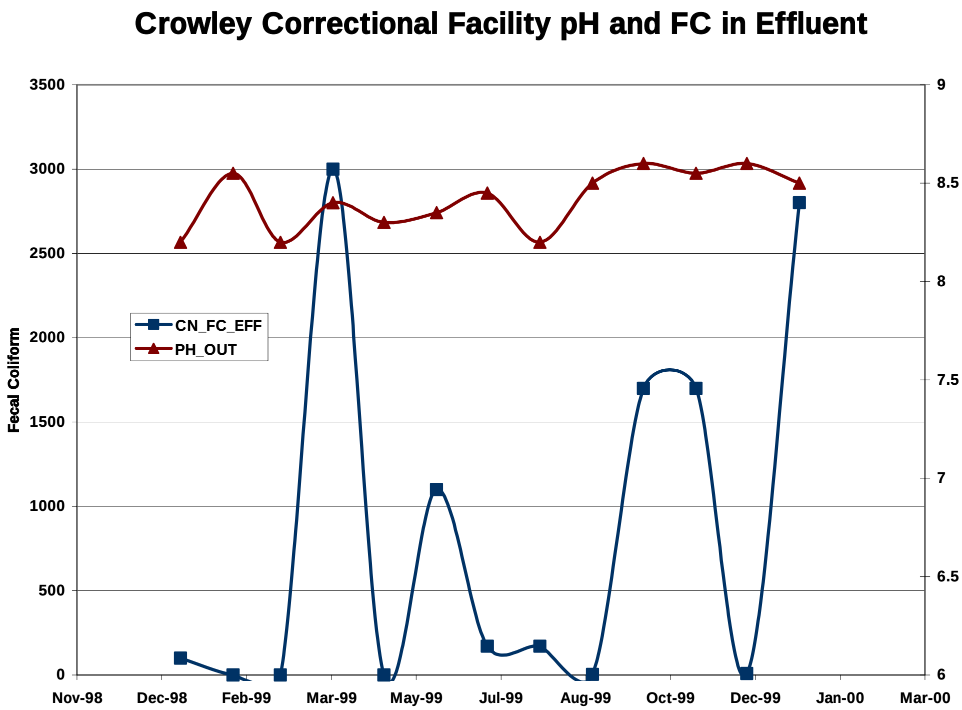
The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly BOD in the influent is 278 mg/l and the average monthly effluent is 13 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. The average monthly pH value is 8.42 , consistently stayed within the allowable range of 6.5 to 9.

The average monthly fecal coliforms in the effluent are 1075. This meets the discharge permit requirements.



General Ecological Setting

The Crowley County Correctional Facility constructed wetlands consist of two flat, rectangular basins, approximately 2.75 acres each, which discharge into the Arkansas River. The wetlands are approximately 96 percent vegetated and 4 percent water. This wetland is located on the prison grounds in a former agricultural field. The site is located a considerable distance from any creek or other wetland.

Cell Vegetation

The two wetland cells support identical wetland vegetation. Cattail (*Typha latifolia* and *Typha angustifolia*) dominate, and reed canarygrass (*Phalaris arundinacea*), duckweed (*Lemna minor*), and creeping spikerush (*Eleocharis palustris*) compose the remaining 10 percent of the wetland vegetation.

Planting/Seeding

Small cattail plugs were planted in the wetland cells on approximate 3 to 4 foot spacing in the spring of 1998.

Weeds

No noxious weeds were found on the project site.

Wildlife

The wetlands provide habitat for a variety of song and shore birds. Killdeer and swallow were observed during the site visit, and red winged blackbirds potentially use the site. The site contains some vegetative structural diversity, which is mainly a result of small pockets of shallow water among cattail stands. This habitat is unique on the landscape because there are no other wetlands or ponds in the vicinity. The treatment wetlands provide habitat for waterfowl, songbirds, and probably muskrats.

Wetland Biodiversity Functional Assessment

General wildlife habitat and uniqueness rated moderate for this wetland. Sediment/toxicant/nutrient removal was rated high. All other functions of the wetland rated low. The wetland received 33 percent of the possible functional points, and falls into Category IV, the lowest functional category.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.4 (mod.)	1
General Fish/Aquatic Habitat	0.0	1
Production Export/Food Chain Support	0.3 (low)	1
Habitat Diversity	0.1 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.0 (40%)	5
Wetland Category (I, II, III, or IV)	IV	

Human Use

The wastewater wetland is part of a restricted public access area, but it is used as part of a program to train inmates in the operations of wastewater facilities. Opportunities such as this could prove to be quite valuable to the prison system and to inmates following their release.

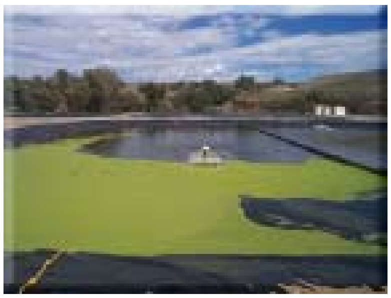
Maintenance Issues

The only maintenance issue noted is the need to thoroughly remove non-organic waste from the prison wastewater before it enters the lagoon and wetland system. The wetland system is burned every winter.

Overall Site Comments

This wetland is functioning as intended in the treatment of wastewater. It also supports a healthy stand of vegetation.

Overview of Wastewater Treatment Facility



Aerated Lagoon

Influent to wetland cells

Delta Correctional Facility Statistics	
Nearest Town:	Delta
County:	Delta
River Basin:	Lower Gunnison
Receiving Water Body:	Roubideau Creek
Year Constructed:	1997
Population:	492 inmates, 100 staff
Elevation (feet):	4977
Design Flow (mgd):	0.067
Average Flow (mgd):	0.038
Size (acres):	1.38

Facility Description

The Delta Correctional Center is a minor municipal lagoon system. The facility consists of two aerated lagoons, a polishing pond, a surface flow constructed wetland, and a chlorine contact chamber. The influent is measured by calibrated run time meters on the influent pumps. The effluent flow is measured by a 45° v-notch weir.

Lagoons

The Delta lagoon systems consist of 3 aerated cells operated in series. The aerators are operated 24 hours a day, 7 days a week. Effluent from pond three can be taken from two different elevations. The lagoon system is detailed in the table below.

Lagoon Information			
Cell No.:	**1**	**2**	**3**
Surface Area (sq. ft.)	**13,470**	**14,640**	**9,753**
Avg. Depth (ft)	**9.51**	**9.55**	**9.29**
Avg. Volume (Million gallons)	**0.597**	**0.653**	**0.392**
Detention time (days)	**8.8**	**9.7**	**5.8**
Aerator size (hp)	**16**	**6**	**2**

Background Information

The existing lagoon system was not able to meet discharge permit requirements for TSS and BOD removal. Addition of a wetland system for polishing of the lagoon effluent was attractive for several reasons.

- Wetlands do not require a highly trained operator
- Climate at this site is favorable for a wetland system
- A baseball field adjacent to the lagoons provided adequate space to install a wetland.

Energy Analysis

The treatment facility uses a lift station with a 5hp motor to provide the head requirements needed for flow through the system. The lagoons utilize aerators and mixers. A total of 4 Tornado mixers and 4 Aeromix systems are used in the lagoons.

Wetland Design

Design Methods

Technical literature was utilized to determine key design parameters for reducing TSS. The hydraulic residence time and the aspect ratio were determined to be the most critical design issues. The wetland was designed to provide a minimum hydraulic residence time of 5 days and an average aspect ratio greater than 10 to 1.

Objectives

The treatment wetland was designed primarily to address TSS permit compliance issues.

Size

The wetland system consists of one treatment cell with an area of 60,000 ft2. The wetland cell has a substrate thickness of 12 inches and an operating water depth of 24 inches.

Shape

The wetland cell is rectangular with an aspect ratio of 10 to 1. The flow path is serpentine in order to maximize the aspect ratio and minimize short-circuiting.

Hydraulics

The inlet to the wetland cell is an 8" aluminum gated pipe. An HDPE liner eliminates groundwater influences. Adjustable irrigation pipes are used to adjust the water level in the pond. The water flows by gravity through the wetland system.

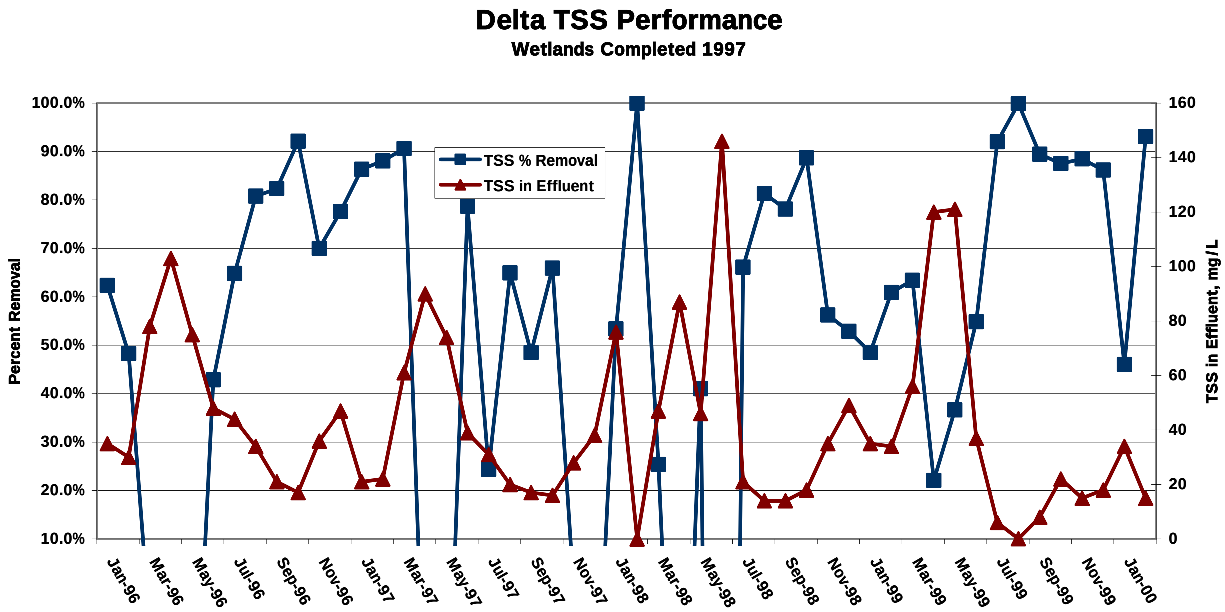
Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.0 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

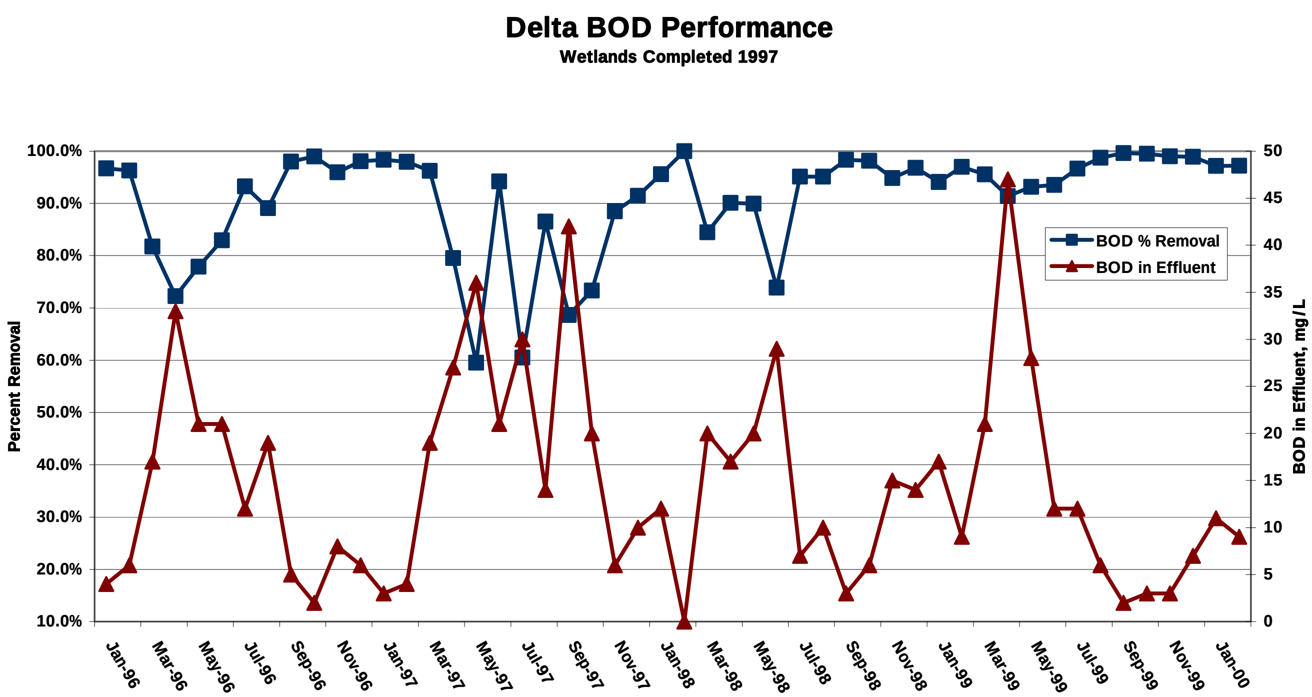
TSS Data

The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, since the wetland implementation, has been 94 mg/l and the average monthly effluent has been 39 mg/l. This meets the permit discharge requirement of 75 mg/l.



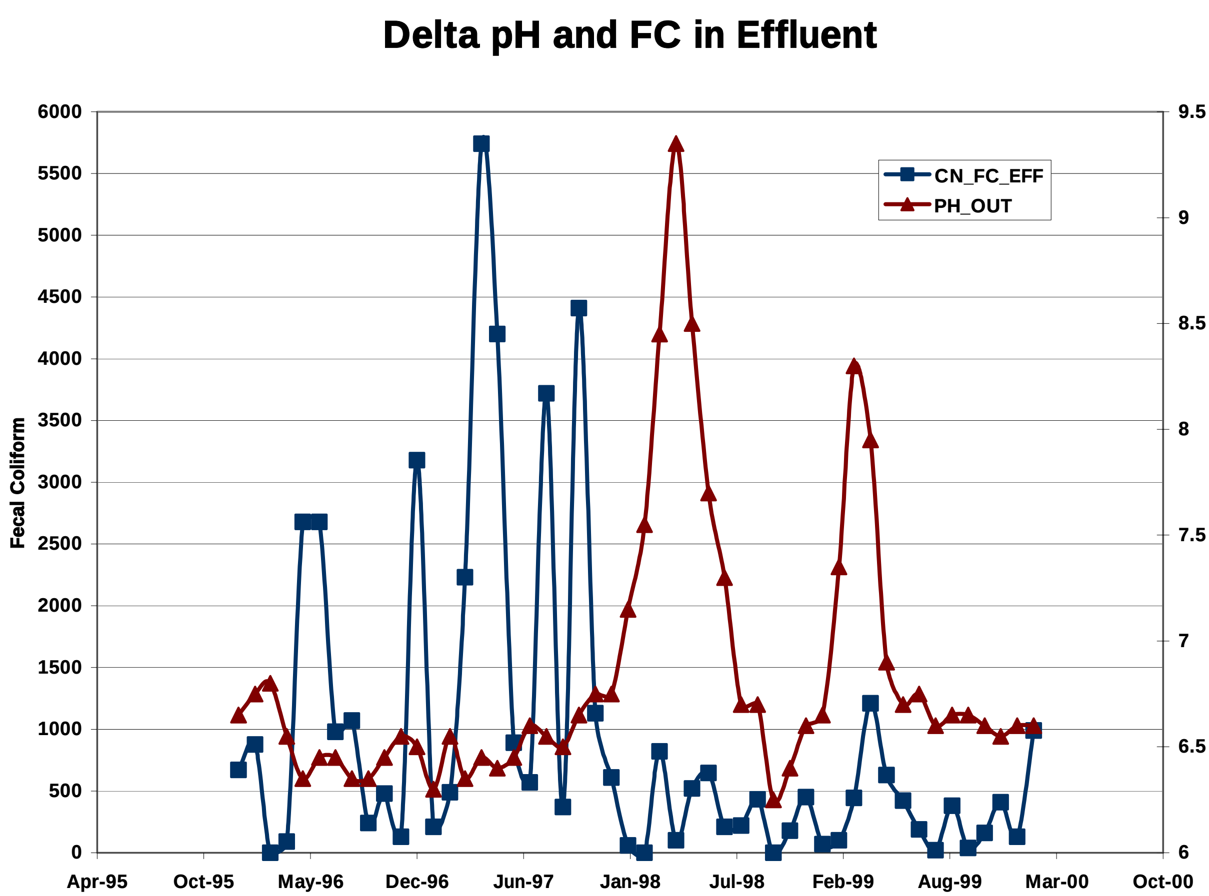
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly influent amount has been 277 mg/l and the average monthly effluent amount has been 15 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.



General Ecological Setting

Rocky outcrops surrounding the area are generally woodlands dominated by species of juniper that often occur with sagebrush. Other areas of the landscape are dominated by saltbush. These are usually relatively pure saltbush stands, often sparsely vegetated with bare soil constituting most of the land surface.

Cell Vegetation

Vegetation cover in the single cell is 95 percent cattail (*Typha latifolia*) and 5 percent Baltic rush (*Juncus balticus*). Foxtail barley (*Hordeum jubatum*) and tamrisk (*Tamarix chinensis*) were also observed during the site visit.

Planting/Seeding

In December 1997, 20,000 cattails were planted. In Spring 1999 the wetland was replanted by breaking the seed heads of cattails.

Weeds

A few single stems of tamarisk, a noxious weed, were noted during the site visit. Tamarisk consumes large quantities of water, possibly more than woody native plant species that occupy similar habitats.

Maintenance Issues

Removal of tamarisk and follow-up monitoring should prevent establishment of the species.

Wildlife

The wetland provides habitat for songbirds and small mammals. The general wildlife habitat and diversity are relatively low. Total functional points were 1.3.

Wetland Biodiversity Functional Assessment

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	**0.5 (mod.)**	**1**
General Fish / Aquatic Habitat	**0.0**	**1**
Production Export / Food Chain Support	**0.4 (mod.)**	**1**
Habitat Diversity	**0.2 (low)**	**1**
Uniqueness	**0.2 (low)**	**1**
Total Points	**1.3 (26%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

The constructed wetland is part of the larger treatment facility used as an overall training environment for operators. This wetland serves and important educational purpose because it is used to train inmates in the management of wastewater treatment facilities. This wetland has moderate aesthetic value.

Overall Site Comments

The Delta correctional Facility treatment wetland operates as intended. This facility supports healthy plants and consistently meets discharge permit requirements.


Water level control


Buried inlet pipe with stub-outs for maintenance


Cattails establishing themselves


View of parallel wetland cells

Dove Creek Facility Statistics	
Nearest Town:	**Dove Creek**
County:	**Dolores**
River Basin:	**La Plata River**
Receiving Water Body:	**Dove Creek**
Year Online	**1999**
Population:	**743**
Elevation (feet):	**6844**
Design Flow (mgd):	**0.115**
Average Flow (mgd):	**0.035**
Size (acres):	**1**

Facility Description

The Dove Creek Wastewater Treatment Facility is a minor municipal lagoon system. This facility consists of two aerated lagoons, one settling pond, followed by a surface flow constructed wetland. Disinfection consists of a gas chlorination system followed by a tablet-style dechlorination unit.

Lagoons

The Dove Creek lagoon system consists of 2 aerated cells, followed by a settling pond. The shallow lagoon system was retrofit with a methane fermentation pit covered by a 45-mil polypropylene liner, in cell 1. Lagoon system features are outlined in the table below.

Lagoon Information				
Cell No.:	**Fermentation Pit**	**1**	**2**	**3**
Surface Area (sq. ft.)	**5,878**	**47,000**	**40,000**	**4,500**
Avg. Depth (ft)	**18**	**8**	**8**	**11**
Avg. Volume (Million gallons)	**0.747**	**1.83**	**2.06**	**0.15**
Detention time (days)	**13**	**30**	**34**	**2.2**
Aerator size (hp)	**36**	**10**	**5**	**NA**

Background Information

The Dove Creek system experienced numerous violations for BOD and TSS removal since plant start-up . In October of 1995 the town received a Notice of Violation and Cease and Desist Order, and continued to operate under this notice with significant noncompliance for several years. A study was completed in December 1997 in order to determine remedial alternatives for improved wastewater treatment. The study looked at each option for treatment and cost factors. Options considered included intermittent sand filters, land application of wastewater, utilizing a managed duckweed pond, providing a “pretreatment” anaerobic stabilization zone, increase depths of existing lagoons, and installing constructed wetlands. Dove Creek looked at the Town of Ouray wetlands. Also mentioned is the pilot scale study at Las Animas between 1991 and 1993 to evaluate the effectiveness of constructed wetlands for algae removal.

Energy Analysis

The majority of the energy consumption at this facility is in the operation of the aerators. A typical energy bill per moth is $1,600.

Construction Cost

The approximate construction costs for this system were $363,000.

Wetland Design

Size

The wetland system consists of 4 surface-flow cells and 1 sub-surface flow cell covering approximately 1 acre of ground.

Shape

As shown in the schematic, the wetland cells are generally rectangular, with some curves added in order to fit the site location.

Hydraulics

Design features include: 45-mil polypropylene liners on all cells; distribution boxes to allow bypass of any one cell for maintenance; infinitely-adjustable flow control devices for each wetland cell; recirculation pump and lines that will allow recirculation to the wetlands headworks and/or to the treatment plant headworks.

Treatment Goals

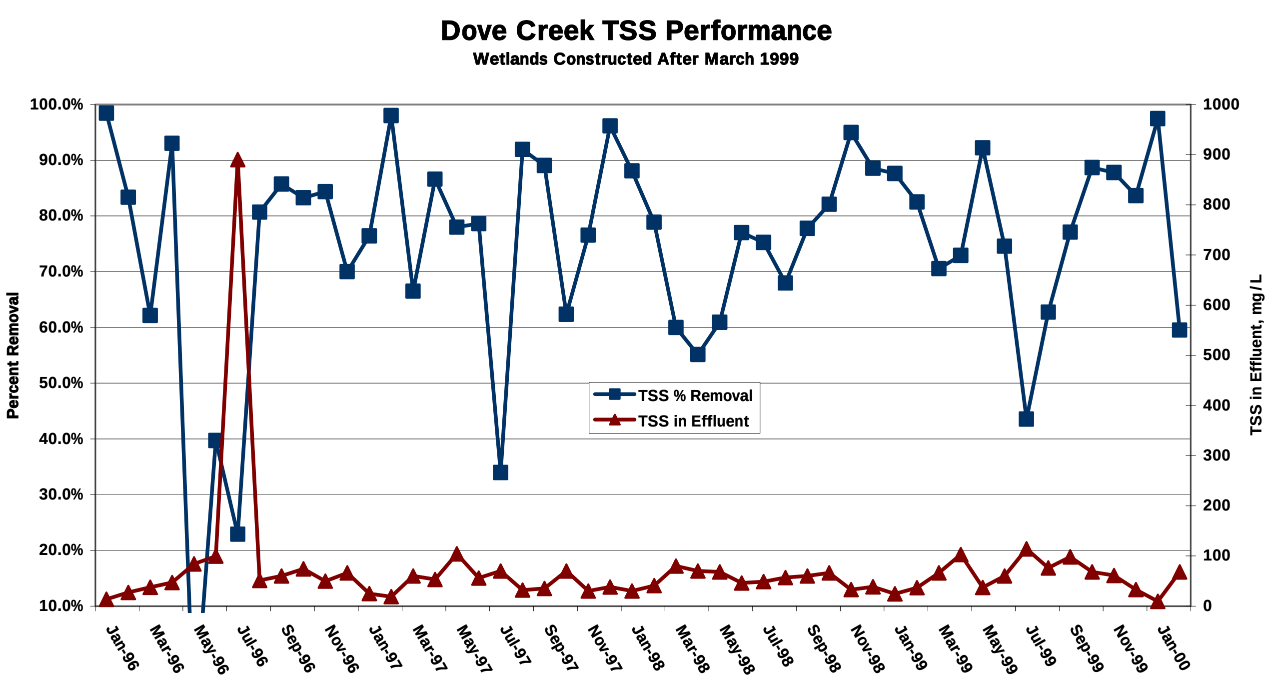
Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**2,000 organisms per 100 ml (Daily Max)**

Water Quality Data

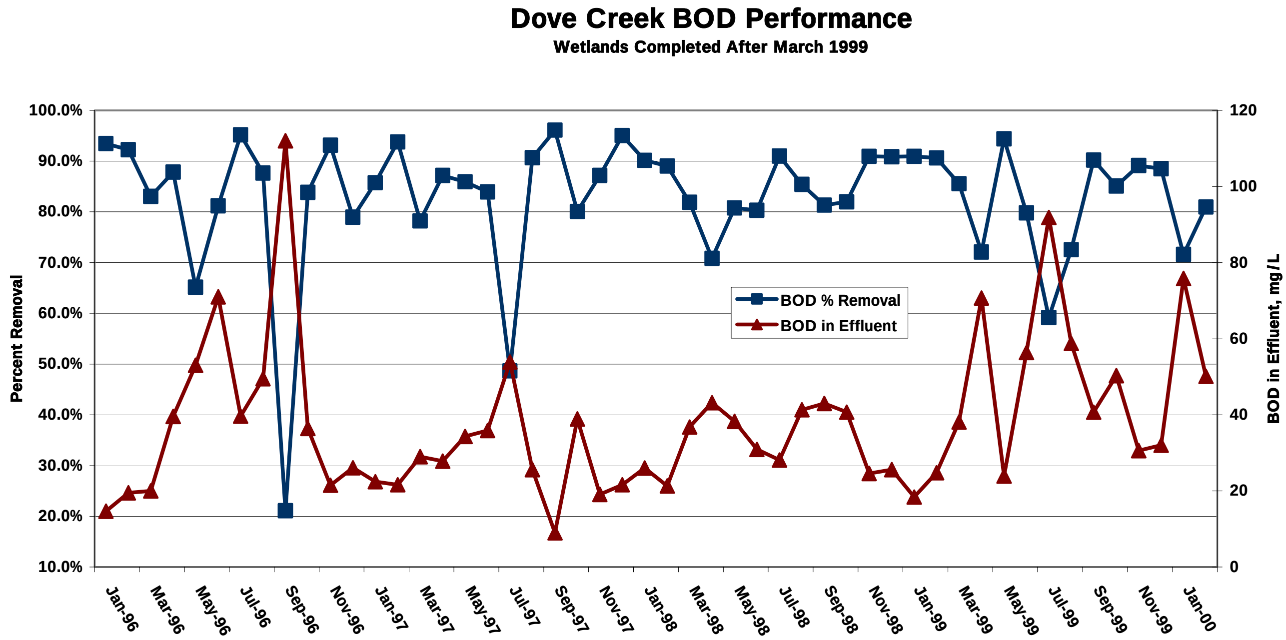
TSS Data

Some general observations can be made by reviewing the plotted 30-day average TSS data. The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, since the wetland implementation, has been 342 mg/l and the average monthly effluent has been 66 mg/l. This meets the permit discharge requirement of 105 mg/l.

BOD Data

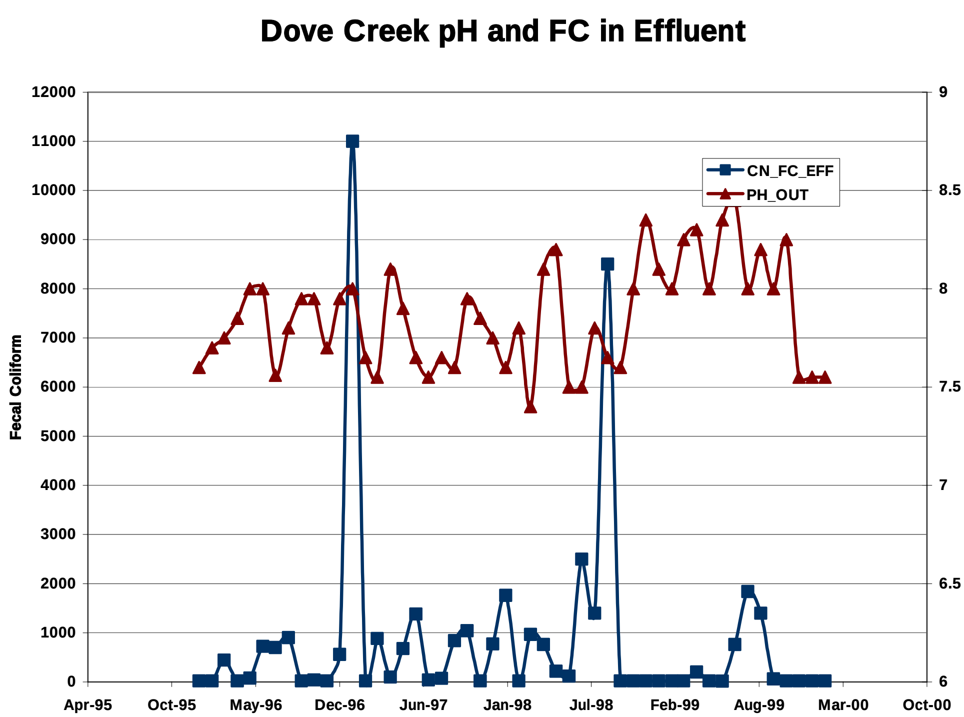


The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly influent amount has been 294 mg/l and the average monthly effluent amount has been 52 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the



minimum and maximum 30-day values that are reported in the monthly reports. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.

General Ecological Setting

A mixture of piñon pine and juniper dominate forested areas surrounding the Dove Creek wetland. This type of forest rarely forms a closed canopy. The general area is also surrounded by agricultural lands that include non-irrigated cropland, dryland improved pastures, fallow lands, rural development, ranch and farm facilities and shelter belts.

Cell Vegetation

Each of the five cells are about 75 percent vegetation, 15 percent bare soil, and 10 percent open water. The only plant species present is cattail (*Typha latifolia*)

Planting/Seeding

Cells were originally planted in fall 1999 with 9000 cattails from Minnesota at a cost of $0.33 per plant. In summer 2000, 2700 cattails were replanted. Topsoil from the site was used for the plantings.

Weeds

No noxious weeds were noted during the site visit.

Wildlife

Areas adjacent to the wetland were highly disturbed during construction and vegetation has yet to reestablish. The wetland itself has low structural diversity and the cattails are not fully established. Maturation of the vegetation along with the attribute of open water may provide future wildlife habitat of higher value. At present, the general habitat and habitat diversity are low to moderate. Total functional points were 52% of the total possible, and this wetland rated as a category III wetland.

Wetland Biodiversity Functional Assessment

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	**0.5 (mod.)**	**1**
General Fish / Aquatic Habitat	**0.0**	**1**
Production Export / Food Chain Support	**0.7 (mod.)**	**1**
Habitat Diversity	**0.2 (low)**	**1**
Uniqueness	**0.2 (low)**	**1**
Total Points	**2.6 (52%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

This site is in a restricted human use area, and has never been used for educational purposes. This wetland has moderate aesthetic value. It has a healthy vegetation cover.

Maintenance Issues

No maintenance issues were noted during the site visit.

Site Summary

This site has good vegetation cover and is functioning as intended. There are no major maintenance or weed problems at the site.

Team members standing on top of wetland

Close-up of vegetation in the wetland cell

Highlands Presbyterian Camp Facility Statistics	
Nearest Town:	Highland Camp
County:	Boulder
River Basin:	North Saint Vrain
Receiving Water Body:	None (leach field)
Year Online:	1996
Population:	240 (summer)
Elevation (feet):	8300
Design Flow (mgd):	0.0005
Average Flow (mgd):	.0005
Size (acres):	0.014

Facility Description

The Highland Park constructed wetland is a pilot scale system consisting of a septic tank, an upflow anaerobic filter, a vertical flow aerobic filter, a subsurface constructed wetland, and an automatic dosing siphon tank that discharges to a subsurface disposal field.

Background Information

The original treatment system at this site was a septic tank built in 1958. A planned expansion of the Highlands Presbyterian Camp conference center created the need for an updated system. The camp decided to implement a pilot scale subsurface flow constructed wetland system. With the assistance of the Colorado State University and the USEPA Region VIII, a pilot scale system was built in July 1996.

At the time of the site visit, this system was no longer operating as intended. The camp was not satisfied with the wetland performance and was considering an alternative form of wastewater treatment.

Energy Analysis

This system was designed to be a passive treatment method and therefore consumes no energy

Wetland Design

Design Methods

Empirical data was used to size the wetland to accommodate a hydraulic loading of 0.83 gpd/ft2 with an aspect ratio of 3:2, a hydraulic residence time of 7 days and a BOD5 loading rate of 63 lb BOD/acre/day.

Objectives

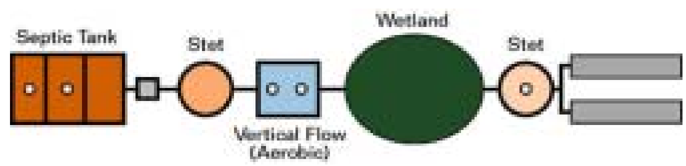
The wetland was designed to provide nitrification, denitrification, and removal of TSS.

Size

The subsurface wetland consists of one cell with a surface area of 600 ft2. The cell is approximately 2.5 ft deep, with a water depth maintained within the range of 1.5 to 2 ft.

Shape

The wetland cell roughly resembled an hourglass shape. Since the wetland site blends in with the surrounding vegetation, it does not have easily defined borders.



Hydraulics

The inlet system consists of two infiltrator units positioned perpendicular to the direction of flow, with perforations to allow for even distribution of flow across the entire cross section of the cell. The outlet mechanism is a 24” wide flat perforated pipe positioned vertically in the wetland cell. The intent is to collect water from the entire wetland cross section. The soil matrix is composed of 2.5 feet of ¾” andesite gravel with a shallow layer of pea gravel on the surface. The water depth was designed to be maintained within the range of 1.5 to 2 ft. A flexible RV type sewer hose that serves as an overflow outlet can adjust the water level in the wetland. The wetland was fully lined with a composite bentonite and geotextile liner to prevent interaction with groundwater.

Water Quality Data

This site operates under a groundwater discharge permit and therefore does not submit monthly discharge monitoring reports. Data have been collected at this site for research purposes. Presented below are data documented in a Master’s Thesis titled “First Year Performance Evaluation of a Cold Climate Constructed Wetland for Wastewater Treatment” submitted by Mary DeMartini Andre to the Colorado State University Civil Engineering Department, Fall 1999.

TOC

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	144	101	30
11/5/1996	108	103	5
11/19/1996	103	78.2	24
12/3/1996	88.1	95.2	-8
1/14/1997	102	86.6	15
1/22/1997	112	87.5	22
1/28/1997	148	94.1	36
2/11/1997	181	130	28
2/18/1997	226	152	33
2/25/1997	199	163	18
3/11/1997	214	236	-10
3/25/1997	179	151	16
4/8/1997	182	120	34
4/22/1997	142	172	-21
5/6/1997	23.2	25	-8
5/20/1997	141	30.4	78
6/3/1997	134	113	16
6/17/1997	138	117	15
7/1/1997	133	112	16
7/15/1997	142	102	28
7/30/1997	167	108	35
8/12/1997	102	78	24
8/26/1997	97.5	72	26
9/9/1997	66.1	91	-38
AVERAGE	*136*	*109*	*0.20*

NH3/NH4

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	58	52.1	10
11/5/1996	61.9	53.6	13
11/19/1996	52.2	52.5	-1
12/3/1996	45.7	56.3	-23
1/14/1997	36.3	53.3	-47
1/22/1997	34.4	46.4	-35
1/28/1997	32.3	48.3	-50
2/11/1997	37.8	43	-14
2/18/1997	38.4	42.2	-10
2/25/1997	37.1	39.8	-7
3/11/1997	46.3	48.4	-5
3/25/1997	33.6	36.7	-9
4/8/1997	30.6	29.8	3
4/22/1997	18.7	29.2	-56
5/6/1997	1.06	4.37	-312
5/20/1997	19.5	5.94	70
6/3/1997	29.4	21.4	27
6/17/1997	47.5	35.4	25
7/1/1997	25.6	28.3	-11
7/15/1997	61.4	40.7	34
7/30/1997	63	42.5	33
8/12/1997	41.4	50.5	-22
8/26/1997	39.6	47.8	-21
9/9/1997	40.9	51	-25
AVERAGE	*39*	*40*	*-0.20*

TSS

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	45	18	60
11/5/1996	22	5	77
11/19/1996	20	7	65
12/3/1996	17	4	76
1/14/1997	31	4	87
1/22/1997	19	4	79
1/28/1997	25	13	48
2/11/1997	84	52	38
2/18/1997	40	34	15
2/25/1997	40	35	13
3/11/1997	5	61	-1120
3/25/1997	36	8	78
4/8/1997	30	23	23
4/22/1997	31	25	19
5/6/1997	6	6	0
5/20/1997	28	8	71
6/3/1997	27	4	85
6/17/1997	49	4	92
7/1/1997	200	11	95
7/15/1997	34	8	77
7/30/1997	32	14	56
8/12/1997	22	11	50
8/26/1997	16	6	63
9/9/1997	8	46	-475
AVERAGE	*36*	*17*	*-0.1*

BOD

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	293	214	27
11/5/1996	179	185	-3
11/19/1996	156	95.4	39
12/3/1996	130	114	12
1/14/1997	189	143	24
1/22/1997	224	133	41
1/28/1997	330	170	48
2/11/1997	411	243	41
2/18/1997	395	282	29
2/25/1997	366	275	25
3/11/1997	400	438	-10
3/25/1997	362	312	14
4/8/1997	316	203	36
4/22/1997	326	410	-26
5/6/1997	25.4	30	-18
5/20/1997	256	27.2	89
6/3/1997	242	204	16
6/17/1997	155	239	-54
7/1/1997	/280	247	12
7/15/1997	260	164	37
7/30/1997	291	170	42
8/12/1997	168	107	36
8/26/1997	172	110	36
9/9/1997	141	187	-33
AVERAGE	*253*	*196*	*0.20*

Highlands Presbyterian Camp

NO2/NO3

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	<0.05	<0.05	0
11/5/1996	<0.05	<0.05	0
11/19/1996	<0.05	<0.05	0
12/3/1996	<0.05	<0.05	0
1/14/1997	<0.05	<0.05	0
1/22/1997	<0.05	<0.05	0
1/28/1997	<0.05	<0.05	0
2/11/1997	<0.05	<0.05	0
2/18/1997	<0.05	<0.05	0
2/25/1997	<0.05	<0.05	0
3/11/1997	<0.05	<0.05	0
3/25/1997	<0.05	<0.05	0
4/8/1997	<0.05	<0.05	0
4/22/1997	<0.05	<0.05	0
5/6/1997	0.15	<0.05	0
5/20/1997	<0.05	<0.05	0
6/3/1997	<0.05	<0.05	0
6/17/1997	<0.05	<0.05	0
7/1/1997	0.14	<0.05	0
7/15/1997	0.33	<0.05	0
7/30/1997	<0.05	<0.05	0
8/12/1997	<0.05	<0.05	0
8/26/1997	<0.05	<0.05	0
9/9/1997	<0.05	<0.05	0
AVERAGE	*<0.05*	*<0.05*	*0*

NO2/NO3

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	<0.05	<0.05	0
11/5/1996	<0.05	<0.05	0
11/19/1996	<0.05	<0.05	0
12/3/1996	<0.05	<0.05	0
1/14/1997	<0.05	<0.05	0
1/22/1997	<0.05	<0.05	0
1/28/1997	<0.05	<0.05	0
2/11/1997	<0.05	<0.05	0
2/18/1997	<0.05	<0.05	0
2/25/1997	<0.05	<0.05	0
3/11/1997	<0.05	<0.05	0
3/25/1997	<0.05	<0.05	0
4/8/1997	<0.05	<0.05	0
4/22/1997	<0.05	<0.05	0
5/6/1997	0.15	<0.05	0
5/20/1997	<0.05	<0.05	0
6/3/1997	<0.05	<0.05	0
6/17/1997	<0.05	<0.05	0
7/1/1997	0.14	<0.05	0
7/15/1997	0.33	<0.05	0
7/30/1997	<0.05	<0.05	0
8/12/1997	<0.05	<0.05	0
8/26/1997	<0.05	<0.05	0
9/9/1997	<0.05	<0.05	0
AVERAGE	*<0.05*	*<0.05*	*0*

TP

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	8.01	8.31	-4
11/5/1996	7.17	7.61	-6
11/19/1996	5.23	6.24	-19
12/3/1996	2.94	5.92	-101
1/14/1997	3.13	4.33	-38
1/22/1997	3.21	3.18	1
1/28/1997	4.35	2.98	31
2/11/1997	4.48	3.15	30
2/18/1997	5.23	3.77	28
2/25/1997	4.8	3.79	21
3/11/1997	6.71	6.85	-2
3/25/1997	6.07	5.44	10
4/8/1997	6.09	4.81	21
4/22/1997	3.23	3.56	-10
5/6/1997	0.26	0.47	-81
5/20/1997	3.78	0.5	87
6/3/1997	5.73	4.28	25
6/17/1997	6.48	5.87	9
7/1/1997	5.31	4.62	13
7/15/1997	5.52	5.36	3
7/30/1997	7.18	6.2	14
8/12/1997	5.54	5.35	3
8/26/1997	5.22	4.11	21
9/9/1997	5.06	6.15	-22
AVERAGE	*5*	*5*	*0*

Fecal Coliform

Date	Wetland inlet	Wetland Outlet	% Removal
10/22/1996	680,000	180,000	74
11/5/1996			
11/19/1996	11,000	1700	85
12/3/1996	70,000	350	100
1/14/1997	6700	3600	46
1/22/1997			
1/28/1997	420,000	5500	99
2/11/1997	112,000	81,000	28
2/18/1997	66,000	260,000	-294
2/25/1997			
3/11/1997			
3/25/1997	43,200	13,500	69
4/8/1997	93,500	24,000	74
4/22/1997			
5/6/1997	11,000	1500	86
5/20/1997			
6/3/1997	10,000	280,000	-2700
6/17/1997	180,000	2000	99
7/1/1997	5000	140	97
7/15/1997	1,100,000	40,000	96
7/30/1997	500,000	100,000	80
8/12/1997	50,000	10,000	80
8/26/1997	220,000	10,000	95
9/9/1997	440,000	8000	98
AVERAGE	*223,244*	*5*	*-0.9*

General Ecological Setting

The ponderosa pine ecosystem is the dominant forest of the foothills region near Highland Camp, where it inhabits the warm, dry areas of the lower portion of the mountains (5600 to 9000 feet elevation). Stands of ponderosa pine gradually thin as elevation increases, while the frequency of Douglas fir increases in the montane region. Ponderosa pine continues to populate the south-facing slopes of the montane zone forming mixed stands with Douglas fir relative to slope exposure.

Cell Vegetation

Vegetation consists of one plant community. About 80 percent of the cover consists of reed canary grass (Phalaris arundinacea). Sub-dominant species include curly dock (Rumex crispus), prickly lettuce (Lactuca seriola), and Canada thistle (Cirsium arvense).

Planting/Seeding

The subsurface cell was originally planted in fall 1996 with transplants from nearby riparian areas. Species planted included willow (*Salix* spp.), sedges (*Carex* spp.), and rushes (*Juncus* spp.). The willows died and were replanted in summer 1997.

Weeds

Canada thistle comprises 10 percent of the plant cover within the cell. Canada thistle is one of the most widespread and economically damaging noxious weeds in Colorado. Infestations are found in cultivated fields, riparian areas, pastures, rangeland, forests, lawns and gardens, roadsides, and in waste areas. Without control measures, Canada thistle will become the dominant cover species in the Highland Camp wetland.

Wildlife

The small size (600 square feet) and the absence of open water severely limit the use of the wetland by any wildlife species. At the landscape level, the constructed wetland does not add to or enhance existing wildlife habitat. Species that may use the wetland include deer mice, pocket gophers, and other rodents. Both the vegetative structural diversity and the wildlife habitat value of the wetland are low. It was noted that this site experienced liner damage due to pocket gophers.

Wetland Biodiversity Functional Assessment

The general wildlife habitat, habitat diversity, and uniqueness of the Highland Camp constructed wetland all rated low. Total functional points were 18% of the total possible for this wetland, and it was rated as a category IV wetland.

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
General Wildlife Habitat	**0.1 (low)**	**1**
General Fish / Aquatic Habitat	**NA**	**1**
Production Export / Food Chain Support	**0.1 (low)**	**1**
Habitat Diversity	**0.1 (low)**	**1**
Uniqueness	**0.1 (low)**	**1**
Total Points	**0.9 (18%)**	**5**
Wetland Category (I, II, III, or IV)	**IV**	

Human Use

This wetland has low aesthetic value because it is dominated by areas of bare gravel and weedy species. This site provided researchers an opportunity to investigate the use of constructed wetlands in high elevation settings. Several graduate students conducted research at this site, and at least one received a master's degree for a thesis discussing this research.

Maintenance Issues

Canada thistle should be hand-pulled to prevent further spread.

Overall Site Comments

This site no longer functions as intended for wastewater treatment, and a large portion of the site now contains weedy species. The treatment wetland provides only limited habitat and the weeds may spread and impact surrounding habitat The primary reason for problems in the system appeared to be hydraulic overloading. In addition, it was noted that the plants had a hard time getting established in the coarse media. Another issue was the intrusion of pocket gophers that damaged the liner and could have contributed to the difficulties in maintaining a water level in the wetland that would promote plant growth.

Aerated lagoon

View of wetland cells

Inlet pipe to wetland cells

Horizon Facility Statistics	
Nearest Town:	**Eckert**
County:	**Delta**
River Basin:	**Saint Vrain**
Receiving Water Body:	**Surface Creek**
Year Online:	**1988**
Population:	**220**
Elevation (feet):	**5400**
Design Flow (mgd):	**0.015**
Average Flow (mgd):	**0.010**
Size (acres):	**1**

Facility Description

The wastewater treatment facility consists of two aerated lagoons, a settling pond, a surface flow wetland followed by a meadow area. Chlorine disinfection can be provided as needed prior to discharge from the facility.

Background Information

The Horizon Nursing Home treatment wetland is the oldest recorded treatment wetland in Colorado. The decision to incorporate a wetland system into this treatment facility was based on costs and aesthetics. Dr. Hammer, a wetland scientist, designed this system. At the time that the Horizon wetland was designed, there were only 11 other treatment wetlands in the United States.

Energy Analysis

Energy consumption in this system is primarily due to aerators in the lagoons. A 3hp aerator in the primary lagoon and a 1.5 hp aerator in the settling pond are operated 24 hours and day, 7 days a week.

Wetland Design

Design Methods

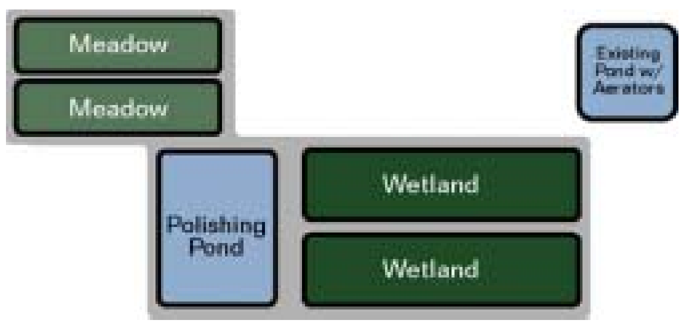
This system was designed over 12 years ago during the early years of treatment wetland use. At the time that the Horizon wetland was constructed, only 11 other treatment wetlands were being used in the United States. First-order decay functions were assumed for BOD and TSS removal. Temperature dependent reaction coefficients were used.

Objectives

In addition to typical domestic waste, the wastewater effluent from this institutional facility contains greases (the kitchen does not have a grease trap), pharmaceuticals, and cleaning products. High BOD and TSS amounts in the lagoon effluent were resulting in values that exceeded permit limitations.

Size

The wetland system consists of two parallel wetland cells, that are 100’ by 50’ each. The effluent from the wetland cells flows into a 100’ by 60’ meadow area.



Shape

The Horizon wetland cells are rectangular, with a direct flow path.

Hydraulics

The inflow mechanism to the wetland is a standard gated pvc irrigation pipe. An HDPE liner runs the full length of the wetland cells to prevent interaction with groundwater. The liner was keyed in at the edges with sandbags to prevent exposure to the sun. The collection pipe is a gated irrigation pipe surrounded by coarse gravel. The water level typically operates at 18” in the wetland and can be adjusted with weir plates.

Treatment Goals

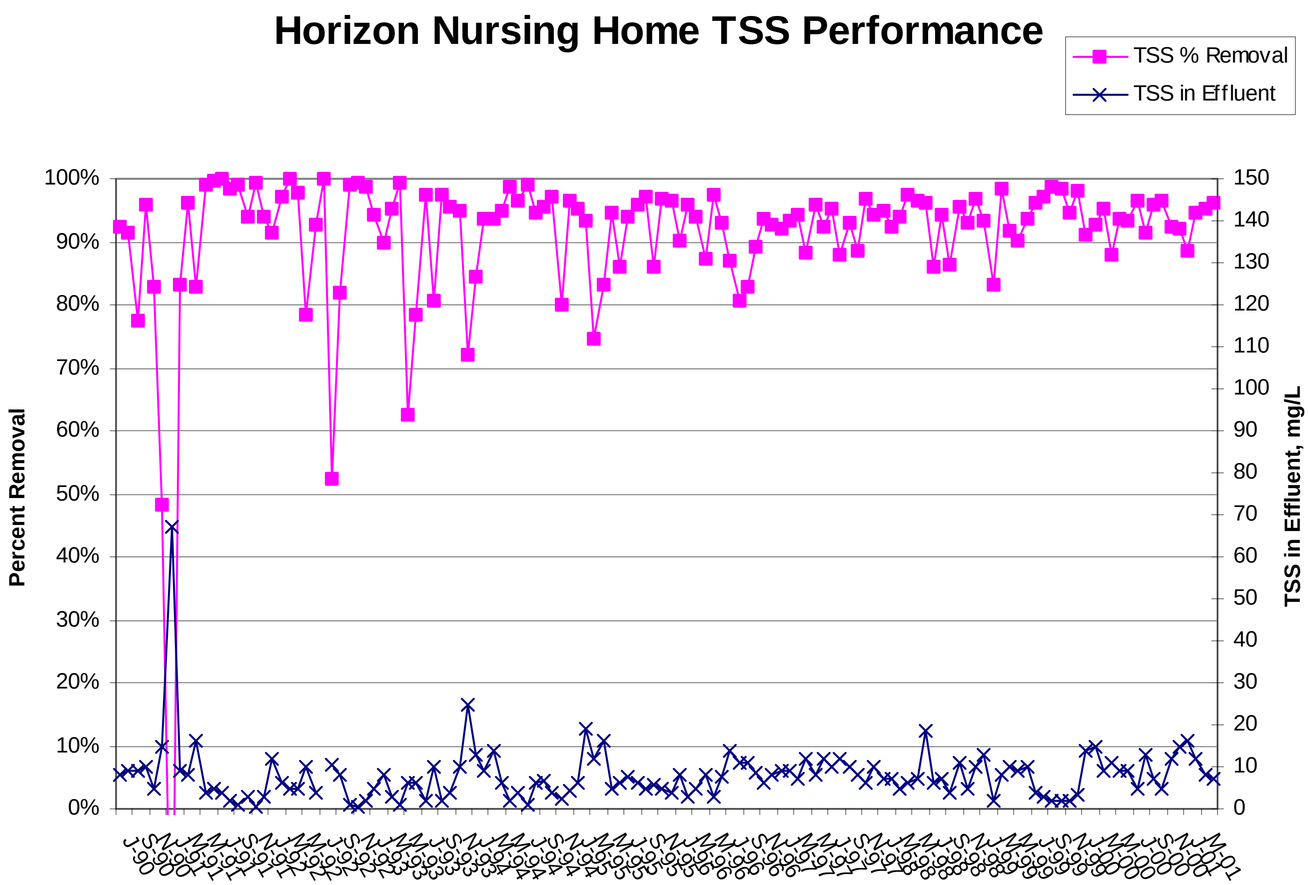
Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
$CBOD_5$:	**25 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**105 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

This system has been in operating in compliance of its discharge permit for over 12 years.

TSS Data

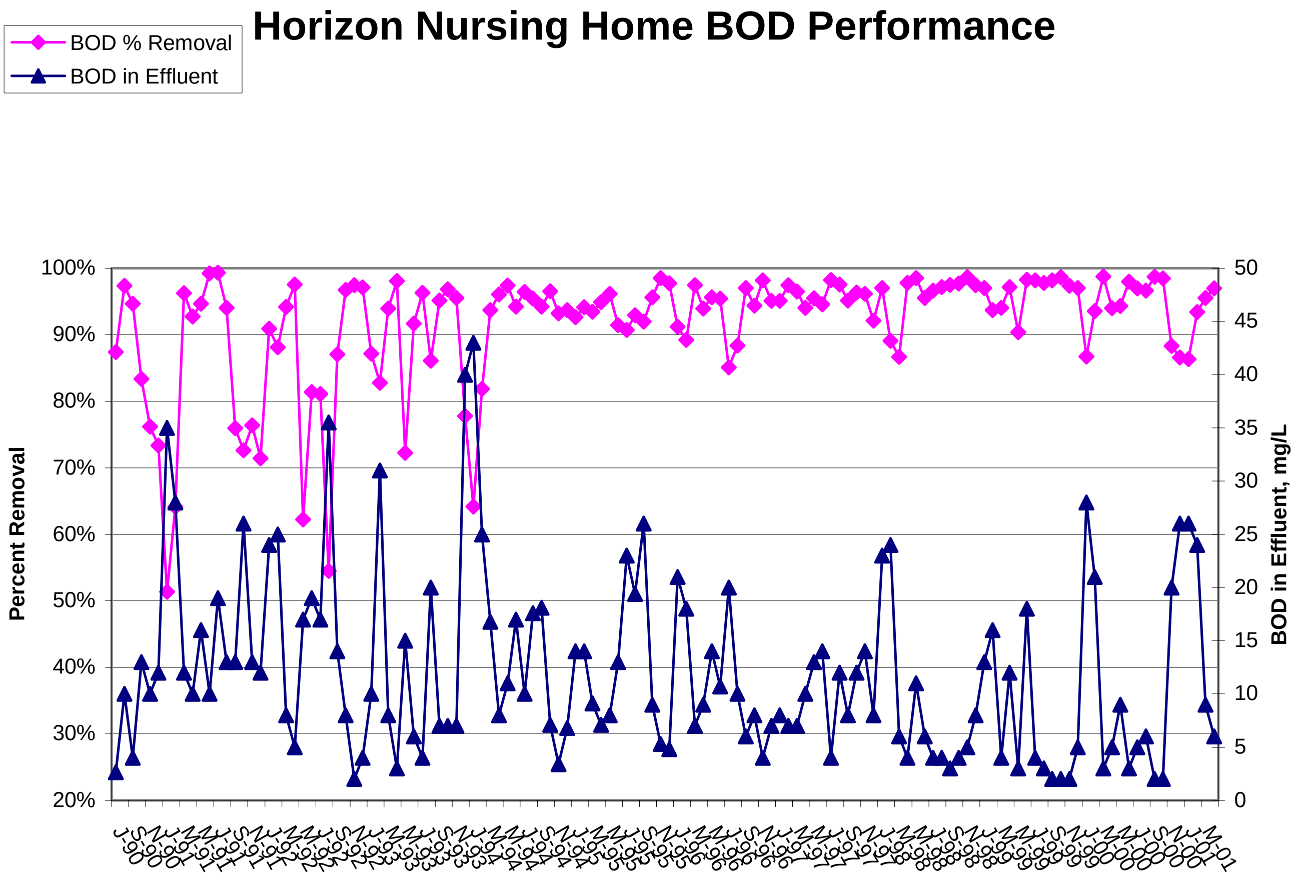
The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, since the wetland implementation, has been 195 mg/l and the average



monthly effluent has been 8 mg/l.

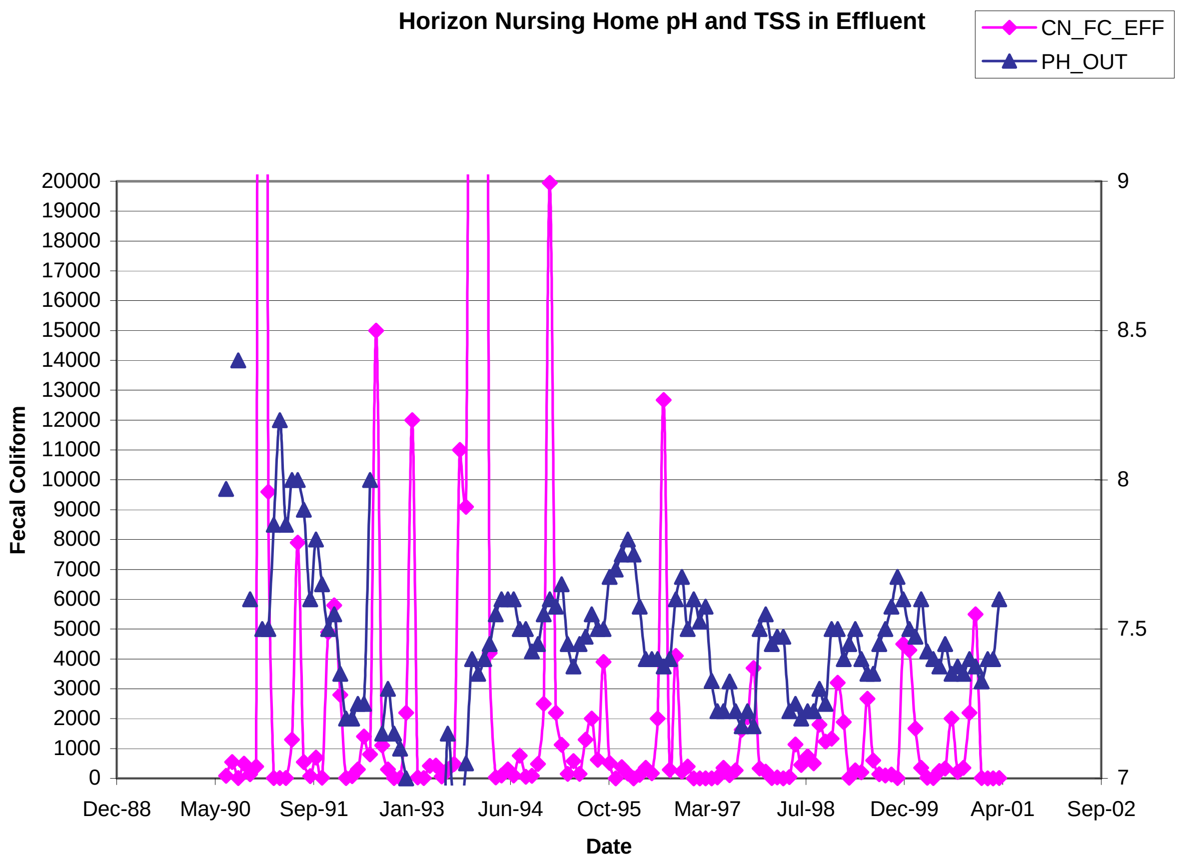
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly influent amount has been 213 mg/l and the average monthly effluent amount has been 12 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9. The average fecal coliform value reported in the effluent since 1990 has been 1325.



General Ecological Setting

The landscape surrounding Eckert is generally irrigated agriculture including most row crops, irrigated pastureland and hay fields and associated farm or ranch facilities. Natural areas are shrubland with basin big sagebrush often dominating the shrub cover. This cover often occurs mixed with grasses.

Cell Vegetation

The two wetland cells support identical wetland vegetation. Cattail (*Typha latifolia*) dominates about 80 percent of the cells. Reed canarygrass (*Phalaris arundinacea*), duckweed (*Lemna minor*), lady's thumb (*Polygonum persicaria*), prickly lettuce (*Lactuca seriola*) compose the remaining 20 percent of the wetland vegetation.

Planting/Seeding

Cattails from nearby ditch cleaning were planted in the spring. Overburden, also from the ditch cleaning, was used as an organic amendment to help with plant establishment.

Weeds

No noxious weeds were identified during the site visit.

Wildlife

The constructed wetland is located adjacent to a residential area and subsequent human activity. The general wildlife habitat and habitat diversity are low to moderate. Fauna likely to use the wetland include songbirds, deer mice, muskrat, raccoon, and deer. Total functional points were 44% of the total possible, and it rated as a category III wetland.

Muskrats have been an issue at this site. The operator trapped 20 muskrats from the site in one year. In order to prevent damage to the wetland berms, a metal exclosure was placed around the wetland cells in the spring of 1999. This appears to be working.

Wetland Biodiversity Functional Assessment

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
General Wildlife Habitat	**0.5 (mod.)**	**1**
General Fish / Aquatic Habitat	**0.0**	**1**
Production Export / Food Chain Support	**0.3 (low)**	**1**
Habitat Diversity	**0.2 (low)**	**1**
Uniqueness	**0.2 (low)**	**1**
Total Points	**2.2 (44%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

In summer 2000, the Youth in Natural Resources with the Colorado Department of Natural Resources toured the facility as part of a study of wastewater systems. This wetland has moderate aesthetic value.

Maintenance Issues

Water levels of the wetland are raised each winter to inhibit freezing. Each spring the cell vegetation is burned to remove litter and stimulate plant growth. Odor problems due to sludge in the wetland have been experienced at this site. After 12 years of operation, the sludge layer in the wetland was about 1’. This layer was removed during the spring of 2000.

Overall Site Comments

This wetland functions as intended and has good vegetation cover. Historical data show that this wetland system has consistently and reliably operated within discharge permit requirements.

Aerated Lagoon

Edge of wetland cell showing plant diversity

Wetland cell

Island Acres Facility Statistics	
Nearest Town:	Grand Junction
County:	Mesa
River Basin:	Colorado River
Receiving Water Body:	Non-discharging
Year Online:	1995
Population:	380
Elevation (feet):	5763
Design Flow (mgd):	0.020
Average Flow (mgd):	0.015
Size (acres):	1

Facility Description

The total treatment process consists of an initial sedimentation tank, primary treatment with an aerated lagoon, and final treatment in a zero discharge constructed wetlands marsh. Accumulated sludge in the sediment tank is removed and disposed of off-site. The aerated lagoons are designed to remove a minimum of 50% of the BOD at maximum flow rates. The lagoons are lined with a synthetic liner and equipped with Aeromix system Tornado Aeration Units.

Background Information

Island Acres State Recreation Area is located 15 miles east of Grand Junction, Colorado on Interstate 70. An expansion to the park offered full service hook-ups for campsites, including shower and laundry facilities. Prior to the expansion the only wastewater treatment facilities within the Park were individual disposal systems for the Park maintenance building and the residence building. Only vault toilets were available to the public. The expansion added 66 full service campsites with related facilities to the Park's 34 unimproved overnight campsites.

Several treatment options were ruled out at this site. Leach fields were ruled out because of the water table in the aquifer, the closeness of the Colorado River, and the swimming and fishing lakes being fed by the aquifer. The Division of Parks has used package treatment plants at other locations and had bad experiences. In addition, both of the above solutions are discharge systems; and a primary treatment goal was to have a zero discharge system. This left two treatment options for further consider evaporative lagoons or constructed wetlands. Of these two alternatives, constructed wetlands were more desirable to the Division of Parks for the following reasons:

- Ability to accommodate extreme flow variations
- Ease of operation and maintenance
- Compatibility with Park operations
- Potential benefits
- Familiarity.

The Division of Parks currently has two wetland systems in the Western Region at Highline Lake and Ridgeway Reservoir State Parks.

Energy Analysis

The primary energy consumers at this site are the aerators and mixers in the lagoon. Flow through the wetland is achieved by gravity.

Wetland Design

Design Methods

The peak loadings for 100% usage and occupancy at complete buildout are 20,000 gpd with a corresponding BOD of 72 #/day. Wastewater effluent is measured with a 60-degree V-notched trapezoidal flume. Wastewater discharges from the sewer system into a sedimentation / grit chamber that consists of a 4000 gallon septic tank. This provides 3.6 to 9.6 hours of detention, at maximum and average daily flows. The aeration basin consists of a single cell with a total capacity of 200,000 gallons. The basin is rectangular with rounded corners. Aeration and mixing are provide by two 1.5 hp Aeromix System Tornado Aerators. The system is designed to maintain a minimum of 2.0 mg/l of dissolved oxygen and supply 1.5 lbs. of oxygen for each pound of BOD. The Effluent is conveyed via a pipeline from the aerated lagoon to the wetland. The two major design components for the wetlands are climatic date and evapotranspiration rates to size the wetland. The second component is the hydraulic and organic loading rate.

Objectives

The main treatment goals of the constructed wetland marsh are to complete the biological treatment of the wastewater and to dispose of the excess fluids through an evapotranspiration process.

Size

The wetland system is comprised of a single 3.90 surface flow cell. Average flows are well below design flows. This results in a transition area in the wetland from inundated soils to varying moisture levels. This 'over-sizing' in a wetland boundary similar to a natural wetland. Changes in vegetation dominance are evident as the flow and nutrient load of the wastewater decrease along the flowpath.

Shape

The wetland cell is generally rectangular, with some irregular borders necessary in order to fit within the site.

Hydraulics

Discharge from the lagoon system is discharged through a pvc pipe to a river rock lined corner of the wetland cell. The wetland is sloped so that the flow is distributed diagonally across the wetland cell. This system is an evaporative system. Plumbing is available to collect effluent at the outlet end of the wetland, if discharge is ever required.

Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
$CBOD_5$:	**25 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**105 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

This wastewater treatment facility operates under a groundwater permit. Since it is not discharging into a surface water, monthly discharge monitoring reports are not required. Water quality data is not available for this site.

General Ecological Setting

Island Acres is the eastern-most unit of the Colorado River State Park, a 20-mile long reach of the Colorado River. Ecologically, uplands support desert shrublands dominated by species such as big sagebrush and greasewood. Big sagebrush communities are well represented, occupying high terraces along the river. Much of the landscape along the river has been altered to support agricultural crops, flood control, and highway construction. Within the river corridor, diverse wetland and riparian communities occur on islands, point bars, and along the banks.

Cell Vegetation

The Island Acres wetland has two plant communities. Plant community 1, which represents 85 percent of the total cell area, is dominated by cattail (*Typha latifolia*). Other dominant species include softstem bulrush (*Scirpus tabernaemontana*), creeping spikerush (*Eleocharis palustris*), and Torrey's rush (*Juncus torreyi*). Plant community 2, 15 percent of the cell, is dominated by short-awn foxtail (*Alopecurus aequalis*).

Planting/Seeding

The constructed wetland at construction was planted with cattail.

Weeds

Tamarisk or saltcedar (*Tamarix chinensis*), a noxious weed, is prolific along the Colorado River reach adjacent to Island Acres and saplings of the escaped ornamental are present in the wetland. Tamarisk is a facultative phreatophyte, i.e., it can draw water from underground sources but once established it can survive without access to ground water. It consumes large quantities of water, possibly more than woody native plant species that occupy similar habitats.

Maintenance Issues

Tamarisk is a maintenance concern for park staff and is commonly controlled in riparian areas and wetlands because of its potential to displace native vegetation and its lower value as wildlife habitat.

Wildlife

The vegetative structural diversity and subsequent wildlife habitat value are moderate. When viewed at the landscape level, the Island Acres constructed wetland has not added significantly to the acreage of suitable, adequately isolated habitat for waterfowl and other wildlife along the reach of the Colorado River. Proximity to a public campground and Interstate 70 will generally preclude specialist species from using the wetland. Species for which habitat is available include various songbirds, waterfowl, muskrat, deer mouse, raccoon, coyote, and mule deer.

Wetland Biodiversity Functional Assessment

The general wildlife habitat, habitat diversity, and uniqueness of the Island Acres constructed wetland all rated moderate to low. Total functional points were 52% of the total possible for this wetland, and it was rated as a category III wetland.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	**0.5 (mod.)**	**1**
General Fish / Aquatic Habitat	**0.0**	**1**
Production Export / Food Chain Support	**0.7 (mod.)**	**1**
Habitat Diversity	**0.2 (low)**	**1**

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
Uniqueness	**0.2 (low)**	**1**
Total Points	**2.6 (52%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has moderate aesthetic value. The aesthetic value of this wetland is limited because of its proximity to Interstate 70, but its location along the Colorado River and its location in a state park give it aesthetic and recreational value.

Overall Site Comments

This wetland functions effectively in the treatment of wastewater and it also has healthy vegetation cover. It has value to the public because it is located in a state park and can be used for public education and is an excellent conservation measure for the park.

View of aerated lagoon

Perimeter of wetland cell

Effluent end of wetland cell

La Veta Facility Statistics	
Nearest Town:	La Veta
County:	Huerfano
River Basin:	Middle Arkansas
Receiving Water Body:	Cucharas
Year Online:	1993
Population:	850
Elevation (feet):	6910
Design Flow (mgd):	0.125
Average Flow (mgd):	0.075
Size (acres):	1.6

Facility Description

The Town of La Veta has a domestic, minor municipal lagoon wastewater treatment facility. The Town of La Veta's wastewater treatment facility utilizes a partially aerated lagoon system followed by a constructed wetlands system to treat influent wastewater. The Town's treatment facility utilizes the following treatment components and unit processes: influent flow measurement, lagoon system consisting of one mechanically aerated cell and two stabilization cells, wetland system consisting of two cells, chlorination, dechlorination using sulfur dioxide, effluent flow measurement and a continuous effluent flow measuring device.

Lagoons

The La Veta lagoon system consist of one aerated cell and two stabilization cells. The aerators are operated 24 hours a day, 7 days a week during the winter and 8 hours a day during the rest of the year. Some features of this lagoon system are detailed in the table below.

Lagoon Information			
Cell No.:	1	2	3
Surface Area (sq. ft.)	46,180	118,040	43,380
Avg. Depth (ft)	4.85	4.85	5.5
Avg. Volume (Million gallons)	1.554	3.972	1.674
Detention time (days)	17.5	44.8	18.9
Aerator size (hp)	3	NA	NA

Background Information

La Veta's original wastewater collection and treatment facilities were constructed in 1974 to provide central sewage treatment to residents of the service area. The 1992 expansion and modification of the original treatment facility was brought about as a result of the original treatment facility being overloaded, its inability to produce an effluent which could consistently comply with the facility's discharge permit limitations and the need to provide additional treatment capacity to accommodate projected growth in the service area.

Energy Analysis

The wastewater flows through the system by gravity. Energy is consumed in the aerated lagoons by submersible 3hp pumps. During the winter months these pumps run 24 hours a day. The rest of the year, the pumps are operated 8 hours, during the night. A typical energy bill is about $450 a month.

Construction Costs

This wetland system cost approximately $365,000 to construct. Since it was established in an abandoned lagoon, earthwork was minimized.

Wetland Design

Design Methods

The design of the wetland system is based on BOD5 removal using the first order, plug flow, reaction kinetics model developed by Reed, Middlebrooks and Crites. It is assumed that the bulk of settleable solids will be removed in the lagoon system, therefore; influent BOD5 will be primarily soluble BOD and floatable or suspended algal material. A water balance was done to determine the typical wetland hydraulic loading rate. The required water depth for a hydraulic residence time of 11.9 days in the winter and 5 days in the summer will be an operating depth of 6" to 12", with the maximum depth kept to less than 24".

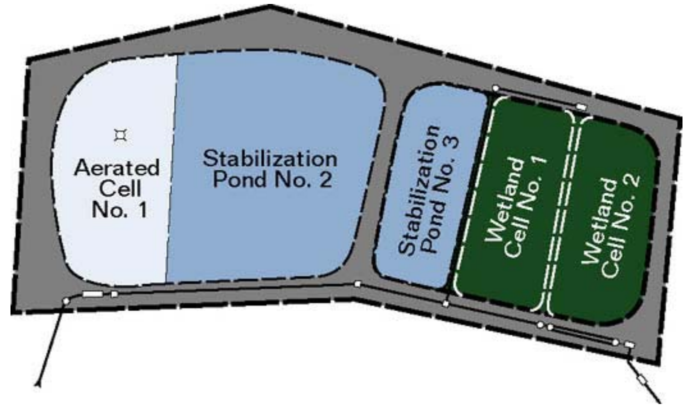
Objectives

The main objective of the wetland cells is to remove TSS due to algal carryover from the lagoons.

Size

The wetland system is a surface flow system consisting of two cells. The total area of the wetland system is 69,400 square feet (1.6 acres).

Shape



As shown by the schematic, the sedimentation forebay is rectangular and the wetland cells are rectangular with a direct flow path. The wetland cells are constructed within the embankments of an abandoned lagoon.

Hydraulics

Each wetland cell is equipped with its own influent and effluent flow system. A timber wall equipped with a longitudinal weir plant at its top, runs along the width of each wetland. This structure provides uniform flow into the wetlands. Both wetland cells can be bypassed, or one cell can be taken offline for maintenance. The water flow to each wetland is controlled by adjustment of the weir plates installed in the influent control structure. Flow depth in the wetland cells can be adjusted by installing stop planks at the effluent end of each cell. During normal summer months, the depth in the cells operates in the range of 6 to 12 inches. During the winter, the flow is maintained 4 to 6 inches under the ice cover. The effluent end of each wetland cell consists of timber walls with semi-circular corrugated metal pipe fitted in open sections. Outlet pipes are located outside the timber walls. Each outlet pipe is equipped with a perforated cap and buried in river rock.

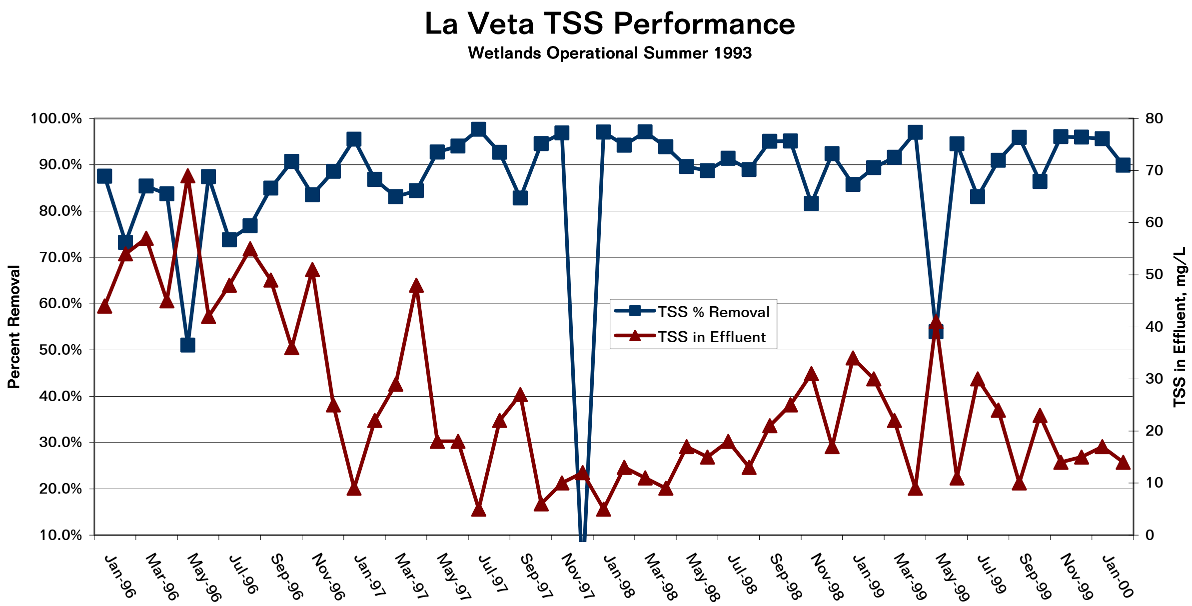
Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	10 mg/l (Daily Max)
BOD_5:	30 mg/l (30-day ave)
BOD_5 Removal:	85%
TSS:	75 mg/l (30-day ave)
PH, su (min – max)	6.5 – 11.5 (Daily Max)
Total Chlorine Residual	0.048 (Daily Max)
Total Ammonia (as N), mg/l	5.2 – 68 (varies seasonally, based upon the allowable instream total ammonia concentrations.)
Fecal Coliform Bacteria:	6,000 organisms per 100 ml (Daily Max)

Water Quality Data

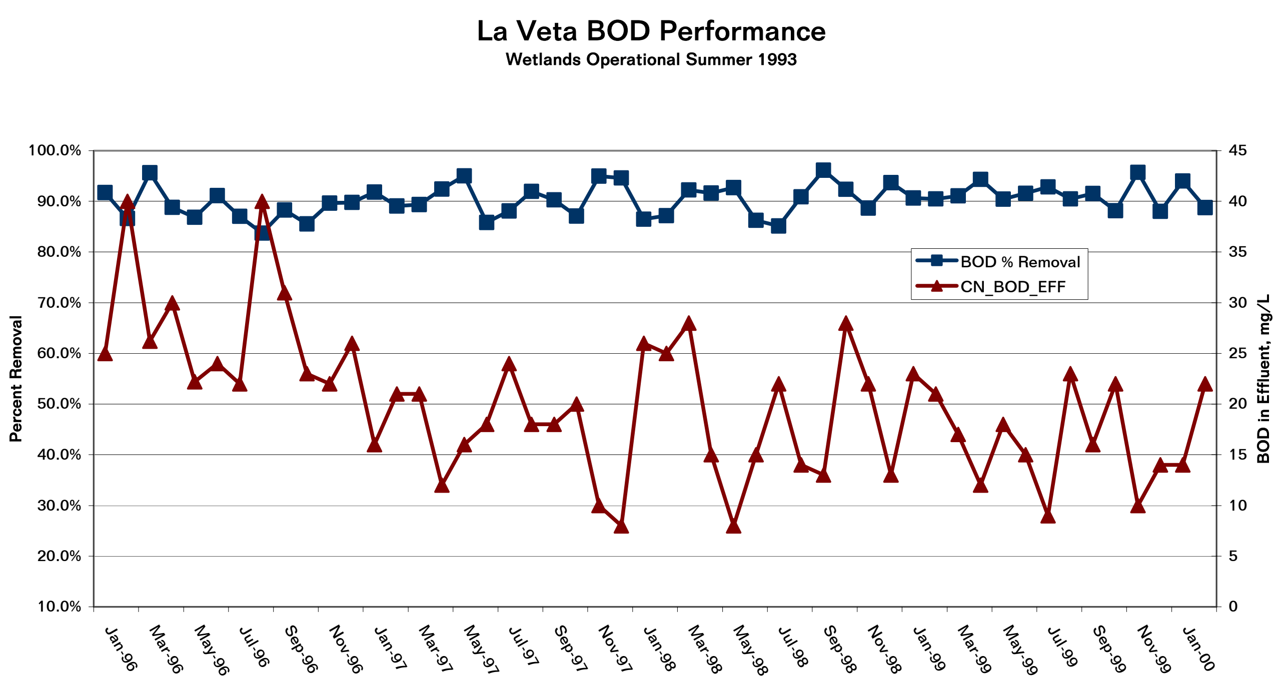
TSS Data

The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, since 1996, has been 245 mg/l and the average monthly effluent has been 26 mg/l. This meets the permit discharge requirement of 75 mg/l.



BOD Data

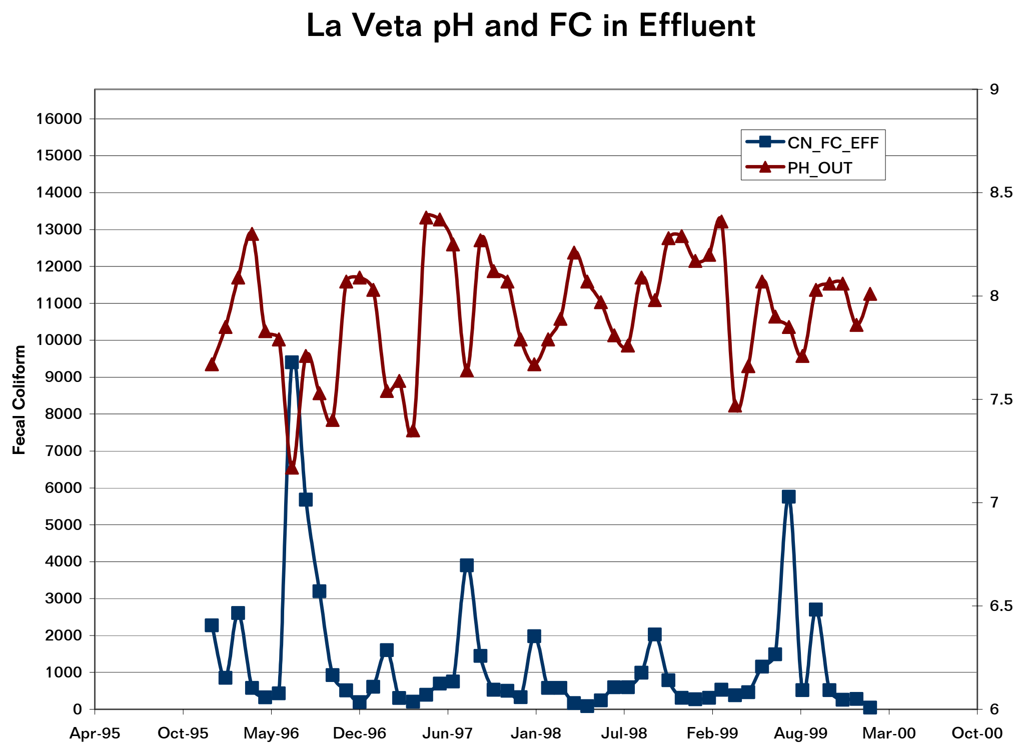
The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly influent amount has been 217 mg/l and the average monthly effluent amount has been 20 mg/l.



pH and Fecal Coliform

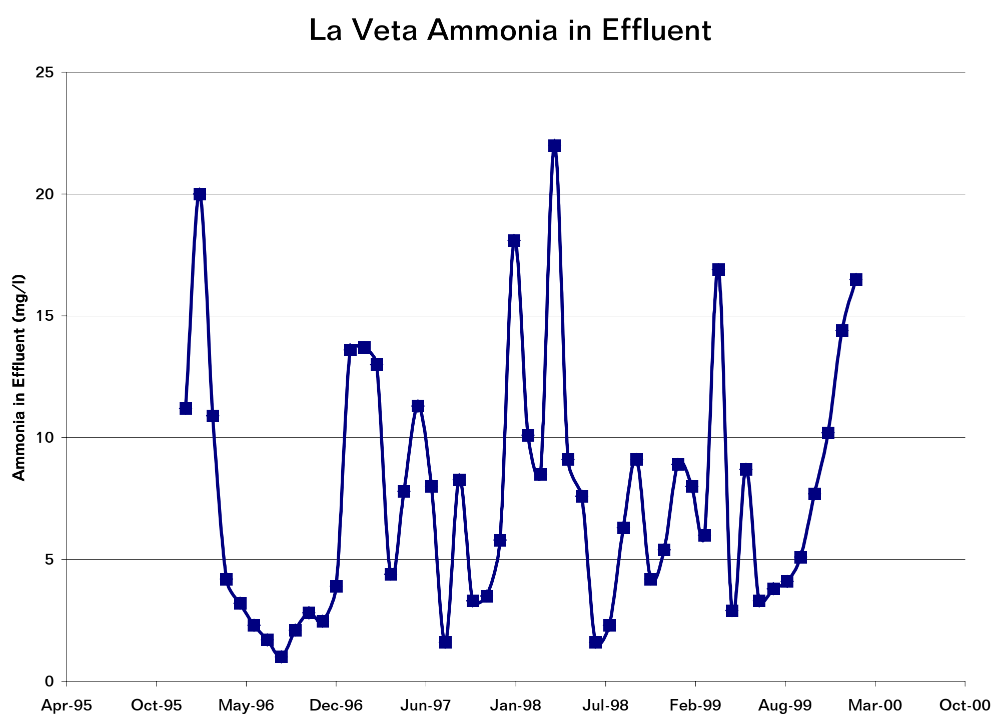
Data for these two categories has been plotted on the same graph. Data reflect the quality of the effluent, not influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Previous to the wetland implementation, data indicate that average pH values in the effluent were close to the maximum daily allowable of 11. An amendment to the discharge permit changed the maximum pH limitation from 9.0su to 11.0 s.u. La Veta was eligible for this amendment because it met both applicable requirements, 1) no inorganic chemical could be added to the wastestream, and 2) contributions from industrial sources do not cause the pH of the effluent to be less than 6.0 s.u. or greater than 9.0 s.u. It was determined that the high pH in the system was due to significant algae bloom in the lagoons.

A chlorination-dechlorination system is provided as a part of the treatment to meet the fecal coliform permit limitations. This system has not been used in the last 5 years because effluent quality has been suitable for discharge without their use.



Ammonia

The discharge permit for the wastewater treatment facility required a two-year ammonia monitoring program. All data gathered during this monitoring program was submitted to the Water Quality Control Division to establish ammonia discharge parameters. The average monthly ammonia in the effluent has been 7.6 mg/l.



General Ecological Setting

The two LaVeta constructed wetland cells are flat and rectangular. The wetland discharges to the Cuchares River. The LaVeta treatment wetlands are located in the broad valley of the Cucharas River, at the base of a piñon pine-dominated bluff.

Cell Vegetation

Two cells are present at the LaVeta site. Cell 1 is composed of 80 percent water, 10 percent litter, and 10 percent vegetation. The vegetation communities for cells 1 and 2 are identical. Community 1, which composes 90 percent of each wetland cell, is dominated by cattail (*Typha latifolia*), with *Scirpus americanus* and duckweed (*Lemna minor*) present but not dominant. Vegetation community 2, which composes the remaining 10 percent, is dominated by cattail, softstem bulrush (*Scirpus tabernamontanae*) with duckweed, willowherb (*Epilobeum ciliata*), creeping spikerush (*Eleocharis palustris*), foxtail barley (*Hordeum jubatum*)and sandbar willow (*Salix exigua*) present but not dominant. The site is dominated by 95 percent water and 5 percent vegetation.

Planting/Seeding

Cattails were planted at the site in the fall. The planting rate is not known..

Weeds

Canada thistle (*Cirsium arvense*), mullein (*Verbascum thapsus*), and gumweed (*Grindelia squarosa*) are present around ponds and wetlands in both cells. Canada thistle and mullein are on the State Noxious Weed list. They are invasive in areas of recent disturbance, and spread quickly. They also prevent the establishment of native species and have low wildlife value.

Maintenance Issues

No maintenance items were noted.

Wildlife

The LaVeta wetland provides habitat for muskrat, beaver, red winged black birds, waterfowl, and geese. Mallards and herons were observed during the site visit. This wetland has structural diversity in the form of small patches of open water interspersed with cattail stands. From a landscape perspective, it provides valuable wildlife habitat. There are no other similar wetland/open water complexes in the area, and the treatment facility gains extra value because of its location between the Cucharas River floodplain and the piñon bluff.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal and production export/food chain support both rated high. General wildlife habitat rated moderate. Habitat diversity and uniqueness of the constructed wetland rated moderate to low. This wetland received 45 percent of the total possible functional points. It rated as a category III wetland.

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.5 (mod.)	1
General Fish/Aquatic Habitat	0.0	1
Production Export/Food Chain Support	0.2 (low)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.7 (54%)	5
Wetland Category (I, II, III, or IV)	III	

Human Use

The wastewater wetland is part of a restricted public access area. A local student studied the wetland system and participated in a science fair. This wetland has high aesthetic value because it is well vegetated and located in a visually interesting area.

Overall Site Comments

This wetland functions well in treating wastewater and it has high biological and aesthetic value.

Aerated Lagoon

View of wetland cells

Removable sleeves are used to control the water elevation in the wetland cells.

Fines from unwashed media results in plugging

Las Animas Facility Statistics	
Nearest Town:	**Las Animas**
County:	**Bent**
River Basin:	**Lower Arkansas**
Receiving Water Body:	**Diversion Ditch routed to Arkansas River**
Year Online:	**1999**
Population:	**2500 + 1000 inmates**
Elevation (feet):	
Design Flow (mgd):	**0.50**
Average Flow (mgd):	**0.25**
Size (acres):	**2.1**

Facility Description

The Las Animas wastewater treatment system is a domestic minor municipal lagoon system. The facility consists of a continuous influent flow-measuring device, two aerated lagoons, one settling pond, a constructed wetland, ultraviolet disinfection and a continuous effluent flow-measuring device.

Lagoons

Some of the features of the Las Animas lagoon system are detailed in the table below.

Lagoon Information			
Cell No.:	**1**	**2**	**3**
Surface Area (sq. ft.)	**540,000**	**540,000**	**250,000**
Avg. Depth (ft)	**4.1**	**4.1**	**6.0**
Avg. Volume (Million gallons)	**16.56**	**16.56**	**11.22**
Detention time (days)	**7**	**6.6**	**2.9**
Aerator size (hp)	**100**	**14**	**7.5**

Background Information

The Las Animas wastewater treatment plant was initially constructed in 1958 as a three-cell, facultative lagoon system, with a design capacity of 0,22 mgd. The plant was later expanded in 1983 to a four-cell, facultative lagoon system, with a design capacity of 0.36 mgd. The only unusual waste source in the City's service area is that coming from blowdown from water softeners in the community. The City has experienced problems with meeting discharge requirements since the system came online in 1983. These violations are attributed to high TSS related to algae growth. In October 1986 the City of Las Animas was issued a Notice of Violations and Cease and Desist Order. The City had several violations, including violations of BOD5 percent removal, BOD5 concentrations, TSS concentrations, pH exceedances, and fecal coliform exceedances that persisted through the summer of 1994.. Constructed wetlands were chosen to be the most promising method to achieve algae removal.

The City undertook a 3-year pilot scale study, starting in October 1991, to design and construct 4 pilot scale wetlands. Each wetland was 20 x 40 feet, 3 feet deep, had a 2% slope, and was planted with 200 locally harvested cattails. Each was loaded at 1000 gpd. Three of the wetlands were designed to be subsurface. Gravel size was varied for each wetland (4", 1.5" and .75" sizes were tested). The fourth wetland cell was designed as a surface flow system. The results from this study were used to design the full size subsurface wetland system.

Energy Analysis

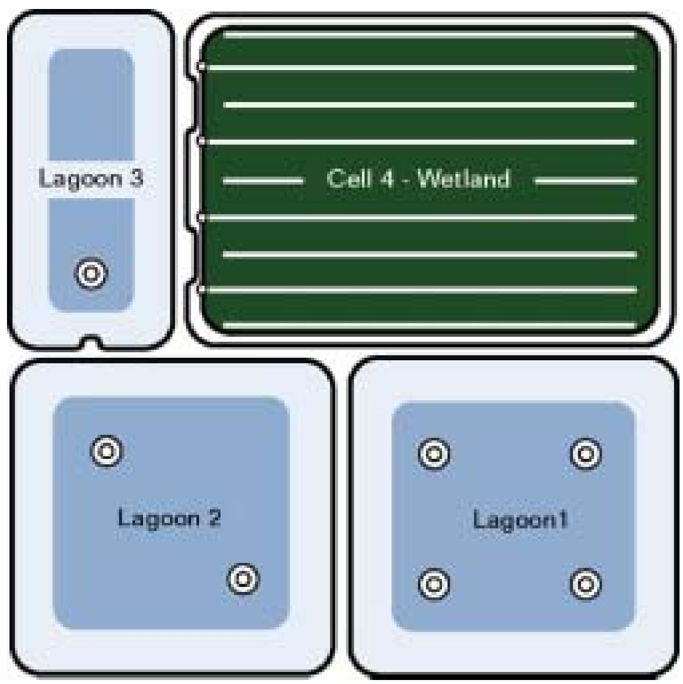
The wetland system operates under gravity. Energy is consumed by the aerators in the lagoons, and by the UV disinfection system.

Wetland Design

Design Methods

Results from the pilot scale study were used to design a full size subsurface system. Some of the conclusion from this study that were used in the final design are discussed below.

- The surface flow wetlands did not consistently remove algae, in fact, at times algae cell numbers increased due to algae growth in the system. This was due to a short detention time in the surface flow wetland.
- The subsurface wetlands significantly removed algae cells.
- No plugging occurred in the subsurface wetlands. Performance increased as the gravel size decreased. In addition, the two coarser gravel wetlands had poorer plant development compared to the finer gravel wetland.
- The subsurface wetlands were oxygen limited for nitrification but had sufficient oxygen for BOD5 removal.
- The subsurface wetland with a 0.75 inch gravel size was chosen for the full scale wetland because of its performance in algae removal and BOD5 and TSS reduction without plugging problems during its two years of operation.



Objectives

The wetland was sized using empirical data collected during the pilot scale study. The primary objective of the wetland component was to remove BOD and TSS from the lagoon effluent.

Size

An existing lagoon was retrofit to include the subsurface wetland cells.

Shape

As shown by the schematic, the wetland cells are rectangular.

Hydraulics

Lagoon effluent is introduced into the wetland cells by perforated pipes installed approximately 36” below the ground surface. PVC piping was used. PVC risers distribute the water within the wetland. Adding or removing collars onto PVC tees within effluent collection boxes controls the water level. At the time of the visit, the system was experiencing plugging problems. A potential cause of the plugging was theorized to be the use of unwashed gravel in the wetland cells. Hypochloride was being introduced into the pipes to clean them out.

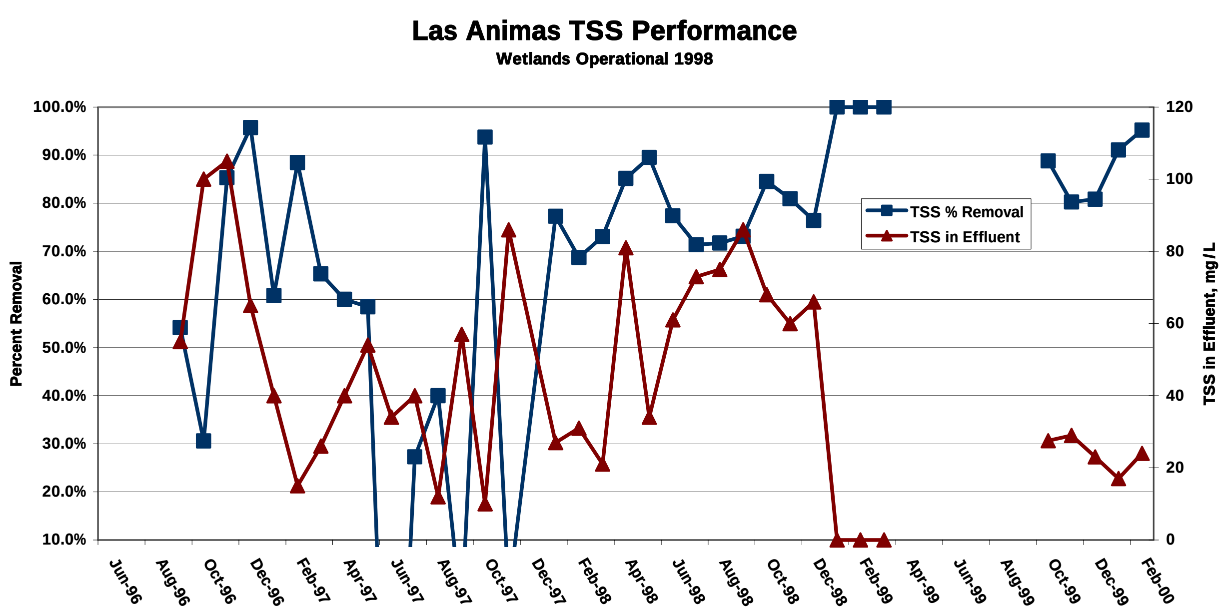
Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	10 mg/l (Daily Max)
BOD_5:	30 mg/l (30-day ave)
BOD_5 Removal:	85%
TSS:	105 mg/l (30-day ave)
PH, su (min – max) :	6.5 – 9.0 (Daily Max)
Ammonia (as N):	26.7 (lbs/day)
Chlorine Residual:	0.026 mg/l (Daily Max)
Fecal Coliform Bacteria:	6,000 organisms per 100 ml (Daily Max)

Water Quality Data

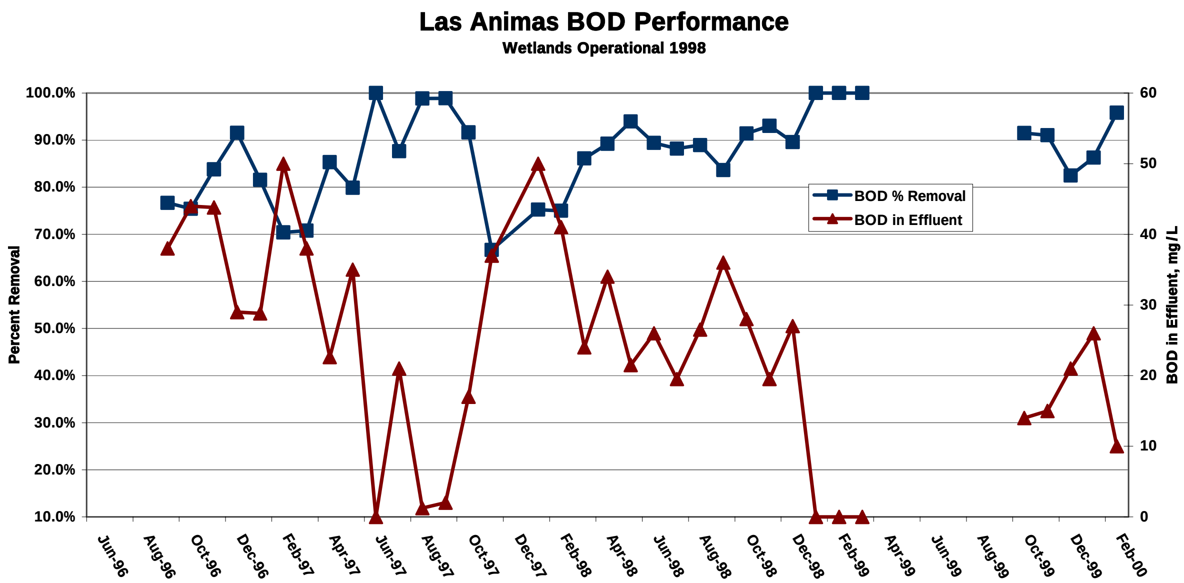
TSS Data

The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, since the wetland implementation, has been 240 mg/l and the average monthly effluent has been 24 mg/l. This meets the permit discharge requirement of 105 mg/l.



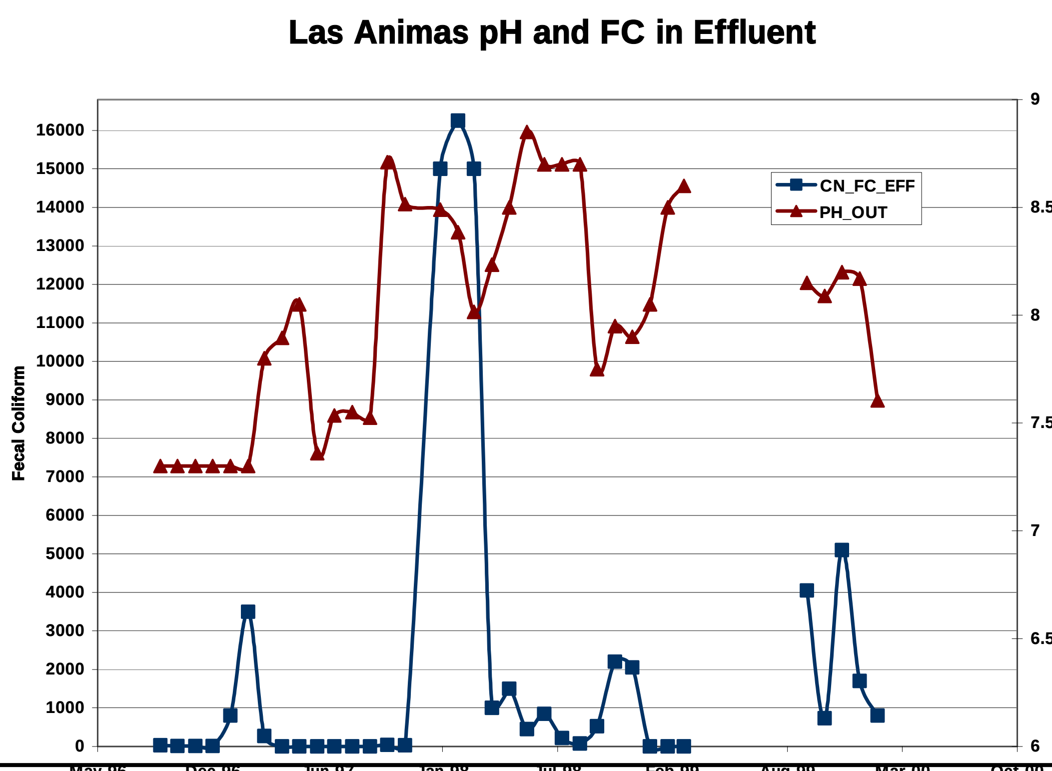
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly influent amount has been 176 mg/l and the average monthly effluent amount has been 17 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.



General Ecological Setting

The Las Animas constructed wetland is flat, rectangular, and are 90 percent vegetated and 10 percent rock. The wetland discharges into the Arkansas River. The treatment wetland is located on the north side of the Town of Las Animas, near the Arkansas River floodplain.

Cell Vegetation

Two vegetation types are present in the wetland cell. Plant community 1, which comprises 80 percent of the wetland, is dominated by cattail (*Typha latifolia*), narrow leaved cattail (*Typha angustifolia*), and softstem bulrush (*Scirpus tabernamontanae*). Curley dock (*Rumex crsipus*), witchgrass (*Panicum capillare*), and switchgrass (*Spartina pectinata*) are present but not dominant. Plant community 2 accounts for 20 percent of the cell's vegetation cover. It is dominated by cattail, softstem bulrush, and ragweed (*Amaranthus retroflexis*), with tamarisk (*Tamarix chinensis*) and gumweed (*Grindelia squarosa*) present but not dominant.

Planting/Seeding

The site was planted with cattail and softstem bulrush to encourage vegetation establishment.

Weeds

Tamarisk or saltcedar (*Tamarix chinensis*), a noxious weed, is a facultative phreatophyte, i.e., it can draw water from underground sources, but once established it can survive without access to ground water. It consumes large quantities of water, possibly more than woody native plant species that occupy similar habitats. Tamarisk is a maintenance concern and is commonly controlled in riparian areas and wetlands because of its potential to displace native vegetation and its lower value as wildlife habitat.

Maintenance Issues

The water level for the wetland cell is about 1.5 feet below the design elevation of about 3 to 6 feet below the surface, which has resulted in plants drying up and dying. This die-off is particularly significant in community 2, where vegetative cover is only 50 percent. Community 1 has 80 to 90 percent vegetative cover. In addition, gravel at the mouth of the distribution pipe is causing clogging. A strategy should be developed to mitigate this.

Wildlife

The Las Animas wetland provides habitat for red winged black birds, songbirds, and potentially muskrats. No wildlife species were observed during the site visit. The site is located near the Arkansas River floodplain, and is not a unique feature in the area. Riparian areas along the river, and wetlands and open water associated with the John Martin Reservoir likely provide more valuable habitat. Because there are some gravel areas devoid of vegetation, there is some structural diversity, but this is probably not very valuable to wildlife.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high in this wetland. General wildlife habitat and production export/food chain support rated moderate. Habitat diversity and uniqueness of the constructed wetland rated low. The wetland received 35 percent of the total possible functional points and was rated as a category III wetland.

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
General Wildlife Habitat	**0.4 (mod.)**	**1**
General Fish / Aquatic Habitat	**NA**	**1**
Production Export / Food Chain Support	**0.4 (mod.)**	**1**
Habitat Diversity	**0.1 (low)**	**1**
Uniqueness	**0.2 (low)**	**1**
Total Points	**2.1 (42%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has moderate aesthetic value. It is dominated mainly by emergent vegetation, but has some openings composed of bare gravel.

A pilot scale wetland study was performed at this site[1]. The results of this study were used in the design of the existing facility. Several subsequent wetland systems have cited this study for design parameters.

Overall Site Comments

This wetland functions effectively in the treatment of wastewater, and vegetation has established over most of the site. Problems with the water distribution system into the wetlands may adversely impact vegetation establishment and health if the problems are not addressed, but the plant operators are taking a proactive role in addressing these problems.

[1] Richard, Michael Ph.D., and Snyder, John M.S., "Results of the Pilot Wetlands Study at Las Animas, CO, Final Report", submitted to John Trent Public Works Director, City of Las Animas, CO, February 10, 1994.

Manzanola

Lagoon

First wetland cell

Wetland cells #1 and #2

Influent pipe to cell #1

Manzanola Facility Statistics	
Nearest Town:	Manzanola
County:	Otero
River Basin:	Lower Arkansas
Receiving Water Body:	Unnamed irrigation ditch, less than 1 mile from Arkansas River
Year Online:	1998
Population:	450
Elevation (feet):	4230
Design Flow (mgd):	0.125
Average Flow (mgd):	0.045
Size (acres):	2.3

Facility Description

The Manzanola wastewater treatment facility is a domestic minor municipal lagoon system. The facility consists of one aerated lagoon, a settling pond, constructed wetlands followed by chlorine disinfection.

Lagoons

The Manzanola lagoon system consists of 2 cells, separated by two floating curtains. Some features of this lagoon system are detailed in the table below.

Lagoon Information		
Cell No.:	**1**	**2**
Surface Area (sq. ft.)	**51,500**	**12,200**
Avg. Depth (ft)	**5**	**5**
Avg. Volume (Million gallons)	**1.559**	**0.339**
Detention time (days)	**12.5 - 36**	**2.7 – 7.6**
Aerator size (hp)	**12**	**NA**

Background Information

The Town of Manzanola has operated its wastewater treatment facility since the 1930's. The original system consisted of a two-cell stabilization lagoon. Actual effluent discharge data was not reported by the Town until September of 1994. The Town's inability to meet permit regulations resulted in a notice of significant non-compliance for exceeding BOD5 and fecal coliform limitations in March 1995 the Town of Manzanola received. This noncompliance continued resulting in the issuance of a Notice of Violation and Cease and Desist Order in July 1995. An engineering evaluation concluded that a new mechanical facility would require both substantial initial capital cost and heightened ongoing annual operation and maintenance costs. They also require a higher level of operator certification. Small communities like Manzanola are best served by adhering to a simpler form of treatment if only secondary treatment levels are required. The recommended improvements converted the original two-cell facultative lagoon into an aerated cell, a facultative cell, followed by a surface flow constructed wetland.

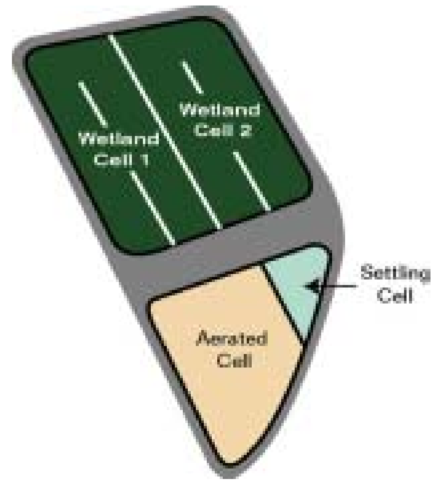
Energy Analysis

The lagoon aerators and the chlorine injection system are the primary energy consumers. The lagoon system uses 4 – 3hp aerators.

Wetland Design

Design Methods

The design of the constructed wetland was based on a minimum hydraulic residence time of 6 days and a minimum aspect ratio of 8 to 1. A secondary consideration was BOD5 removal during the spring. A water balance was done to determine the hydraulic loading rate of the constructed wetland system. The hydraulic loading rate was based on a volume per area basis. For the Manzanola system a maximum design HLR of 1.228 gpd/ft2 was selected. BOD reduction was modeled by first order, plug flow, reaction kinetics model developed by Reed, Middlebrooks and Crites. This is an iterative design method necessary to ensure that all minimum design requirements are met.



Objectives

The primary design concern is solids (algae) carry-over in the treatment facility effluent and the BOD5 load associated with these solids. Two of the most significant design parameters with regard to TSS control are hydraulic residence time (HRT) and aspect (length to width) ratio.

Size

The wetland system consists of two treatment cells, each with an area of 49,800 ft. The total area for the wetland system is 99,600ft2, or 2.3 acres.

Shape

The constructed wetland cells are rectangular with a serpentine flow pattern.

Hydraulics

Gravity conveyance is used throughout the system. Perforated pipes are used to introduce the wastewater into the wetland cells. Adjustable tees are used to vary the water depth in the wetland. A serpentine flow path provides prevents short-circuiting through the system.

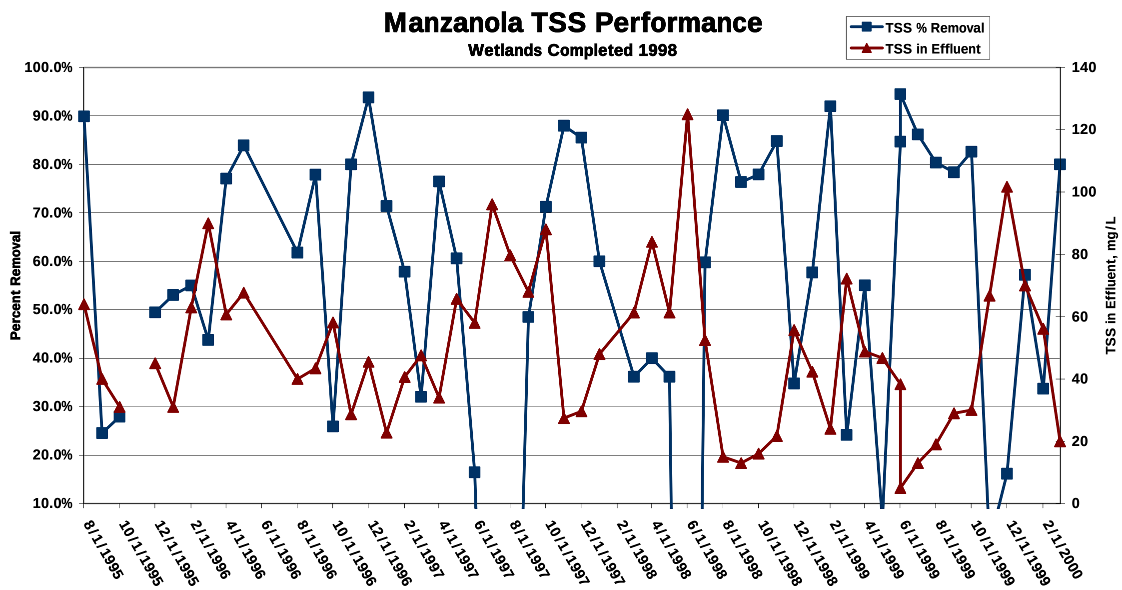
Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.0 – 9.0 (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

TSS Data

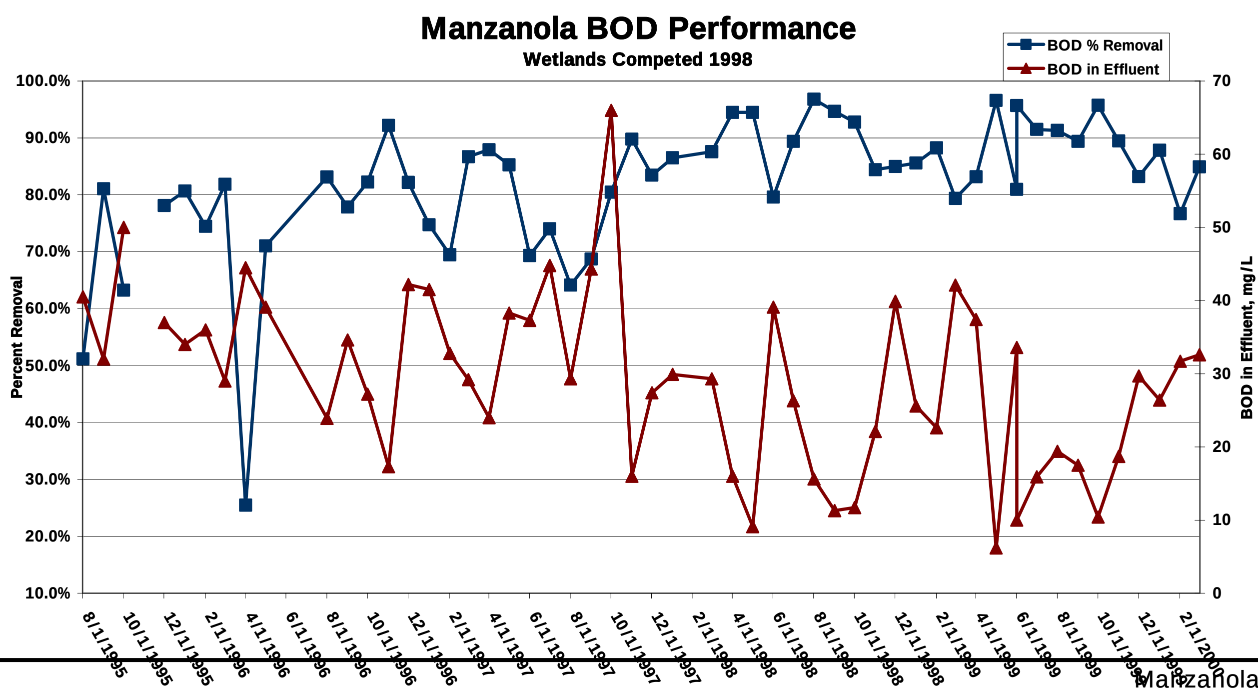
The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis.



The average monthly TSS in the influent, since the wetland implementation, has been 121 mg/l and the average monthly effluent has been 34 mg/l. This meets the permit discharge requirement of 75 mg/l.

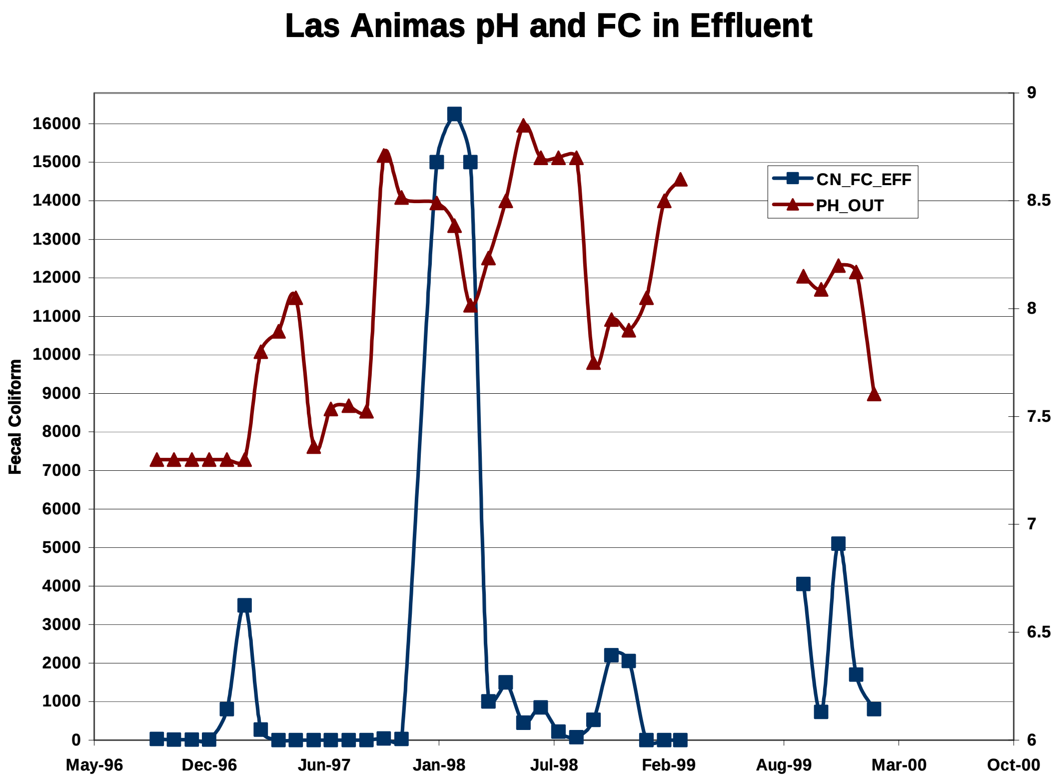
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. . The average monthly influent amount has been 211 mg/l and the average monthly effluent amount has been 23 mg/l.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Previous to the wetland implementation, data indicate that average pH values in the effluent were close, and sometimes exceeded,



the maximum daily allowable of value 9. Since the wetland implementation, pH values have consistently stayed within the allowable range of 6.5 to 9.

General Ecological Setting

The Manzanola constructed wetland is located along a ditch that empties into the Arkansas River. The cells are flat, rectangular, and are 99 percent vegetated and 1 percent open water. The wetland is located on the north side of Manzanola, on the Arkansas River terrace. The design of this treatment wetland is identical to the Town of Crowley treatment wetland.

Cell Vegetation

The Manzanola site consists of two identical cells, which total 2.3 acres. The two cells have similar plant communities dominated by cattail (*Typha latifolia*) and duckweed (*Lemna minor*); however, the west cell (cell 1) has significant algal growth, and the vegetation is almost entirely dead. No water is currently flowing into or out of the wetland. Vegetation covers 45 percent of the wetland, open water covers 45 percent, and litter accounts for the remaining 10 percent cover. The soil surface is inundated from 0 to 1 foot. The east cell (cell 2) is 80 percent covered by vegetation, 10 percent open water, and 10 percent litter. This cell also has narrow leaved cattail (*Typha angustifolia*), and has no significant amount of algal growth. Die-off is not as significant as in the western cell.

Planting/Seeding

The site was planted to encourage vegetation establishment; however, no records document the species and amounts planted.

Weeds

No noxious weeds were noted.

Maintenance Issues

The cause of vegetation die-off should be identified and mitigated.

Wildlife

The Manzanola wetland provides habitat for muskrat, waterfowl, songbirds, and red winged black birds. During the site visit, waterfowl, songbirds, and red winged black birds were observed. Muskrat have caused problems for site maintenance, and are being eliminated. When the cattail stands are in good health, this wetland probably has some vegetative structural diversity because of the presence of the shallow water pockets. The presence of shallow water and emergent vegetation provides habitat for waterfowl, songbirds, and muskrats.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high, and production export/food chain support rated moderate. General wildlife habitat rated moderate because of the presence of open water and potential habitat; however, extensive open water is present because a significant number of cattail have died. Habitat diversity and uniqueness of the constructed wetland rated low.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.5 (mod.)	1
General Fish / Aquatic Habitat	0.0	1
Production Export / Food Chain Support	0.7 (mod.)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.8 (56%)	5
Wetland Category (I, II, III, or IV)	III	

Human Use

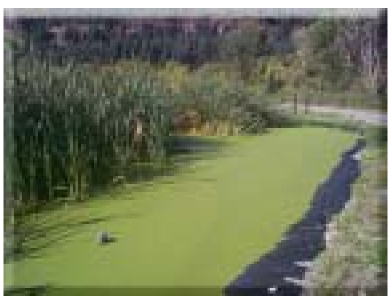
The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has low aesthetic value because it is dominated by areas of bare gravel and weedy species.

Overall Site Comments

A large portion of the site has not developed wetland vegetation. The sewage lagoons at the site provide open water habitat for wildlife, but the treatment wetland provides only limited habitat. This site has consistently had trouble meeting discharge permit limitations.

Lagoon

Aerated influent end of wetland



Effluent end of wetland cell

Vista down wetland cells

Avondale Facility Statistics	
Nearest Town:	**Ouray**
County:	**Ouray**
River Basin:	**Uncompahgre River**
Receiving Water Body:	**Uncompahgre River**
Year Online:	**1995**
Population:	**700 (winter)** **2000 (summer)**
Elevation (feet):	**7700**
Design Flow (mgd):	**0.363**
Average Flow (mgd):	**0.26**
Size (acres):	**0.76**

Facility Description

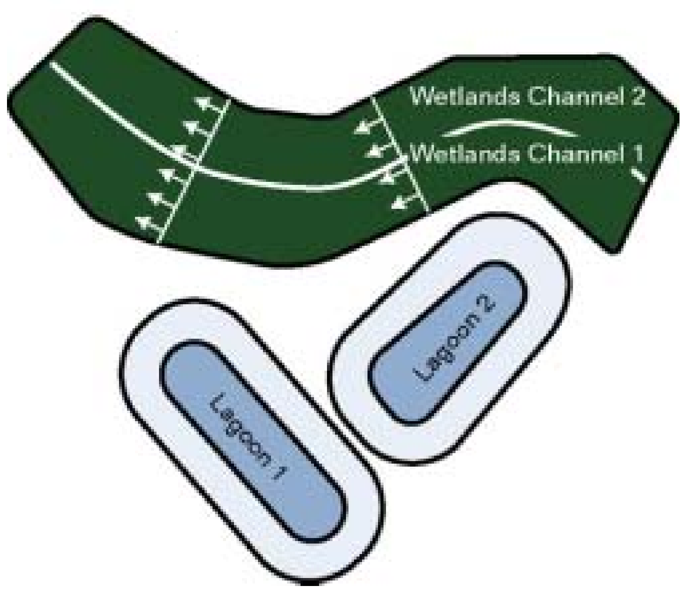
The Ouray wastewater treatment facility is a domestic minor municipal lagoon system. This new facility consists of headworks with a bar screen, a Parshall flume, a grit channel, and an influent lift station followed by two aerated lagoons, a wetlands system for polishing, an effluent Parshall flume, hypochlorination, a chlorine contact chamber, and dechlorination prior to discharge to the Uncompahgre River.

Lagoons

The Ouray lagoon system consist of 2 cells operated in series. Multiple take-off elevations are provided for the effluent from cell 2. The table below discusses some of the lagoon features.

Lagoon Information		
Cell No.:	**1**	**2**
Surface Area (sq. ft.)	**18,880**	**16,920**
Avg. Depth (ft)	**14.8**	**14.3**
Avg. Volume (Million gallons)	**2.09**	**1.81**
Detention time (days)	**5.8 - 8.4**	**5.0 - 7.2**
Aerator size (hp)	**30**	**15**

Background Information



The City's main collection system was constructed in the early 1900's as a combination groundwater, storm sewer, and sanitary sewer with a direct discharge to the river. Ouray's first treatment system was built in 1969 as an activated sludge wastewater system. An aerated lagoon was added in 1976. In 1989 a 201 Facility Study suggested that a new aerated lagoon system be constructed.

Energy Analysis

This system uses energy in its aerated lagoons. A lift station is provided after the headworks to convey the flow to the lagoons. The forebay to each wetland cell provides compressed air into the wastewater.

Wetland Design

Design Methods

The facility consists of a headworks with a bar screen, a Parshall flume, a grit channel, and an influent lift station followed by two aerated lagoons, a wetlands for polishing, and effluent Parshall flume, hypochlorination, a chlorine contact chamber, and dechlorination prior discharging to the Uncompahgre River. The wetland cells follow aerated lagoon #1 (volume = 2.09mg with a summer hrt of 5.8 days and a winter hrt of 8.4 days), lagoon #2 (volume = 1.81 mg with a summer hrt of 5 days and a winter hrt of 7.2 days). The wetland cells have a summer hrt = 2 days and a winter hrt = 2.9 days.

Objectives

The primary treatment objective was the removal of TSS due to algal carryover from the lagoons.

Size

The constructed wetland consists of two 70' X 470' basins, with a maximum depth of 1.5'.

Shape

The wetland cells are contoured to fit the site topography. As shown in the schematic, the borders are curved.

Hydraulics

A swivel tee located in a manhole prior to discharge from the plant allows for variability in the water level in the wetland system. Flexibility in the system allows for cells to be bypassed and dried out. This proved to be an important feature when anoxic conditions became a problem in a wetland cell. Taking the cell offline allowed it to dry out and reaerate. In addition, drying out the cell resulted in muskrats leaving the site.

Treatment Goals

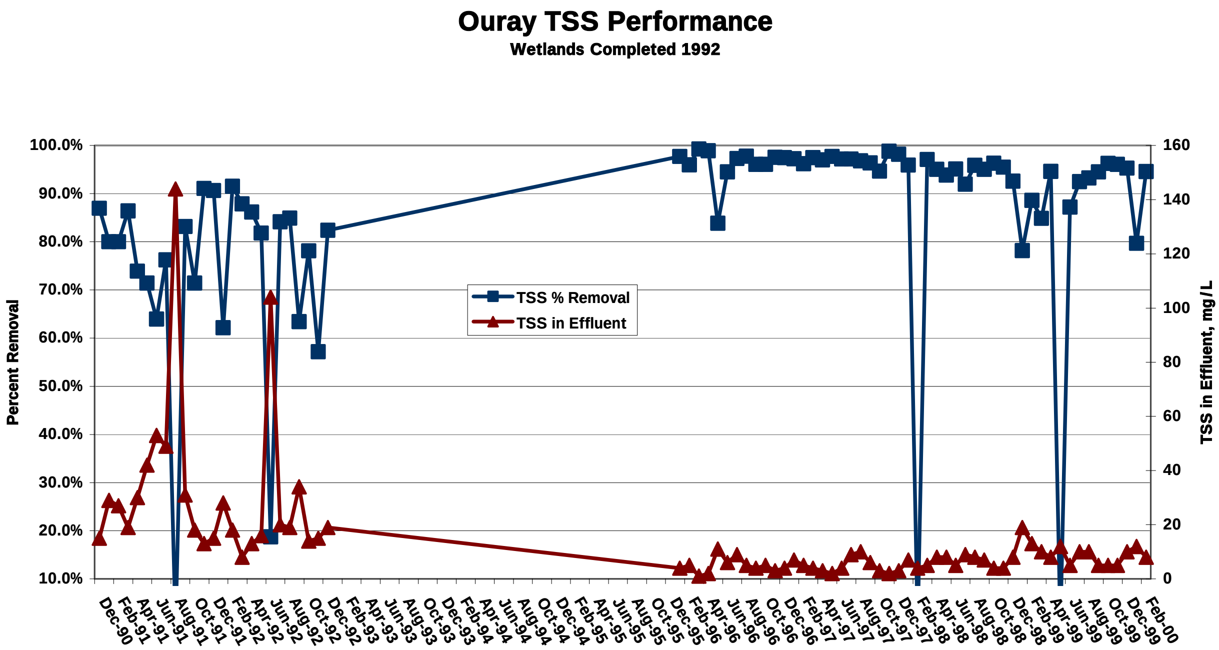
Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
$CBOD_5$:	**25 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**30 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

Monthly discharge monitoring reports document the historical performance of the Ouray system. Treatment before and after the wetland implementation show a clear improvement in the system performance after the addition of the wetlands.

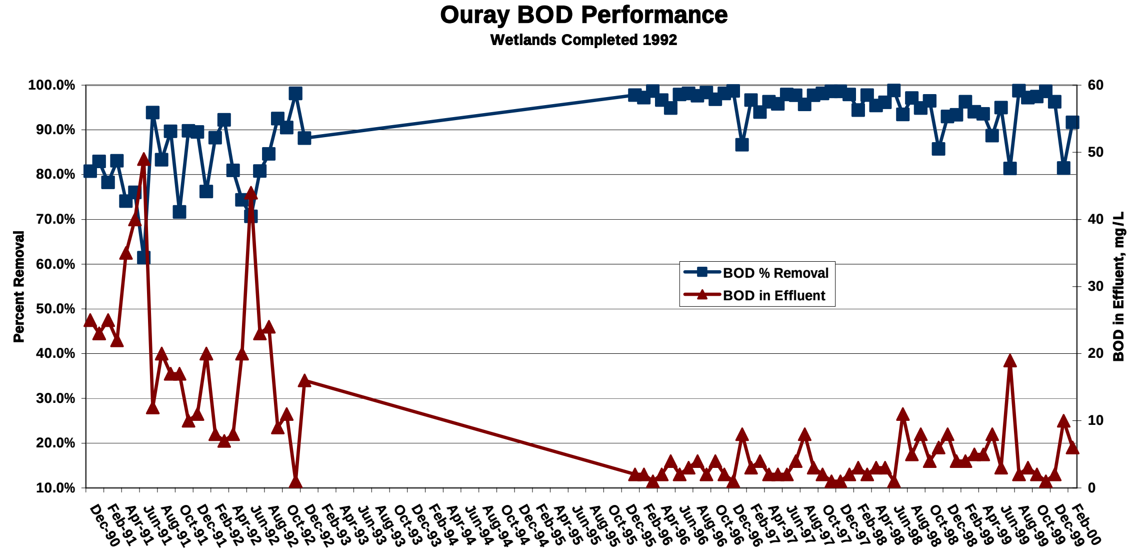
TSS Data

The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, since 1996, has been 139 mg/l and the average monthly effluent has been 7 mg/l. This clearly meets the permit discharge requirement of 30 mg/l.



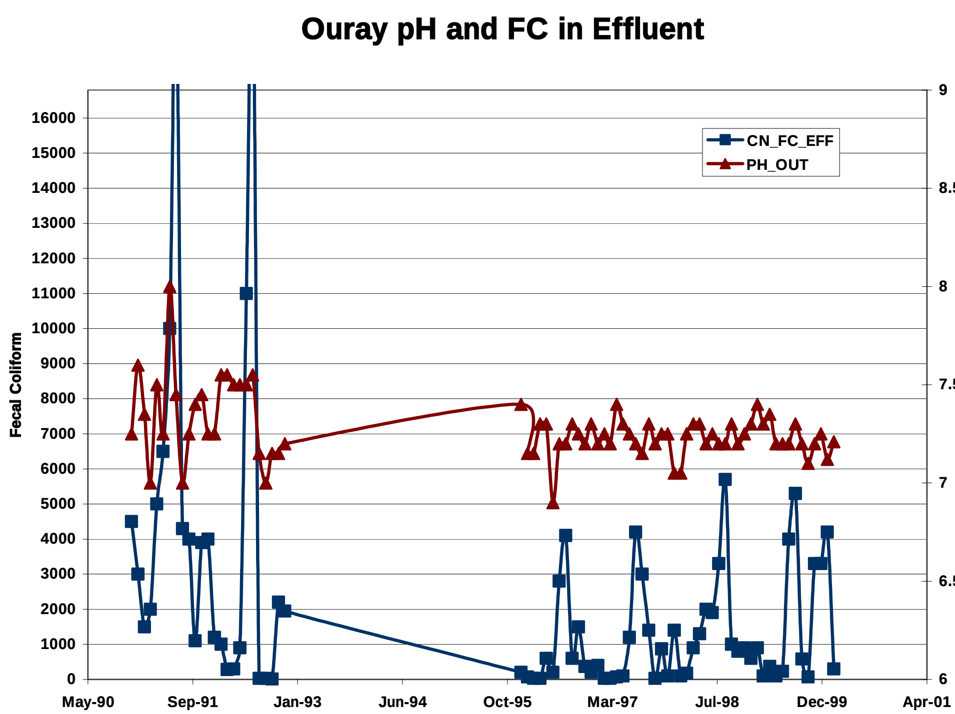
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. . The average monthly influent amount has been 96 mg/l and the average monthly effluent amount has been 4 mg/l.



pH and Fecal Coliform

Data for these two categories has been plotted on the same graph. Data reflect the quality of the effluent, not influent measurements are taken for these parameters. The pH values plotted are an average of the minimum



and maximum 30-day values that are reported in the monthly reports. Over the recorded period, pH values have consistently stayed within the allowable range of 6.5 to 9.

The average fecal coliforms in the effluent has been 1300 organisms per 100 ml. This clearly meets the discharge permit requirements of 6,000 organisms per 100 ml.

General Ecological Setting

Situated at 7,760 feet, the constructed wetland is surrounded by the San Juan Range, the youngest and steepest range of the Rocky Mountains. Peaks surrounding Ouray rise 13,000 to 14,000 feet. Numerous aspen forests are found in the valley around Ouray, particularly in areas once heavily disturbed by mining, logging, and grazing. Vegetation communities along the Uncompahgre River include mixed conifer forests, piñon-juniper woodlands, mixed mountain shrublands, and western slope grasslands.

Cell Vegetation

Vegetation in all six cells is 80 to 90 percent cattail (*Typha* spp.) with the exception of cell 3, which is 80 percent duckweed (*Lemna minor*) and 20 percent cattail (*Typha latifolia*). Two small stands of phragmites or common reed (*Phragmites australis*) are present in cells 1 and 4. Other species present included curly dock (*Rumex crispus*) and lady's thumb (*Polygonum persicaria*).

Planting/Seeding

Cattails were planted in each cell.

Weeds

Phragmites is a large perennial rhizomatous grass frequently regarded as an aggressive, unwanted invader in the East and upper Midwest; however, in the western United States, phragmites can be regarded as a stable, natural component of a wetland community if the habitat is pristine and the population does not appear to be expanding. Many native populations of phragmites are "benign" and pose little or no threat to other species and should be left intact.

Maintenance Issues

The wetland system experiences an outside flow problem with sulfates, which concentrate in filters. The addition of aeration should mitigate this problem.

Wildlife

The constructed wetland in Ouray provides habitat muskrat, raccoon, rodents, waterfowl, and songbirds. Red winged blackbirds and mallard were observed during the site visit. The vegetative structural diversity and wildlife habitat value of the constructed wetland are moderate when isolated. At the landscape level, the constructed wetland does not add significantly to wildlife habitat found within the Uncompahgre River Valley.

Wetland Biodiversity Functional Assessment

Wildlife habitat rated moderate due primarily to the overall size or available habitat. Habitat diversity and uniqueness of the Ouray constructed wetland rated moderate and low. Total functional points were 52% of the total possible for this wetland, and it was rated as a category III wetland.

Wetland Biodiversity Functional Assessment.		
Function and Value Variables	**Functional Points (0.1 to 1)**	**Possible Points**
General Wildlife Habitat	**0.5 (mod.)**	**1**
General Fish / Aquatic Habitat	**0.0**	**1**
Production Export / Food Chain Support	**0.7 (mod.)**	**1**
Habitat Diversity	**0.2 (low)**	**1**
Uniqueness	**0.2 (low)**	**1**
Total Points	**2.6 (52%)**	**5**
Wetland Category (I, II, III, or IV)	**III**	

Human Use

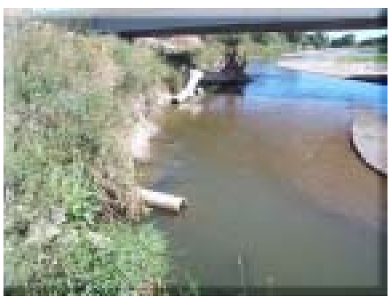
The constructed wetland in Ouray is located along Highway 550 and has an informal associated pullout area. As parks and trails are developed in the valley, the wetland may be used for interpretive purposes. This wetland has high aesthetic value, and can be seen from the highway.

Overall Site Comments

This wetland has good vegetation cover and functions well in treating wastewater. It has wildlife and aesthetic value.

Lagoon

Wetland cells



Discharge point at South Platte River

Platteville Facility Statistics	
Nearest Town:	Platteville
County:	Weld
River Basin:	Middle South Platte
Receiving Water Body:	South Platte River
Year Online:	1992
Population:	2500
Elevation (feet):	5100
Design Flow (mgd):	0.348
Average Flow (mgd):	0.13
Size (acres):	3

Facility Description

The Platteville waster treatment facility is a domestic minor municipal lagoon system. The system consists of an aerated lagoon, a settling lagoon and two surface flow constructed wetland cells, followed by chlorine disinfection.

Background Information

Platteville converted a portion of their third lagoon to a constructed wetland to eliminate effluent quality problems resulting from excessive algae growth in the polishing pond. Platteville received a notice of significant noncompliance in July of 1997 for exceeding BOD5 limitations. These violations were considered to be the result of various problems with the aeration equipment.

Energy Analysis

Energy in the system is used to aerate the lagoon. Typical energy expenditures are $500 per month.

Wetland Design

Design Methods

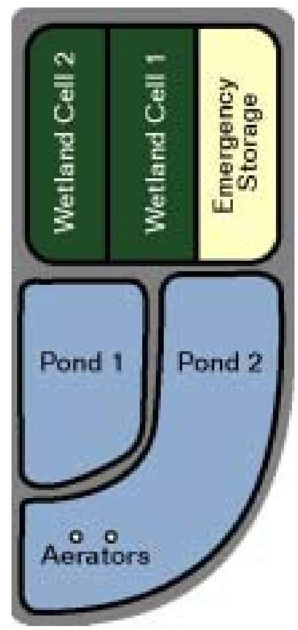
The plug-flow first order kinetics equation was used. The design water elevations were a minimum depth of 6" and a maximum depth of 2'. Detention times of 6 days for summer operations and 1.6 days for winter operations were determined to be sufficient for suspended solids removal.

Objectives

The shallow lagoons at this site produce excessive amounts of algae during summer months. This algal carryover results in high TSS and BOD in the lagoon effluent. The primary objective of the wetland system was the removal of TSS from the lagoon effluent. An influent BOD5 of 40 mg/l was determined to be the average value that the wetlands will see from the lagoon system.

Size

This system was sized to accommodate an average daily flow of 0.348 mgd. The wetland consists of 2 cells, with a total surface area of 3 acres.



Shape

An abandoned lagoon was retrofit to accommodate the wetland cells. As a result, the wetlands are rectangular with a direct flow path.

Hydraulics

Lagoon effluent enters the two parallel wetland cells by a perforated irrigation pipe. A splitter box is located prior to the wetland cells and provides for the bypass of the wetland system. Wastewater flows by gravity towards the outlet end of the wetland cells. An 8" perforated collection pipe is oriented along the width of the wetland cell. Flow is directed through the collection pipe to a flow control structure. The water level in the wetland can be adjusted in the flow control structure by the use of moveable weir plates.

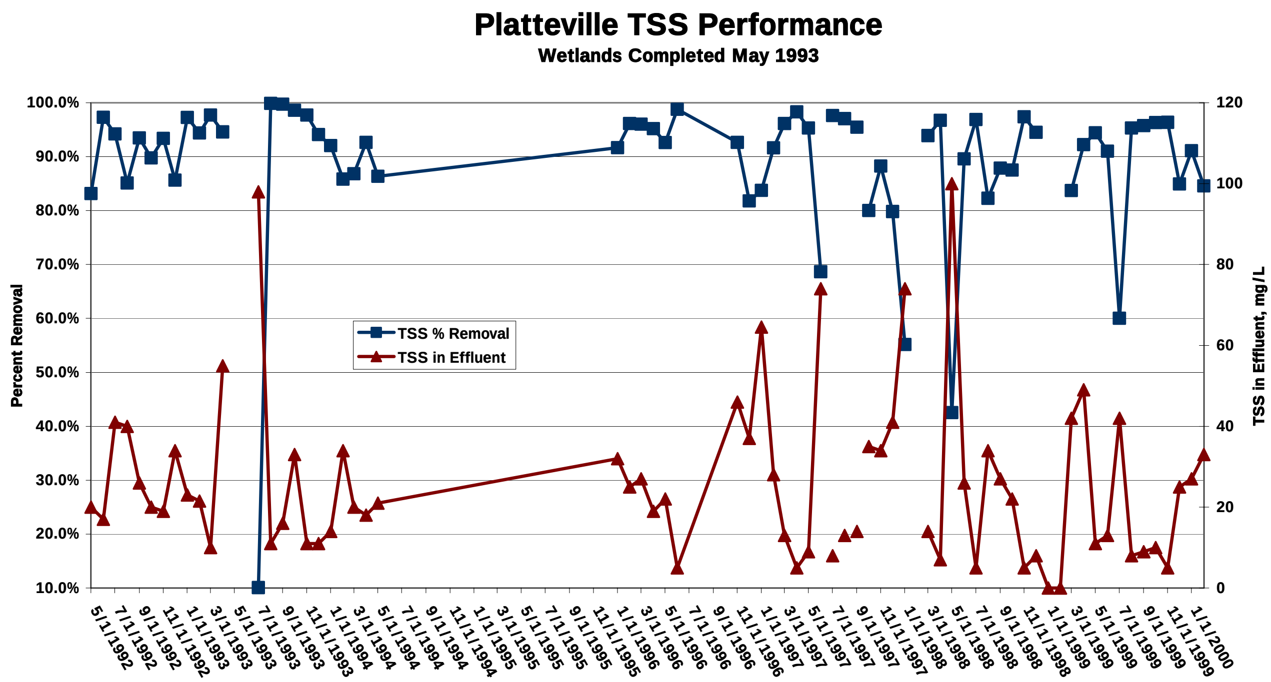
Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**25 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

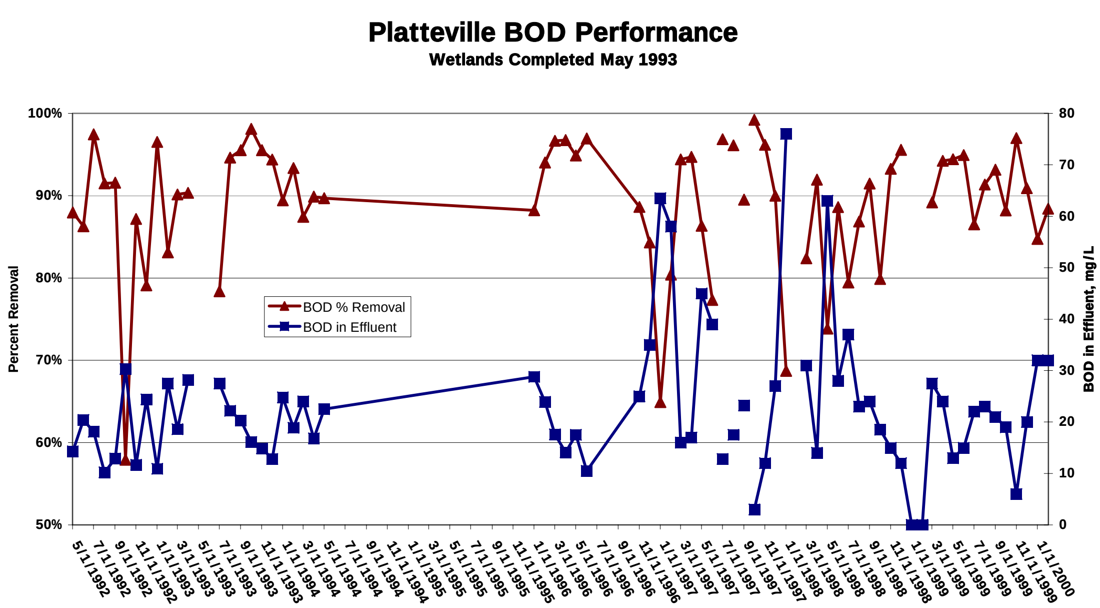
TSS Data

The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, over the period of record, has been 271 mg/l and the average monthly effluent has been 30 mg/l. This meets the permit discharge requirement of 75 mg/l.



BOD Data

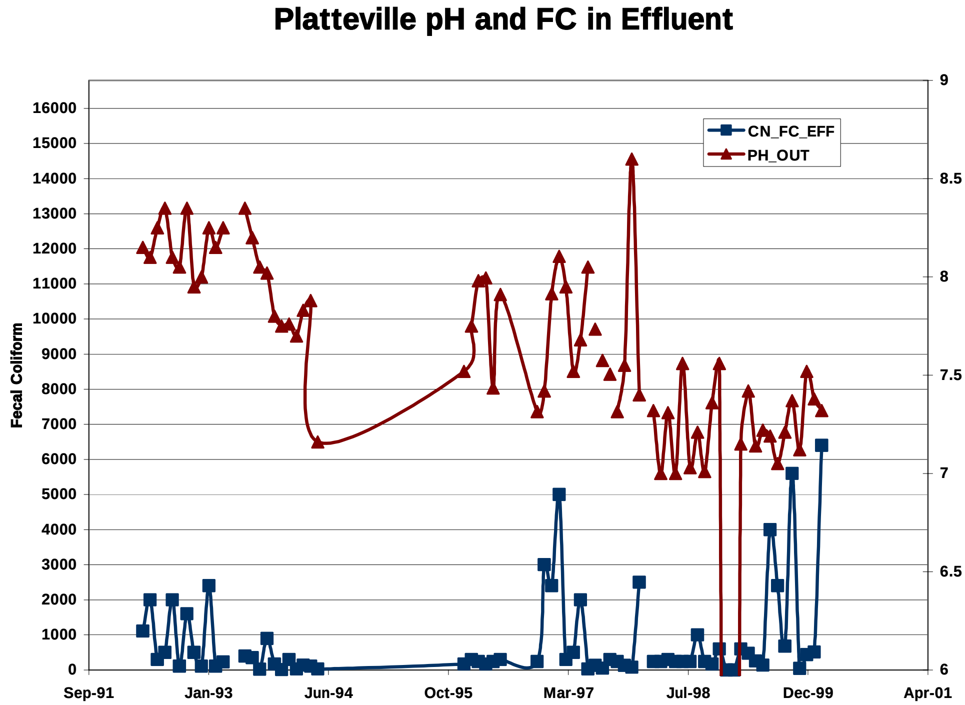
The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. The average monthly influent amount has been 272 mg/l and the average monthly effluent amount has been 26 mg/l



pH and Fecal Coliform

Data for these two categories has been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. Over the period of record, pH values have consistently stayed within the allowable range of 6.5 to 9.

The average fecal coliform level has been 1009 organisms per 100 ml. This meet the discharge permit requirements of 6,000 organisms per 100 ml.



General Ecological Setting

The Platteville wetland is a flat, rectangular basin situated on the northern side of Platteville, adjacent to farmland. The site is in an upland area about 3 miles east of the South Platte River.

Cell Vegetation

The Platteville treatment wetland consists of one cell with a single vegetation community. The cell, which is approximately 1.8 acres, is dominated by cattails (97 percent—*Typha latifolia*) and lady's thumb (3 percent—*Polygonum persicaria*) with trace amounts of softstem bulrush (*Scirpus tabernamontanae*), curly dock (*Rumex crispus*), and duckweed (*Lemna minor*).

Planting/Seeding

There were no records of the planting or seeding plans for this wetland.

Weeds

Canada thistle and cheatgrass are present in small amounts in the Platteville constructed wetland. Both species are State Noxious Weeds. They are invasive in areas of recent disturbance, spread quickly, prevent the establishment of native species, and have low value as wildlife habitat.

Maintenance Issues

No maintenance issues related to vegetation health were noted.

Wildlife

The constructed wetland at Platteville provides habitat for songbirds. Red winged blackbirds and barn swallows were observed at the site visit. This wetland is not structurally diverse , and probably is of limited value to wildlife. Red winged black birds probably nest in the wetland, but the wetland does not provide unique, diverse habitat for wildlife.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high. Production export/food chain support rated moderate. All other parameters measured low. This wetland received 33 percent of the total possible functional points, and was functionally rated as a category IV wetland.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.1 (low)	1
General Fish / Aquatic Habitat	0.0	1
Production Export / Food Chain Support	0.6 (mod.)	1
Habitat Diversity	0.1 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.0 (40%)	5
Wetland Category (I, II, III, or IV)	IV	

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has moderate aesthetic value. The wetland is comprised mainly of a uniform stand of cattail.

Overall Site Comments

This treatment wetland supports healthy vegetation, and no maintenance problems were noted. At the time of the site visit, however, it was not discharging into the South Platte River. The wetland system appeared to be healthy and operating as designed. However, the primary treatment lagoon system was not operating as intended, which resulted in excessive loading to the wetland system and difficulty in meeting permit limitations.

Overview of the Wastewater Treatment Facility

Wetland serves as an aesthetic water feature for park entrance

An island is incorporated into the wetland design for habitat value

A cobbled pathway serves as an overflow structure to connect the wetland cells

Ridgway Facility Statistics	
Nearest Town:	**Ridgway**
County:	**Ouray**
River Basin:	
Receiving Water Body:	**Non-Discharging**
Year Constructed:	**1994**
Population:	**290**
Elevation (feet):	**6800**
Design Flow (mgd):	**.015**
Average Flow (mgd):	
Size (acres):	

Facility Description

This wastewater treatment facility consists of a septic tank for primary sedimentation followed by an aeration cell. Effluent from the lagoon system is further treated in a surface flow constructed wetland system.

Lagoons

The Ridgway lagoon system is described in the table below. The cells are designed to operate in parallel or series.

Lagoon Information		
Cell No.:	**1**	**2**
Surface Area (sq. ft.)	**5766**	**5766**
Avg. Depth (ft)	**10**	**10**
Avg. Volume (Million gallons)	**0.0375**	**0.0375**
Detention time (days)	**5**	**5**
Aerator size (hp)	**3**	**3**

Background Information

Choosing a wetland system was based upon an extensive analysis of several alternatives. The seasonal operation of the park, combined with ideal climatic factors, affords an excellent opportunity to construct an evaporative system. It was also important that constructed wetlands can provide wildlife viewing areas.

Energy Analysis

Aerators in the lagoon system are the primary energy consumers at this facility.

Cost breakdown:

The costs estimated in a technical report[1] for this system are outlined below. These costs are based upon work by Urban Engineering and actual construction costs associated with the Horizon Nursing Home wetlands in Eckert, Colorado.

Concrete basins	$30,000
Earthwork	$30,000
Impervious liner	$75,000
Controls / aerators	$15,000
Wetland plantings	$33,000
Engineering	$15,000

[1] "Ridgway State Park Cow Creek Recreation Site Wastewater Treatment Technical Design Report" Colorado Division of Parks and Outdoor Recreation, Ridgway Design Office, Montrose, CO, March 25, 1992.

O&M:

The annual operational and maintenance costs, as estimated in the above mentioned technical report, are outlined below.

Labor (1/2 hr per day at $20 per hour)	$1,300
Electrical Power (aeration)	$400
Replacement Parts (motors, controls, etc.)	$500

Wetland Design

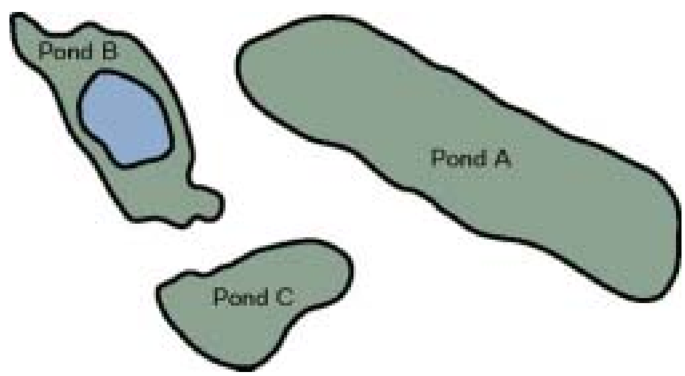
Design Methods

The wetlands were sized based upon estimated inflows, evaporation data, and organic loading parameters. The total annual discharge to the wetland is estimated to be 0.819 mgd. The design of the wetland involves two major components. The first involves the design and analysis of climatic data and evaportranspiration rates to properly size the wetland surface area. The second involves the design of the wetland to ensure that wetland capacity with regard to hydraulic and organic loading and oxygen transfer is not exceeded. The hydraulic loading rate chosen was 0.015 mgd/acre/day. The organic loading rate was chosen to have a seasonal average load of 5.7 lbs/acre/day, a peak month (August) of 9.7 lbs/acre/day and a peak day (assuming 15,000 gpd with 5 day retention and 50% BOD5 removal rate) of 35.5 lbs/acre/day.

Objectives

The primary consideration in designing the wetland system was to provide adequate removal of organic loading from the lagoon system. This system also included the aesthetic component in it design. The system is located at the park entrance, and it therefore highly visible. The shape and layout of the wetland cells are oriented to blend into the scenic surroundings.

Size



The wetland is configured with three ponds. Ponds A and B have a total surface area of 1.0 acre. These ponds are utilized as the primary containment and treatment area. Pond C is 0.5 acres and provides additional storage area, which is used during wet year conditions.

Shape

Since aesthetic value was a design objective, irregular borders and natural shapes were provided for this system. The schematic shows the general shape and relation of the three wetland ponds to each other.

Hydraulics

A gated pipe on the surface introduces wastewater from the lagoon to the wetland cells. There are 7 lateral pipes that distribute flow equally into the wetland system. Dam water can be used as an additive to keep the wetland from drying up. Batter boards are used to change water levels. Original boards were wooden, but muskrats destroyed. Subsequently the wooden boards were replaced with plastic boards. The piping configuration provides for independent diversion of water into each pond. The water is diverted through gated irrigation pipe for even distribution into the ponds. Pond B contains a deeper water level to maintain an open area in the pond.

Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
$CBOD_5$:	**25 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**105 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

This wastewater treatment facility operates under a groundwater permit. Since it is not discharging into a surface water, monthly discharge monitoring reports are not required. Water quality data is not available for this site.

General Ecological Setting

The park's vegetation communities include mixed conifer forests, piñon-juniper woodlands, mixed mountain shrublands, and western slope grasslands. Diverse wetland communities have become established around the reservoir and in the Uncompahgre River Valley above the reservoir and below the dam.

Cell Vegetation

The Ridgway State Park constructed wetland has three cells. Cell 1 (A) is about 0.6 acres and had about 15 percent open water and 85 percent vegetation cover in a single plant community. About 90 percent of the vegetation in the cell was cattail (*Typha latifolia*). Cell 2 (B) is about 0.3 acres with a small constructed island. About 70 percent of the vegetation cover in cell 2 (B) is duckweed (*Lemna minor*) and 30 percent is broadleaf cattail (*Typha latifolia*). Cell 3 (C) is 0.3 acres, has 15 percent open water and a single vegetation community dominated by broadleaf cattail (*Typha latifolia*), duckweed (*Lemna minor*), and reed canarygrass (*Phalaris arundinacea*).

Planting/Seeding

Cattail was planted in summer 1993 and amended with substrate pulled from existing wetlands nearby.

Weeds

Canada thistle (*Cirsium arvense*) occurs along the margins of cell 1 (A). Canada thistle is invasive and particularly troublesome in riparian and other wet areas in the intermountain west. Canada thistle threatens natural communities by directly competing with and displacing native vegetation, decreasing species diversity, and changing the structure and composition of some habitats. Canada thistle spreads primarily by vegetative means, and secondarily by seed.

Maintenance Issues

Mowing temporarily reduces aboveground biomass, but does not kill Canada thistle unless repeated monthly for up to 4 years. Mowing adjacent to the wetland is not practical due to the placement of large cobbles for aesthetic purposes.

Wildlife

The constructed wetland at Ridgway State Park incorporates several features beneficial to wildlife, especially waterfowl. The inclusion of areas designed as wildlife habitat within the Park's wetland system allows the project to serve as a small wildlife area and opens up the site for other uses in addition to wastewater treatment and disposal. The combination of cover, open water, and a small island provides a potential nesting site for waterfowl. However, spatial requirements of waterfowl (e.g., mallard) may limit the site to one nesting pair. Viewed in isolation, the vegetative structural diversity and wildlife habitat value of the constructed wetland are moderate. At the landscape level, the constructed wetland does not add significantly to wildlife habitat found within the Uncompahgre River Valley. The location of the complex adjacent to a park entrance road and maintenance facility may limit wildlife use to human commensal species (e.g., mule deer, raccoon, and skunk).

Wetland Biodiversity Functional Assessment

General wildlife habitat rated relatively high due in large part to the presence of open water and the island designed for waterfowl. Habitat diversity and uniqueness of the Ridgway State Park constructed wetland rated moderate and low. Total functional points were 56% of the total possible for this wetland, and it was rated a category III wetland.

Wetland Biodiversity Functional Assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.7 (mod.)	1
General Fish / Aquatic Habitat	0.0	1
Production Export / Food Chain Support	0.7 (mod.)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.8 (56%)	5
Wetland Category (I, II, III, or IV)	III	

Human Use

The trail to Dutch Charlie with access at the Enchanted Mesa Trailhead skirts the south end of the constructed wetlands. An interpretative sign at that location provides hikers with information on the function of the treatment wetlands. This wetland has high aesthetic value because it is located along a trail in a state park, with interesting visual features and because it has a healthy vegetation cover.

Overall Site Comments

This wetland functions effectively in treating wastewater and it also has a healthy vegetation cover. This site provides waterfowl and wildlife habitat, and the incorporation of an island and irregular borders into the treatment wetland design adds to the habitat and aesthetic values of this wetland.

Septic tank system

View from influent end of wetland cell

Ben Pressman in wetland cell

Discharge point

Rocky Mountain Shambhala Center Facility Statistics	
Nearest Town:	**Red Feather**
County:	**Larimer**
River Basin:	
Receiving Water Body:	**Non-discharging**
Year Online:	**1996**
Population:	**200 (winter)** **500 (summer)**
Elevation (feet):	**7800**
Design Flow (mgd):	**0.05**
Average Flow (mgd):	**Fluctuates seasonally**
Size (acres):	**0.23**

Facility Description

The Rocky Mountain Shambhala Center wastewater facility is a small evaporative system. Each building in the community has an individual septic system. Overflow from these septic systems are collected and conveyed to a bank of 6 – 2200 gallon septic tanks. Overflow from these tanks is then distributed into two parallel subsurface wetland cells. Effluent from the wetlands is discharged into an abandoned lagoon for evaporation and groundwater seepage. No discharges are made to surface waters.

Background Information

The Rocky Mountain Shambhala Center is a non-profit Buddhist organization that provides space for group retreats. The primary use of this Center is during summer months. Planned expansions at the Center will upgrade from temporary housing structures (tent platforms, trailers, etc.) to permanent housing structures that will be used year round. In anticipation of this growth, the Center began the process of upgrading its wastewater treatment system. Some considerations that were taken into account by the Center when choosing a new system were:

- Must be able to handle fluctuations in waste loadings due to seasonal population
- Operation and maintenance must be simple
- Must be able to operated during sustained low temperatures
- Costs must be minimal
- The system should operate in harmony with the natural environment.

The Center decided to install a pilot scale subsurface wetland system. The U.S. Bureau of Reclamation and the U.S.G.S. are currently assisting the Center with performance testing of the wetland system.

Energy Analysis

Energy consumption in the system is minimal. Flow through the wetlands is by gravity. The septic tanks are pumped annually, at a minimal energy expenditure.

Construction Costs

Construction of the wetland was approximately $200,000.

Wetland Design

Design Methods

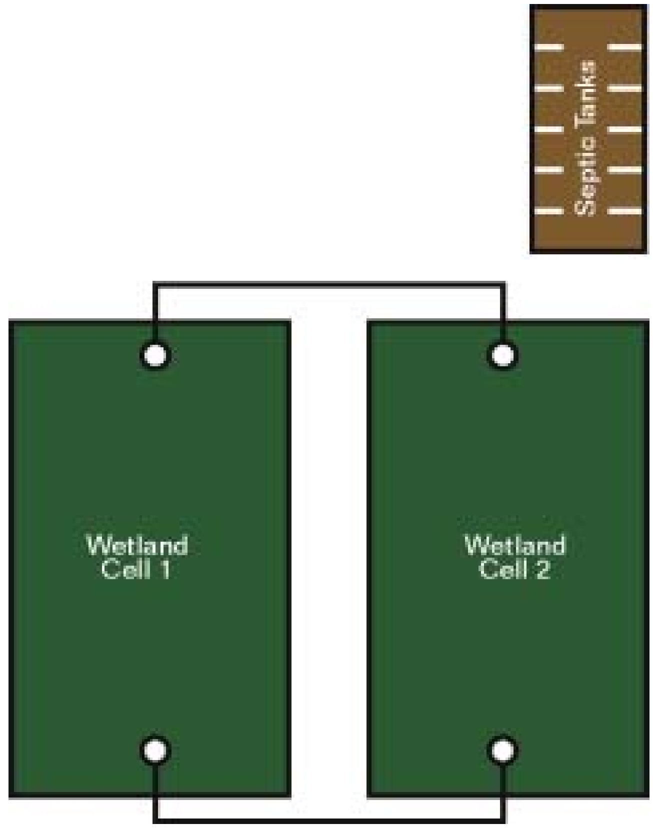
The design method used is based on first order plug flow for BOD and the nitrogen removal model developed by Reed, Middlebrooks, and Crites[1]. The nitrogen model used assumes a that most of the nitrogen will be removed by the nitrification of ammonia and then the denitrification of nitrate. The uptake of nitrogen by the wetland plants is assumed to be negligible. This design procedure is an iterative process.

[1] Reed, Sherwood C., Crites, Ronald W., Middlebrooks, E. Joe, Natural Systems for Waste Management and Treatment, McGraw-Hill Inc., New York, 1995.

The kinetic equations are first used to size the wetland for BOD and nitrogen removal. A heat loss equation is then used to determine the temperature conditions in the wetland cell. This temperature is then used to modify the kinetic equations for BOD and nitrogen removal. This process is repeated until the temperatures calculated by both the kinetic equations and the heat loss equation agree.

Objectives

The primary design objectives for this system were to decrease BOD and TSS in the septic overflow. Nitrogen removal was also addressed by the design methods.



Size

This system has two parallel subsurface flow wetland cells that each have a surface area of 5000 square feet. The dimensions of the surface are 42' by 120'. The average wetted depth is 1.8 feet. The porosity of the gravel is 0.38.

Shape

As shown by the schematic, the wetland cells are rectangular. Each wetland cell has an aspect ratio of 2.9:1.

Hydraulics

The effluent from the septic tanks flows to a splitter box. Flow is discharge through to the subsurface wetland cells. Each wetland cell is fully lined with a 30-millimeter polypropylene liner to prevent groundwater interaction. Flow in the wetland was designed according to Darcy's Equation. Sufficient head was provided to ensure that flow would remain subsurface through the system, even in the event of some clogging in the bed. The water level can be maintained with a swiveling Tee attached to the outlet pipe. This system has experienced problems with maintaining a sufficient water level at the inlet portion of the system to promote plant growth. A temporary sprinkler system was installed to allow the plants to develop root structures that will intercept the water level in the wetland.

Treatment Goals

Treatment Goals	
BOD_5:	**10 mg/l**
TSS:	**50 mg/l**
TN (as TKN)	**40 mg/l**

Water Quality Data

This wastewater treatment facility operates under a groundwater permit. Since it is not discharging into a surface water, monthly discharge monitoring reports are not required. The U.S. Bureau of Reclamation and the U.S.G.S. are currently assisting the Center with performance testing of the wetland system. Data presented below are from the samples collected during this effort.

Removal rates in the wetland system varied over the two-year study period. BOD removal in the wetland system fluctuated from a low of 45% to a high of 97%. TSS removal fluctuated between 50% and 70% removal, with some internal loading of TSS experienced in the wetland. Some ammonia removal was noted, however internal loadings were also experienced in the wetland. Removal efficiencies are not operating at design levels.

Parameter	March 1998	July 1998	Sept 1998	Dec 1998	Jan 1999	July 1999	Sept 1999
Temp, °C							
Inflow	4.22	18.41	18.48	7.98	9.41	19.10	16.25
Cell 1 Outflow	0.76	15.78	15.50	3.63	2.53	15.26	11.25
Cell 2 Outflow	0.76	14.79	15.21	3.43	2.42	15.39	10.90
Conductance, µS/cm							
Inflow	969	918	966	684	763	1035	857
Cell 1 Outflow	960	863	865	773	717	844	954
Cell 2 Outflow	989	8449	933	720	748	827	929
DO, mg/l							
Inflow	0.31	0.79	2.36	1.75	1.46	1.72	7.78
Cell 1 Outflow	0.67	0.73	0.50	2.64	2.24	0.84	1.30
Cell 2 Outflow	0.46	0.51	0.61	2.45	1.90	0.87	2.03
pH							
Inflow	7.18	6.69	6.95	6.90	6.96	7.14	8.33
Cell 1 Outflow	7.20	6.89	7.03	7.14	7.11	7.28	7.25
Cell 2 Outflow	7.14	6.95	6.96	7.19	7.10	7.28	7.24
BOD, mg/l							
Inflow	310	210	130	180	255	295	140
Cell 1 Outflow	170	110	25	68	60	32	4
Cell 2 Outflow	190	61	13	<20	80	56	6
N-Ammonia, mg/l							
Inflow	34	61	50	36	54	85	53
Cell 1 Outflow	26	42	49	31	40	62	64
Cell 2 Outflow	32	37	54	30	34	62	62
N-Nitrate/Nitrite, mg/l							
Inflow	<0.5	<0.5	<0.5	<0.5	0.09	0.05	0.12
Cell 1 Outflow	<0.5	<0.5	0.07	0.35	0.11	<0.5	0.6
Cell 2 Outflow	<0.5	<0.5	0.07	0.32	0.09	<0.5	<0.05

Parameter	March 1998	July 1998	Sept 1998	Dec 1998	Jan 1999	July 1999	Sept 1999
N-Nitrite, mg/l							
Inflow	**<0.02**						
Cell 1 Outflow	**<0.02**						
Cell 2 Outflow	**<0.02**						
P-Total Phosphate, mg/l							
Inflow	**9.6**	**9.3.**	**7.8**	**11.6**	**10.1**	**10**	**7.9**
Cell 1 Outflow	**8.3**	**6.4**	**5.2**	**5.3**	**9.8**	**7.2**	**6.6**
Cell 2 Outflow	**8.5**	**6.7**	**6.0**	**5.5**	**10.9**	**7.3**	**6.9**
Dissolved solids, mg/l							
Inflow	**710**	**390**	**470**	**360**	**400**	**420**	**410**
Cell 1 Outflow	**630**	**398**	**340**	**370**	**360**	**320**	**350**
Cell 2 Outflow	**620**	**366**	**350**	**340**	**380**	**310**	**310**
TSS, mg/l		**50**					
Inflow	**44**	**42**	**40**	**44**	**41**	**72**	**76**
Cell 1 Outflow	**20**	**34**	**36**	**40**	**16**	**<40**	**<20**
Cell 2 Outflow	**26**		**32**	**20**	**22**	**<40**	**<20**
Fecal Coliforms, MPN/100ml							
Inflow	**1,600,000**	**1,600,000**	**240,000**	**1,600,000**	**>2419.2**	**>241,920**	**81,640**
Cell 1 Outflow	**40**	**22,000**	**430**	**8**	**>2419.2**	**48,840**	**1100**
Cell 2 Outflow	**11**	**50,000**	**210**	**13**	**>2419.2**	**98,040**	**740**

General Ecological Setting

The ponderosa pine forests surrounding the constructed wetlands at the Rocky Mountain Shambhala Center are generally open with varying tree density. An abundant herbaceous understory is associated with more open areas. This understory may include common wild geranium and sticky cinquefoil. Bunch grasses and sedges are also common in the open forests.

Cell Vegetation

Vegetation cover in both cells of the constructed wetland was less than 30 percent. Of the species present, cattail (*Typha latifolia*) is dominant. Other species include hardstem bulrush (*Scirpus acutus*), Nebraska sedge (*Carex nebrascensis*), beaked sedge (*Carex rostata*), curly dock (*Rumex crispus*), and wild iris (*Iris missouriensis*). Both willow (*Salix* spp.) and chokecherry (*Prunus virginiana*) were recently planted in less saturated areas of the subsurface wetland.

Planting/Seeding

The constructed wetland was planted in spring 1996 with three-square bulrush (*Scirpus americanus*), Colorado rush (*Juncus confuses*), sunflower (*Helianthus nuttallii*), hardstem bulrush, Nebraska sedge, beaked sedge, and wild iris. The initial planted suffered very high attrition due to the planting of bare root stock.

Weeds

Noxious weeds were not observed in the wetland. Areas without vegetation cover were heavily mulched with straw, which may have inhibited establishment by noxious weeds.

Maintenance Issues

Preventing damage to newly planted willow and cherry should be considered. The three most successful methods for limiting damage from deer, rabbits, and other animals include—

1. Fencing to exclude deer. Conventional deer-proof fence is 8 feet high and constructed of woven wire. Enclosures can also be constructed for individual seedlings and designed to exclude both deer and rabbits.
2. Installing tubes of netting around individual seedlings and small trees. The material (Vexar) degrades in sunlight and breaks down in 3 to 5 years. These tubes can be installed to protect only the growing terminals, or can completely enclose small trees.
3. Installing budcaps. Budcaps are rectangular pieces of material folded and stapled around the terminal branch. They form a protective barrier around the leader and bud.

Wildlife

Vegetation in the constructed wetland provides habitat for songbirds and small and mid-sized mammals. A heavy browse line attributed to mule deer was observed on the willows and cherry. Cottontail rabbits were observed consuming the buds of these plants. In general, the constructed wetland does not add to wildlife habitat available in the surrounding landscape. Wildlife habitat and habitat diversity rated low. Total functional points were 30% of the total possible, and this wetland was rated a category IV wetland.

Wetland Biodiversity Functional Assessment

Wetland biodiversity functional assessment.

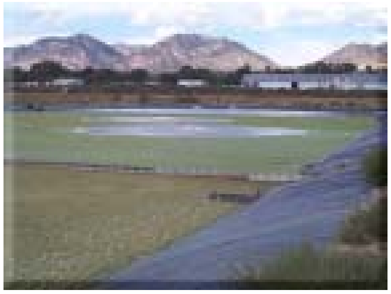
Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.1 (low)	1
General Fish/Aquatic Habitat	NA	1
Production Export/Food Chain Support	0.1 (low)	1
Habitat Diversity	0.1 (low)	1
Uniqueness	0.2 (low)	1
Total Points	1.5 (30%)	5
Wetland Category (I, II, III, or IV)	IV	-

Human Use

From a human use perspective, the Rocky Mountain Shambhala Center treatment wetland was designed as an integral part of the landscape. Wastewater treatment is regarded within the context of the Center's land management. This wetland has low aesthetic value because it is dominated by areas of bare gravel and weedy species.

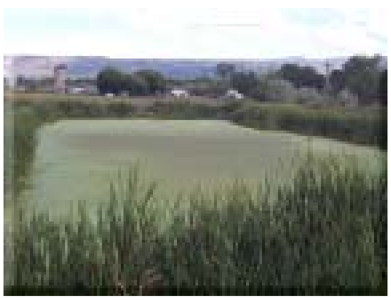
Overall Site Comments

The wetland system has experienced some trouble with establishment of plants. Water quality data show that the system is not operating to the level intended. However, it does perform the function of polishing septic overflow before discharge into an evaporative lagoon. An abandoned sewage lagoon provides open water habitat for waterfowl.



View of lagoons

Wetland cells



Sunken wetland cell

View towards discharge point

Silt Facility Statistics	
Nearest Town:	Silt
County:	Garfield
River Basin:	Lower Colorado
Receiving Water Body:	Colorado River
Year Online:	1992
Population:	1700
Elevation (feet):	5700
Design Flow (mgd):	0.236
Average Flow (mgd):	0.110
Size (acres):	0.83

Facility Description

The Silt wastewater treatment facility is a domestic minor municipal lagoon system. The system consists of influent Parshall flume for flow monitoring, two aerated lagoons, a polishing pond, surface flow constructed wetlands, chlorine gas disinfection, and a V-notch weir for effluent flow monitoring.

Lagoons

Silt operates a 3-lagoon system. The first cell is a shallow (5') aerated cell, with 4 – 5hp aerators. The second cell is aerated with 3 – 5hp aerators. The third cell is used as a polishing pond. Piping is provided to allow subsurface flow between the cells. However, surface transfers have been observed. Excessive algae growth has been experienced in the lagoon. Operators have attempted to alter the effluent piping to avoid algae, installed a fabric liner on the lagoon surface to prevent sunlight penetration, and most recently introduced duckweed into the lagoon cells.

Background Information

In February 1991 Silt was given a Notice of Violation and Cease and Desist Order. In 1992 a 0.85 acre constructed wetland was added to assist with algae removal from the shallow, 5-foot deep, 57-day detention time lagoons. The wetlands have experienced performance problems leading to ongoing compliance difficulties for Silt. Problems with the wetland have included an unintended plumbing by-pass from lagoons directly to the chlorine contact chamber, piping from lagoons pulling from surface of water, large areas of the wetland cells not filled in with vegetation and muskrat damage. In November 1999 the CDPHE issued a Notice of Significant Noncompliance for failing to meet BOD and TSS limitations, as well as failure to repair / replace their flow measuring devices. At the time of the site visit, Silt was in noncompliance.

Energy Analysis

The wastewater flows through the Silt system by gravity. The aerated lagoons utilize 7 – 5hp submersible aerators. The aerators run 24 hours a day, 7 days a week. Energy costs at this site are approximately $1800 per month.

Wetland Design

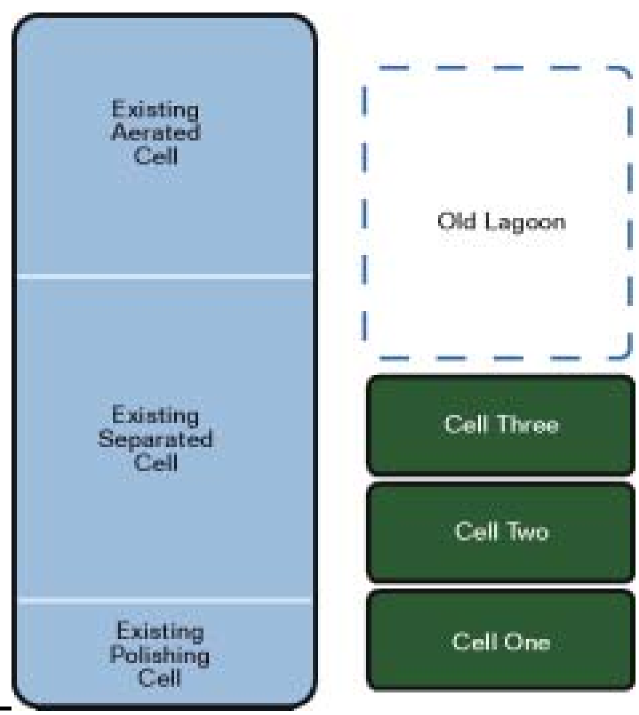
Design Methods

The Silt facility has one of the older treatment wetlands in Colorado. It was determined that a surface flow constructed wetland was the best option for this site because land was available and cost could be minimized by utilizing City crews to perform the earthwork. The wetlands were sized to

Objectives

This site has had ongoing problems with excessive BOD and TSS effluent from their shallow lagoon system.

Size



The wetland system consists of three wetland cells that are approximately 120' by 100'. The total surface area for all three cells is 0.83 acres.

Shape

The wetland cells are rectangular, with an aspect ratio of 1.2:1. The flow path is direct.

Hydraulics

The original hydraulic design of this system included a 'step-feed' distributor as a part of the influent system. Introducing the wastewater in this manner distributes the wastewater more uniformly across the wetland surface area than a typical header distributor pipe. Silt found that more detention time was needed in the wetland, and subsequently, changed the influent to the distributor pipe at the head of each wetland cell.

A splitter box is provided to allow the lagoon effluent to bypass the wetland cells. Adjusting the v-notch weir at the inlet controls water level in the wetland.

The wetland cells were originally designed to be able to be dewatered. Unfortunately, the bed of the wetland cells sank about 18" due to the weight of the wetland media, vegetation and water. This resulted in areas within the wetland that cannot be dewatered. Pea gravel was added to two of the cells in order to raise the ground level and allow plant establishment. The third cell was not easily accessible, and the addition of gravel was not feasible. It has standing water and large, unvegetated areas.

A pvc liner is provided in the wetland cells to prevent groundwater interactions.

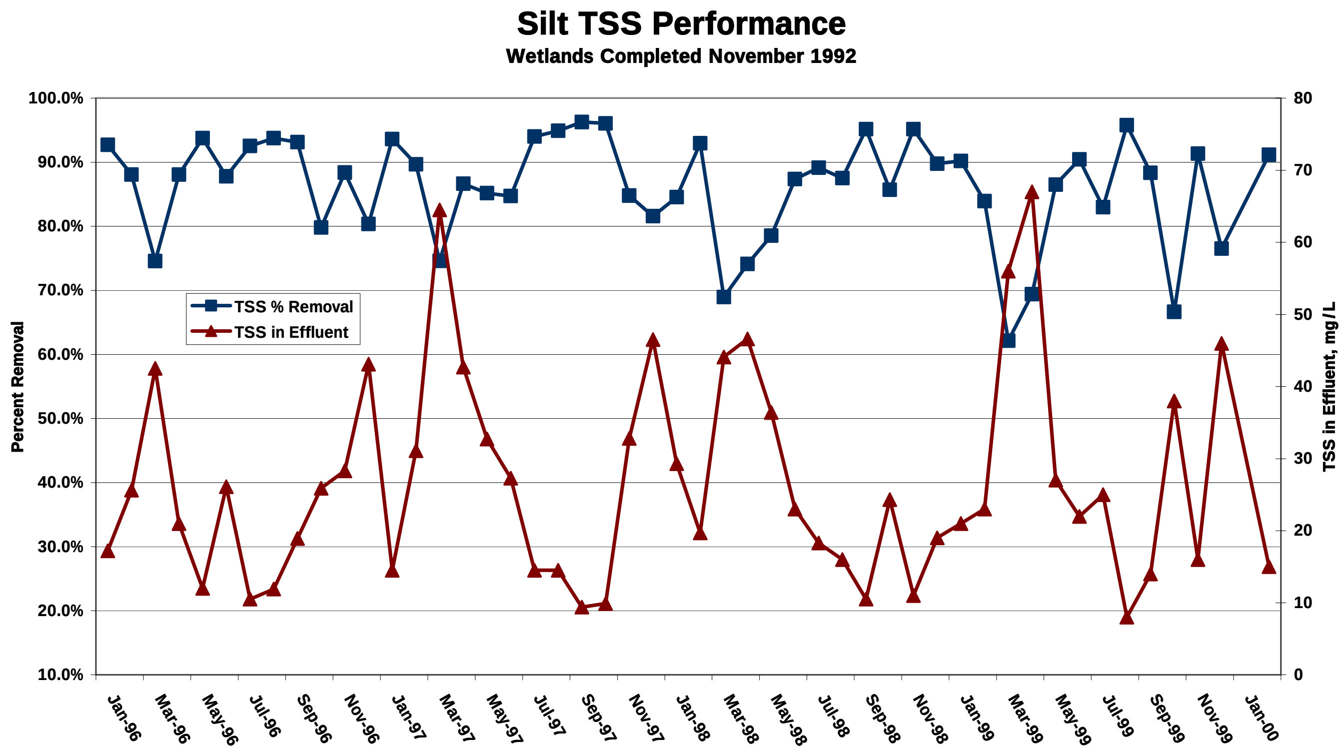
Treatment Goals

Permitted Discharge Limitations	
Oil and Grease:	**10 mg/l (Daily Max)**
BOD_5:	**30 mg/l (30-day ave)**
BOD_5 Removal:	**85%**
TSS:	**75 mg/l (30-day ave)**
PH, su (min – max)	**6.0 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**6,000 organisms per 100 ml (Daily Max)**

Water Quality Data

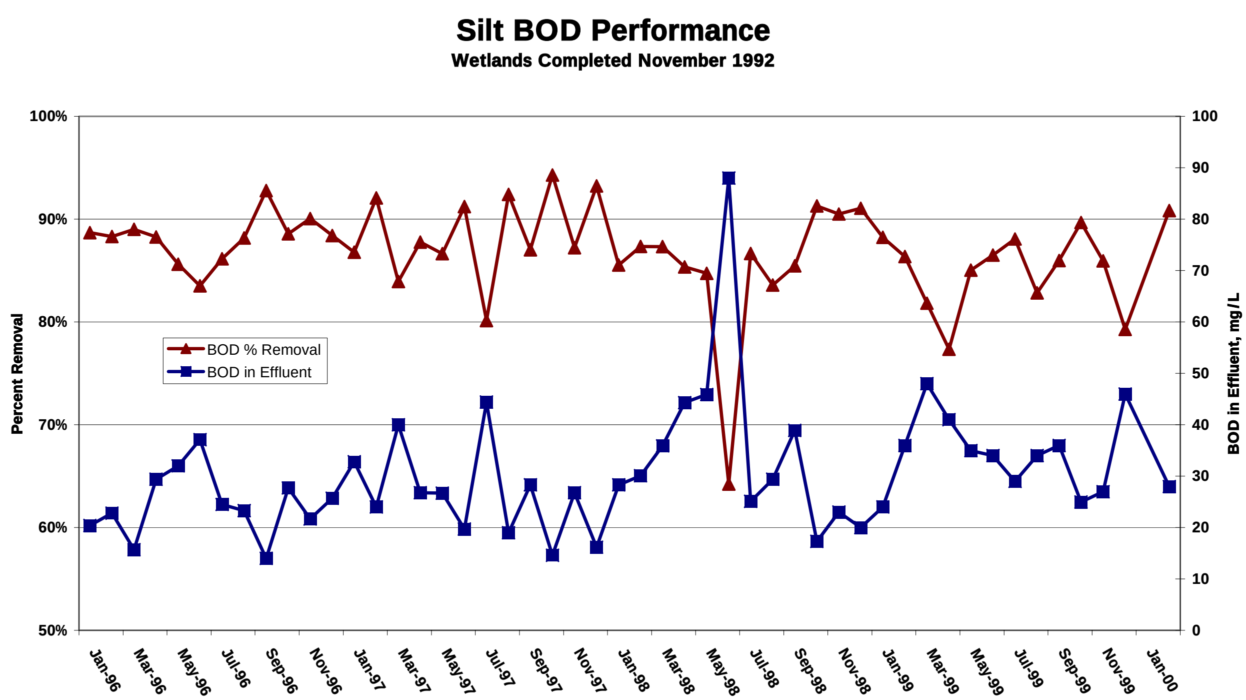
TSS Data

The TSS graph plots the percent removal on the left axis and TSS in mg/l in the effluent on the right axis. The average monthly TSS in the influent, during the period of record, has been 202 mg/l and the average monthly effluent has been 27 mg/l. This meets the permit discharge requirement of 75 mg/l.



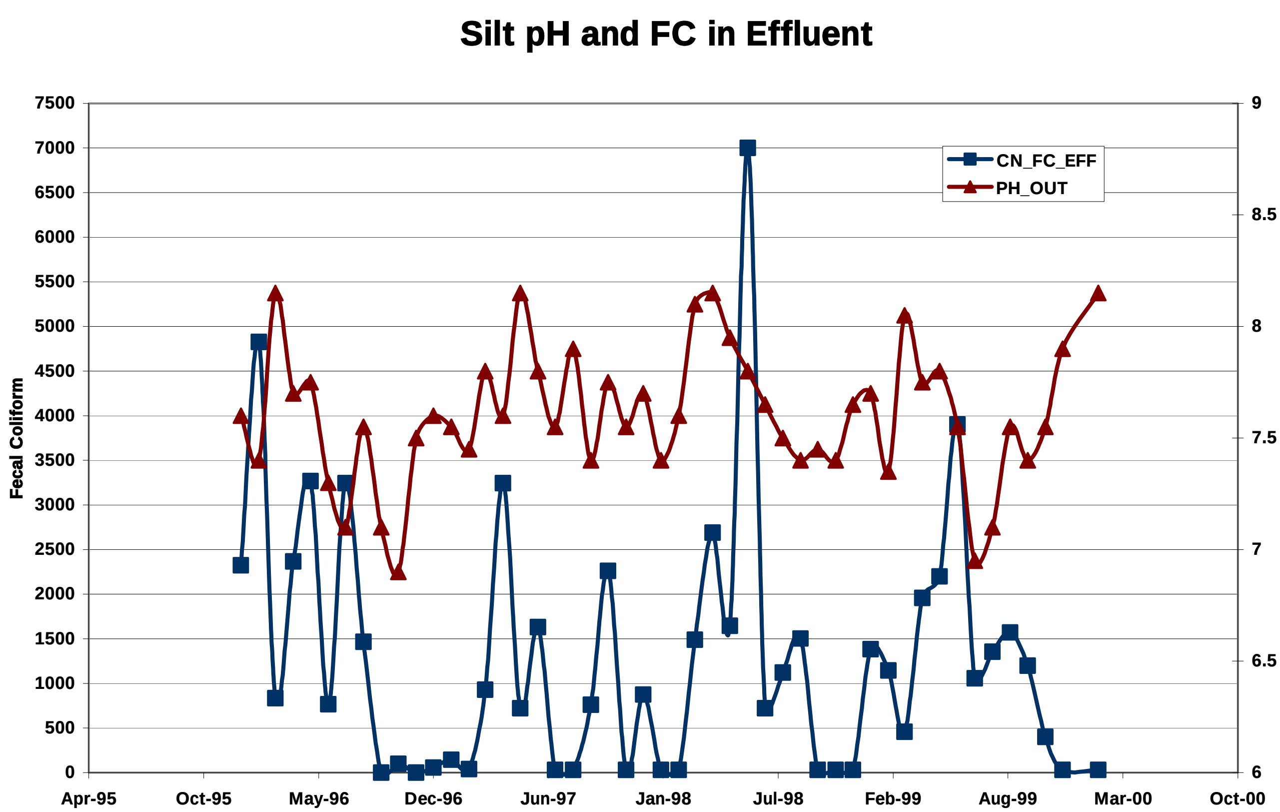
BOD Data

The BOD data is plotted similarly to the TSS data, with mg/l in the effluent on the right axis, and percent removal on the left axis. . The average monthly influent amount has been 229 mg/l and the average monthly effluent amount has been 30 mg/l. Several exceedances of the permit limitation have been experienced.



pH and Fecal Coliform

Data for these two categories have been plotted on the same graph. Data reflect the quality of the effluent; no influent measurements are taken for these parameters. The pH values plotted are an average of the minimum and maximum 30-day values that are reported in the monthly reports. During the period of record, pH values have consistently stayed within the allowable range of 6.5 to 9.



General Ecological Setting

The Colorado River corridor in the Silt area contains a number of diverse wetland and riparian communities that occur on islands, point bars, and along the banks. Much of the vegetation along the river has been altered. The land now supports landscape along the irrigated agricultural areas including most row crops, irrigated pastureland and hay fields and associated farm or ranch facilities.

Cell Vegetation

The dominant species in all three cells are cattail (*Typha latifolia*) and duckweed (*Lemna minor*). Cell 1 has a 50 percent cattail/50 percent duckweed cover. Cell 2 is 80 percent duckweed and 20 percent cattail, and cell 3 is 80 percent cattail and 20 percent duckweed. All three cells have traces of curly dock (*Rumex crispus*), lady's thumb (*Polygonum persicaria*), yellow sweet clover (*Melilotus officionale*), and tamarisk (*Tamarix chinensis*)

Planting/Seeding

Cattails were harvested from adjacent areas and planted during the spring.

Weeds

Tamarisk is a State Noxious Weed. Impacts of tamarisk include: (1) dewatering of sites; (2) crowding out native species causing a loss of biodiversity; and (3) providing less habitat values compared to functioning riparian areas with native species.

Maintenance Issues

One cell was burned in the spring to remove aboveground cattail biomass. Duckweed needs to be harvested annually before the first frost.

A short-circuiting in the system was allowing a substantial portion of the discharge to go directly to the chlorine contact chamber without passing through the wetlands.

Wildlife

The constructed wetland does not add significantly to habitat otherwise present in the immediate area. The Colorado River system supports flora and fauna of the area. Waterfowl, songbirds, small mammals, amphibians, and reptiles may use the constructed wetland. The general wildlife habitat and habitat diversity were low to moderate in value. Total functional points were 46% of the total possible, and it rated as a category III wetland.

Muskrats tunneled into berms, cut vegetation and made muskrat lodges. The community retained a local trapper and it was estimated that there might have been 30 to 40 animals present in the wetlands. The Town staff replaced the fill on the berms and placed wire mesh rodent barrier on the top and flanks of the berms. A raptor perch was also constructed on the edge of the wetlands to encourage owls, hawks and eagles to control the muskrat population.

Wetland Biodiversity Functional Assessment

Wetland biodiversity functional assessment.

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.5 (mod.)	1
General Fish/Aquatic Habitat	0.0	1
Production Export/Food Chain Support	0.4 (low)	1
Habitat Diversity	0.2 (low)	1
Uniqueness	0.2 (low)	1
Total Points	2.3 (46%)	5
Wetland Category (I, II, III, or IV)	III	-

Human Use

The wastewater wetland is part of a restricted public access area, and has never been used for educational purposes. This wetland has moderate aesthetic value. It has good vegetation cover.

Overall Site Comments

The wetland at the Silt facility has not functioned as intended. In part, this is because the wetland cells were not constructed in accordance with the approved design plans. The wetland cells bottoms were found to be uneven, short-circuiting problems due to plumbing went unchecked, and the sinking of the wetland led to excessive water depth in the cells.

Valmont Power Plant

View of the Valmont Power Plant

Septic tank that precedes the wetland cells

Wetland cells

Team during wetland investigation

Valmont Power Plant Statistics	
Nearest Town:	Boulder
County:	Boulder
River Basin:	South Boulder Creek
Receiving Water Body:	Hillcrest Lake
Year Online:	1993
Population:	100
Elevation (feet):	
Design Flow (mgd):	0.50
Average Flow (mgd):	0.25
Size (acres):	0.03

Facility Description

The Valmont Power Plant has two separate subsurface wetland treatment systems. These subsurface wetland cells treat on-site domestic wastewater from office buildings. Each wetland follows a septic tank.

Background Information

The Valmont Power Plant had experienced problems with its leach field. A cost analysis determined the implementation of a subsurface wetland system to be the cheapest option by far. to implement subsurface wetlands in place of traditional leach fields. These subsurface wetlands have been operating since 1993, with no reported problems.

Energy Analysis

No energy is consumed by the wetland treatment systems.

Construction Cost

The cost to construct the wetland systems was $450,000.

Wetland Design

Objectives

The wetlands were designed to polish the septic overflow. In particular, the wetlands reduce the BOD and TSS to permitted discharge levels. The wetlands were sized to provide adequate detention time for 0.003 mgd.

Size

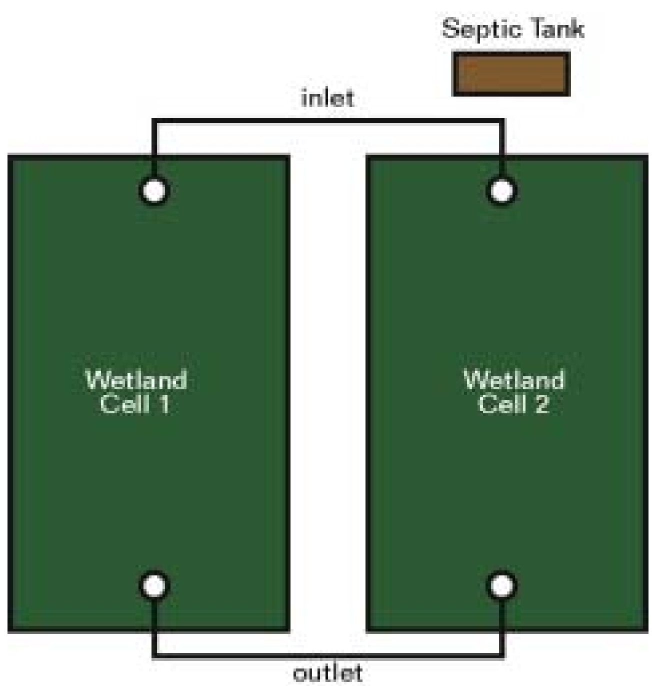
The wetlands cells are 68’ by 22’.

Shape

The rectangular wetland cells have an aspect ration of 3:1.

Hydraulics

A splitter box collecting effluent from the septic tank was removed and currently septic overflow flows directly into the wetland cells. Perforated pipes are buried at the inlet to the wetland and flow by gravity through the system. Groundwater infiltration into the pipeline between the facility and the septic system has led to excess flows into the system.



Treatment Goals

Permitted Discharge Limitations	
BOD_5:	**30 mg/l (30-day ave)**
TSS:	**105 mg/l (30-day ave)**
PH, su (min – max)	**6.5 – 9.0 (Daily Max)**
Chlorine Residual:	**0.5 mg/l (Daily Max)**
Fecal Coliform Bacteria:	**2,000 organisms per 100 ml (Daily Max)**

Water Quality Data

No water quality data are available for this site. The discharge permit requirements were modified for this site in order to consolidate outfall testing. Since the discharges from the wetland systems are a very small portion of the total flow discharged from this facility, and the discharge from the wetlands is into an internal source, it was determined that discharge monitoring tests will be taken at the final discharge from the property.

General Ecological Setting

The Valmont Station wetlands are flat, rectangular basins occurring in Boulder County at Excel Energy's Valmont Power Station. The wetlands are located adjacent to the power plant and are surrounded to the north, east, and south by Leggett, Valmont, and Hillcrest Reservoirs. The reservoirs support large populations of fish, waterfowl, and migratory birds.

Cell Vegetation

Valmont Station contains constructed wetlands at two sites. Site 2a has two cells, each of which is approximately ¼ acre. Cell 1 is dominated by cattail (*Typha latifolia*) and softstem bulrush (*Scirpus tabernamontanae*) with curly dock (*Rumex crispus*). Cell 2 has two vegetation communities. Plant community 1 covers comprises about 70 percent of the vegetation cover in cell 2. This community is dominated by reed canarygrass (*Phalaris arundinacea*), curly dock, crack willow (*Salix fragilis*), and hawthorne (*Crategeus ravalii*). Plant community 2 covers the remaining 30 percent of the wetland and is dominated by Canada thistle (*Cirsium arvense*), prickly lettuce (*Lactuca seriola*), catnip (*Nepeta cataria*), willowherb (*Epilobium ciliatum*), cheatgrass (*Bromus tectorum*), and mullein (*Verbascum thapsus*) with a few golden currant (*Ribes aureum*) individuals. Plant community 1 occurs in areas of the cell where water is close to or above the gravel surface. Plant communities 2 and 3 occur where the water surface is lower.

Site 2b has one cell (approximately ¼ acre)that has two vegetation communities. Cattail, ragweed, softstem bulrush, and Canada thistle cover 90 percent of the cell, and a curly dock/Canada thistle community with ragweed, prickly lettuce, and golden currant occupies 10 percent of the cell.

Planting/Seeding

Cattail, softstem bulrush, common reedgrass (*Phragmites australis*), and reed canarygrass (*Phalaris arundinacea*) were planted, mulched, and fertilized. Upland areas were also seeded with native species. Of the species planted, cattail and reed canarygrass were the most successful, and dominate most of the site. Common reedgrass was not recorded in either cell.

Weeds

In site 2a, cells 1 and 2, Canada thistle, cheatgrass, prickly lettuce (*Lactuca seriola*) and mullein (*Verbascum thapsus*) are present in the reed canarygrass community, and occur around the edges of the cattail community. In cell 2, the Canada thistle community is dominated by Canada thistle. It also contains about 5 percent cover by cheatgrass. Canada thistle, mullein, and cheatgrass (also called downy brome) are State Noxious Weeds. All of these weed species are particularly invasive in areas of recent disturbance, and spread quickly. These weeds prevent the establishment of, or displace, native species and have low value as wildlife habitat.

Maintenance Issues

There were no unusual maintenance issues related to plant health at this site. The cell inflow and outflows are periodically cleaned, and the wetlands have been burned in the past, although not frequently.

Piping within the system must be roto-rooted, and the septic tanks are pumped on an annual basis.

Wildlife

The constructed wetland at Valmont Station provides habitat for songbirds. Red winged blackbirds were observed at the site visit. Geese were a concern during wetland establishment and may still use the site. Although the wetlands are not structurally diverse, their location adjacent to the three reservoirs make them more valuable to songbirds and waterfowl.

Wetland Biodiversity Functional Assessment

Sediment/nutrient/toxicant removal rated high. General wildlife habitat rated moderate, and all other parameters rated low. This wetland received 35 percent of the total possible function points, and its overall function was rated a category III.

Wetland biodiversity functional assessment

Function and Value Variables	Functional Points (0.1 to 1)	Possible Points
General Wildlife Habitat	0.3 (low)	1
General Fish / Aquatic Habitat	NA	1
Production Export / Food Chain Support	0.6 (mod.)	1
Habitat Diversity	0.1 (low)	1
Uniqueness	0.1 (low)	1
Total Points	2.1 (42%)	5
Wetland Category (I, II, III, or IV)	III	

Human Use

The wastewater wetland is part of a restricted public access area, although some students from the Boulder area have visited the site. Xcel Energy, formerly the Public Service Company of Colorado, conducts tours of this historical power plant for school or other community groups. The wetlands at this site have moderate aesthetic value. The wetlands are dominated by a mix of vegetation, and are located adjacent to large reservoirs.

Overall Site Comments

This site functions as intended for wastewater treatment and it also has some wildlife value both because of the varied plant communities in the wetland cells and because it is located adjacent to large reservoirs. This subsurface wetland system has been in operation over 12 years without any significant problems.

General Observations

Chapter Highlights

Treatment wetlands across Colorado are effectively treating wastewater and meeting discharge requirements.

Wetland cells are generally rectangular in shape. A few examples of wetlands with irregular borders provided increased aesthetic and wildlife habitat value without jeopardizing treatment capability.

Treatment wetlands can be designed to operate with negligible energy requirements.

Overview

The project team identified twenty constructed wetlands currently permitted to treat municipal wastewater. An on-site analysis was performed for each of these facilities. Of these sites 13 were surface flow wetlands, 5 were subsurface flow and 2 operated as a combination of surface and subsurface flow.

In addition to the municipal systems, a total of 8 on-site residential treatment, stormwater treatment and commercial wastewater treatment facilities were identified and visited. These wetland sites are discussed briefly in Chapter 6, but were not included in the more rigorous analyses applied to the municipal wastewater facilities.

The project team visited all 20 municipal systems in order to visually examine the systems. Each visit was merely a ‘snapshot in time’. As such, team members relied on treatment facility operators and data files to provide a comprehensive understanding of each system. Since this study was limited to existing data, CDPHE permit files were another important resource for providing a historical context for each system’s performance.

Discussed below are the compiled findings of the study.

Facility

The municipal treatment facilities in Colorado with wetland components utilize preliminary and primary forms of treatment before discharging into the wetland cells. The most prominent treatment process is the use of lagoons as primary treatment with the wetlands serving the function of secondary treatment. Septic tanks are another form of primary treatment used in a wetland treatment facility.

Lagoons

Shallow lagoon systems were a popular form of wastewater treatment at one time. The rationale behind using a shallow lagoon system included providing complete aeration of the shallow water column in order to provide a completely aerobic lagoon without the use of mechanical aerators. A problem encountered with these shallow lagoons is the excessive growth of algae that is carried over in the lagoon effluent. This algae carry-over results in exceedances of BOD and TSS limitations. The use of deeper lagoons allows the operator to vary the level of the discharge pipe in the water column in order to avoid algae growth and the sedimentation layer.

Septic Tanks

Overflow from septic tanks can be discharged into a wetland rather than traditionally used leach fields. Septic tanks remove solids and greases from the raw wastewater. All of the Colorado treatment wetlands utilizing septic tanks as primary treatment were subsurface flow systems.

Background

Interviews with operators and review of CDPHE files provided a historical context for each wetland site. Each site's background information was reviewed in order to answer the question 'why were wetlands chosen to be a part of the treatment system'. The following were the top reasons communities in Colorado have chosen wetland treatment systems.

Remediation of Noncompliance

Providing compliance for historically noncompliant systems is a common reason for retrofitting wastewater systems with a wetland component. Many of the sites visited had shallow lagoon systems with large algae blooms. These shallow lagoons do not have the ability to vary the depth from which water is pulled off the system, and therefore are prone to discharging algae particles. Adding wetland systems provided treatment for the algae carryover.

Aesthetic - Constructed wetlands blend into rural areas where traditional physical facilities would detract from the overall scenic beauty of a rural area.

Part of Mission - Colorado wetlands were also chosen in some areas due to their ability to fit in with an organization's overall mission and goals to promote natural processes. For example

Low Tech - Rural areas often lack the trained personnel to operate complex mechanical systems.

Retrofit - Abandoned lagoons can be retrofitted into a wetland system with minimal excavation work.

Energy

Treatment Components

The wetland systems themselves do not require electric or fuel sources of energy. All of the treatment wetlands in this inventory were designed to operate under gravity flow conditions with no mechanical devices needed for the wetland cells' treatment processes. Heavy equipment may be used once a year, or once every few years, for harvesting and removal of wetland plants. Most of the energy expended on the wetland systems is manual labor necessary for maintaining the system. The amount of electrical and fuel energy that these facilities require is determined by the other treatment components being used, such as aerators and mixers.

Lagoons

Of the 20 sites inventoried, 17 used lagoon systems for primary treatment. Of these 17 lagoon systems, all but one used mechanical aeration devices. Energy requirements for the aeration system depend on the horsepower of the aerators and the operating schedule adhered to. The operating schedule has a large impact on the efficiency of a system. For example, adhering to an operating practice in which the aerators are operated continuously during the winter months, and only 8 hours during the night in the summer months results in the aerators operating for 4800 hours per year. For a lagoon with five, 5hp aerators, this results in an energy consumption of approximately 90,000-kilowatt hours per year. In contrast, operating the same five aerators on a continuous basis year round results in an energy consumption of 163,000-kilowatt hours per year.

Septic Systems

Three of the facilities visited treated wastewater in septic tanks before release to the wetland cells. Energy expenditures with these systems are associated with lift stations in the collection system, rather than components of the treatment processes. All three of the facilities using septic tanks as preliminary treatment incorporated subsurface flow wetland cells into the treatment process. Sufficient hydraulic head was provided to allow gravity flow through the wetland cells.

Headworks

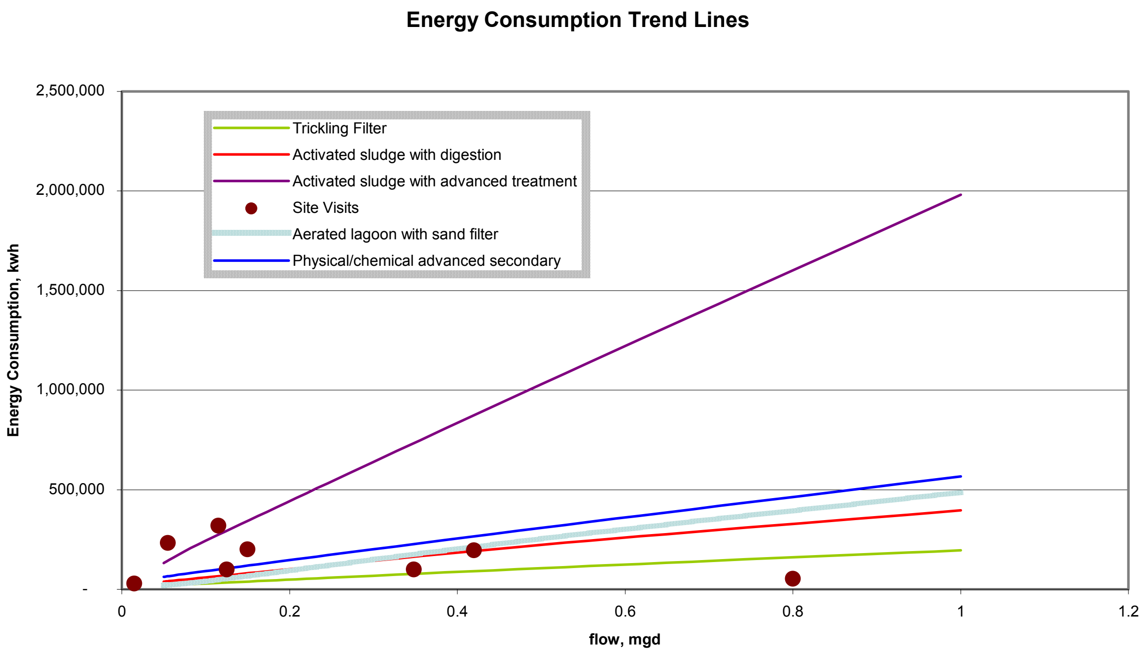
Facilities that receive non-traditional domestic wastewater may need to invest energy in pretreatment. Three of the Colorado treatment wetlands received prison wastewater. Solids-removal devices, such as grinders, are often necessary to remove items that are common in prison wastewater due to prisoners flushing items for protest purposes. These devices must operate continuously, and are large energy consumers.

Energy Costs

Typical utility bills were used to determine energy consumption for entire facilities. This energy consumption includes energy necessary to operate lighting, and miscellaneous uses of energy for measuring equipment and on-site office space. A typical utility bill for the sites visited is around $800 per month. At approximately six cents a kwh, this translates into an energy use of 13,300 kwh pr month, or 160,000 kwh per year.

Comparison to Other Treatment Methods

The energy consumption study undertaken by Middlebrooks (as discussed in Chapter 4) determined energy costs for different treatment methods based on the flow through the treatment facility. The figure below shows trend lines for some common treatment methods. The range of energy use by the facilities using wetlands is indicated on the graph.



The primary consumer of energy at these sites was the operation of aerators for primary treatment lagoons. The use of alternative energy sources, such as solar or wind energy, would reduce the energy consumption of these treatment facilities to near-negligible levels.

Operation and Maintenance

Typical man-hours

Operators typically spend about 2 hours a day at the treatment site. Maintenance includes annual harvesting and / or burning. The operator must maintain flow through the hydraulic system, which requires cleaning out pipes. Other maintenance issues include adjusting water levels, preventing damage due to wildlife, and performing required tests.

Certification

Operators must have at least a class D wastewater treatment license. During the course of the project, it was noted that the training required to get an operator license does not include the operation of natural systems.

Wildlife control

Wetlands will attract wildlife. Incidents of serious damage to wetland sites were recorded. Muskrats were often the culprit in overgrazing of aquatic plants, breaching of wetland berms, and clogging of pipes. However, with appropriate mitigation efforts, wildlife damage can be minimized

Design

Design Methods

Wetlands were designed primarily for BOD removal. Some sites went through calculations to determine size requirements assuming plug-flow reactions and first-order kinetic relationships.

A two-year study completed in 1994 for the Colorado community of Las Animas provided many systems with empirical data from which to size their systems.

Some systems used the guidelines provided by the CDPHE to size systems based on influent flow rates. The Design Criteria adopted by CDPHE for constructed wetlands systems is shown below.

	Treatment Objectives			
	Secondary Treatment		Advanced Treatment	
System Use	Surface Flow	Subsurface Flow	Surface Flow	Subsurface Flow
	Acres / MGD	Acres / MGD	Acres / MGD	Acres / MGD
Basic Treatment	NA	40-15	NA	≥30
Secondary Treatment	75-20	20-5	≥50	≥20
Polishing Treatment	50-10	20-5	≥30	≥20

CDPHE Volumetric Loading Guidelines

The area to flow ratios for the Colorado treatment wetlands vary considerably, as shown by the table below

Site	**Size**	**Design Flow**	**Acre/MGD**
Avondale	0.87	0.11	7.9
Bennett	2	0.42	4.8
Calhan	0.31	0.8	0.4
Crowley	3.04	0.17	17.9
Crowley Correctional Facility	3.3	0.15	22
Delta Correctional Facility	1.38	0.067	20.6
Dove Creek	1	0.115	8.7
Highland Presbyterian Camp	0.014	0.0005	28
Hi-Lands	0.21	0.055	3.8
Horizon	1	0.015	66.7
Island Acres	1	0.02	50
La Veta	1.6	0.125	12.8
Las Animas	2.1	0.5	4.2
Manzanola	2.3	0.125	18.4
Ouray	0.76	0.363	2.1
Platteville	3	0.348	8.6
Ridgway	1.5	0.015	100
Rocky Mountain Shambhala Center	0.23	0.05	4.6
Silt	0.83	0.236	3.5
Valmont	0.03	0.5	0.1

Shape

Many of the wetlands were retrofit into abandoned lagoons and therefore had to be rectangular. It is often necessary, and at least desirable, to minimize the size of the wetland. To this end, many of the wetlands were compacted into a u-shaped design with a serpentine flow path. This design maximizes the length to width ratios in a minimal area. A few of the wetlands provided islands and irregular borders. These features do not interfere with the water treatment function of the wetland, but they do significantly enhance the wildlife value of a wetland by providing niches for various habitats. These features also add to the aesthetic appeal of a wetland.

Size

The wetlands ranged in size from 0.014 acres to 3.3 acres. Surface flow wetlands typically require more surface area than subsurface flow wetlands. The wetland size must be sufficient to provide the desired water depth and hydraulic detention time.

Hydraulics

Simple piping is always best. The sites visited used typical pipe diameters of 4” to 2” to distribute the wastewater within the wetland cells. Plugging was a common maintenance issue. The piping systems should provide easily accessible clean-out stubs and adequate diameters for jetting (flushing out with high pressure water) out the pipes.

In-flow

Perforated irrigation pipe was commonly used to distribute the flow across the head of the wetland cells. The spacing between the slots can be determined by adjusting the slot openings. Subsurface wetlands typically use dendritic piping down the length of the wetland cells to distribute the influent.

Out-flow

Slotted irrigation pipes, and adjustable weirs were used to collect the effluent from the ends of the wetland cells.

Water Level Control

The ability to adjust the water depth in the wetland was determined to be a crucial matter for the following reasons:

- If needed, detention time in the wetland can be extended by increasing the water depth
- Plant growth can be assisted by lowering the water level in a surface flow wetland to prevent the ‘drowning’ of seedlings, or by increasing the flow depth in a subsurface flow wetland to allow the young roots to establish themselves
- Muskrat infestations can be minimized by allowing wetland cells to dry-up
- Anaerobic conditions can be reversed by lowering the water level

Common water level control devices are shown below.

Swiveling Tees

Collared controls

Levees with removable boards

Water Distribution

Effective operation of the wetland requires the ability of the operator to isolate and bypass system components. This allows systems to be taken off-line for maintenance.

Material Selection

Common materials used were wood boards for level control, pvc pipes, wood for berms, earthen berms, and concrete berms. If the long-term maintenance of the wetland will require burning, material should be chosen in the design phase that will minimize potential damages. For example, wooden berms and pvc pipe stub-outs may need additional protective measures during burns.

Biological Perspective

In general, the treatment wetlands included in the study had healthy vegetation cover, however, the treatment wetlands often lack vegetation diversity. In most of the wetlands included in the study, broadleaf cattail or other aggressive introduced species, are generally the dominant plants. Cattail are aggressive colonizers of wetlands, and form a dense cover quickly. From a wastewater treatment standpoint, this plant is effective because it is easy to establish and maintain. From the standpoint of vegetation diversity and wildlife habitat, however, this plant is not considered by ecologists and wildlife managers to be of high value. Cattail often forms monospecific stands and is so aggressive that other species cannot colonize habitats in which it is dominant. Also, only a limited number of wildlife species use these monospecific stands. Treatment wetlands dominated by cattail are easy to maintain, and function in treating wastewater as well as a more diverse species mix, but from a strictly biological perspective, they do not provide exceptional habitat.

Annual weeds are common in upland areas around almost all of the treatment wetlands. While annual weeds generally are not considered noxious, they are not considered desirable. Treatment plant operators and designers are probably not focused on the maintenance of upland areas between wetland cells and lagoons, but seeding grasses and controlling weeds in these areas would be a good management practice.

In some instances, providing vegetation diversity and wildlife habitat may be at odds with management of a site to treat wastewater. Wildlife use can damage liners of treatment wetlands and dead vegetation harvested by muskrats can clog outflows of treatment wetlands. Also, ease of maintenance and consequently low operating cost is often more important to treatment facilities than vegetation diversity or wildlife habitat. In cases where providing for biological, aesthetic, recreational, and educational resources is important, however, treatment wetlands can be designed to provide these functions.

Human Use and Aesthetics

Wetlands offer ancillary benefits to the communities for which they treat wastewater. These benefits can be enjoyed at minimal additional work and/or cost at the site. Some of the ancillary benefits noted at Colorado wetland sites are:

- Interpretive centers along trails
- Local schoolchildren and touring group field trips
- Science fair projects
- Graduate students’ research projects
- Inmate training

Water Quality Data

This study only reviewed existing data. Most of the systems are consistently in compliance with their discharge permit requirements. Historical data depict a marked improvement in BOD and TSS removal rates for systems that were retrofit to include a wetland system. The average BOD in the system effluent was 20.5 mg/l and the average TSS in the effluent was 27 mg/l.

Also of concern in a wastewater treatment facility are pH, and fecal coliform levels. Typically, s system must maintain pH's in the range of 6-9 in order to minimize disturbances to the receiving water body. Fecal coliform levels are monitored to ensure that microorganisms and viruses are destroyed before discharge. Detention times, and sunlight exposure are often sufficient to reduce fecal coliform levels to permit requirements, without the use of additional disinfection. As a precaution, all the wastewater treatment facilities had the ability to provide some form of disinfection when needed.

Overall System Observations

System Age

The oldest constructed treatment wetland in Colorado is the Horizon Nursing Home system, in the Town of Eckert. This surface flow system was implemented in 1988 and has consistently met its discharge permit requirements since coming online. Plants were healthy and the ecosystem appears to be thriving. The system has not experienced diminishing treatment functions.

Newer systems experience a start-up period in which the wetland plants and microorganisms are becoming established. Until these biological systems are fully developed, the wetland operates as a physical filter. Treatment goals may not be reached during this period.

System Type

Colorado has both subsurface flow surface flow constructed wetland treatment systems. These systems are differentiated by the location of the water surface. In subsurface wetlands, the water surface is within the soil matrix, and is not visible. In surface flow wetlands, the water surface ponds on the soil surface. Both constructed wetland types mimic natural wetland behavior. In a natural wetland, the hydrologic regime varies seasonally. At times of low flow, the natural wetland operates similar to a subsurface wetland. The wetland area may appear dry, and not free standing water will be noted. During times of peak flows, the wetland system will operate similar to a surface flow wetland, with a free water surface flowing through the wetland.

Subsurface

The project team visited three subsurface treatment wetland systems. Some experiences noted by these systems are discussed below.

Costs

These systems are generally more expensive than surface flow systems to construct, however, they require less surface area, which may offset some of the construction costs. Construction costs include excavation, subsurface hydraulic systems, and the installation of a specified soil media. An excerpt from Kadlec and Knight's *Treatment Wetlands*[1] book provides the following cost estimates.

Subsurface Flow				
Item	Units	Unit Price	Total Cost	% of Total
Excavation / Compaction	Yd3	$1.80	13,000	10.7
Soil	Yd3	$1.00		
Gravel	Yd3	$16.10	51,900	42.6
Liner	Acre	$15,000	19,250	15.8
Plants	Each	$0.60	13,330	10.9
Plumbing	Lump Sum		7,500	6.1
Control Structures	Lump Sum		7,000	5.7
Other	Lump Sum		10,000	8.2
			121,980	

Operational Issues

Subsurface systems are prone to plugging problems. During the construction of the wetland, it is important to oversee the soil placement to ensure that the specified particles size is used. Contractors must wash the specified gravel in order to minimize the presence of dust, which may lead to plugging of the system.

Subsurface systems have less freezing potential than surface flow systems. In addition, since there is no open water, vector issues are minimized. These systems will typically avoid mosquito infestations. Since contact of the wastewater with the air is minimized, odors should not be an issue for subsurface systems.

Effectiveness

Many of the subsurface wetlands discharged into leach field, or evaporative fields. Since evaporative and groundwater discharge permits do not require sampling of the discharge (groundwater discharge requires sampling from monitoring wells, which will not show how the wetland itself is operating) there is no conclusive data. The project team did visit some SF wetlands that appeared to be functioning, plants were well established, effluent appeared to be reasonable clear and odorless. However, without the presence of certified laboratory data, it cannot be proven that these systems are meeting the same standards as the regulated surface flow wetlands.

Some of the Colorado SF wetlands that were failing in terms of their ability to effectively treat wastewater were due to

- Overloading, up to five times design flows
- Unwashed media
- Uneven distribution of water in the soil matrix resulted in water level too deep at the inlet to allow plant establishment.

Other subsurface wetlands were rated low from an ecological viewpoint because of the lack of established wetland plants.

[1] Robert H. Kadlec & Robert L. Knight: Treatment Wetlands, Lewis Publishers, Boca Raton, 1996.

Surface

Surface flow wetlands operate similar to a wetland under inundated conditions. Interaction of the water surface with the atmosphere provides for both natural surface aeration and some natural disinfection due to sunlight penetration.

Costs

An excerpt from Kadlec and Knight's *Treatment Wetlands*[2] book provides the following cost estimates. Some costs may be minimized if an abandoned lagoon can be retrofit into a wetland system.

Free Water Surface Flow				
Item	Units	Unit Price	Total Cost	% of Total
Excavation / Compaction	Yd3	$1.80	13,000	19.4
Soil	Yd3	$1.00	2,800	4.2
Gravel	Yd3	$16.10		
Liner	Acre	$15,000	19,250	28.7
Plants	Each	$0.60	7,500	11.2
Plumbing	Lump Sum		7,500	11.2
Control Structures	Lump Sum		7,000	10.4
Other	Lump Sum		10,000	14.9
Total			67,050	

Operational Issues

Some of the wetlands had problems due to muskrat invasion and inability or inappropriate control of water level.

Effectiveness

The majority of the surface flow systems were consistently meeting permit limitations. In addition, the open water provides wildlife and aesthetic value. Most of the surface flow wetlands had healthy plant growth and were deemed to be suitable habitat for wildlife.

Overall Site Features

The table below provides a summary for some of the features of Colorado wetlands visited during this inventory. The bottom line for system effectiveness was 'did it meet permit limitations'. From a biological viewpoint, the wetland was scored based on habitat value. It is noted that sites with high habitat scores tended to also provide reliable wastewater treatment, and conversely, systems with low habitat value tended to provide inconsistent wastewater treatment.

[2] Robert H. Kadlec & Robert L. Knight: Treatment Wetlands, Lewis Publishers, Boca Raton, 1996.

Site	Type	Size (acres)	Design Flow (mgd)	Average Flow (mgd)	Population	Meeting permit limitations	Montana Method Score	Educational Uses	Year Online	Primary Treatment
Avondale	FWS	0.87	0.110	0.080	1000	No	2.4	No	1996	Lagoon
Bennett	FWS / SF	2	0.42	0.80	2200	Not online	2.6	Yes	Not online	Lagoon
Calhan	SF	0.31	0.80	0.065	850	Yes	2.6	Yes	1996	Lagoon
Crowley	FWS	3.04	0.170	0.126	1200	Yes	2.5	No	1996	Lagoon
Crowley Correctional Facility	FWS	3.3	0.150	0.110	600	Yes	2.0	Yes	1998	Lagoon
Delta	FWS	1.38	0.067	0.038	590	Yes	1.3	Yes	1997	Lagoon
Dove Creek	FWS	1.0	0.115	0.035	743	Yes	2.6	No	1999	Lagoon
Highland Presbyterian Camp	SF	0.014	0.0005	0.0005	240	No	0.98	Yes	1996	Septic Tanks
Hi-Land Acres	SF	0.21	0.055	0.022	300	Yes	0.90	Yes	1998	Lagoon
Horizon	FWS	1.0	0.015	0.010	220	Yes	2.2	Yes	1988	Lagoon
Island Acres	FWS	1.0	0.020	0.015	380	Yes	2.6	No	1995	Septic Tanks
La Veta	FWS	1.6	0.125	0.075	850	Yes	2.7	Yes	1993	Lagoon
Las Animas	SF	2.1	0.50	0.25	3500	Yes	2.1	No	1999	Lagoon
Manzanola	FWS	2.3	0.125	0.045	450	No	2.8	No	1998	Lagoon
Ouray	FWS	0.76	0.363	0.26	700 – 2000	Yes	2.6	No	1995	Lagoon
Platteville	FWS	3.0	0.348	0.130	2500	No	2.0	No	1992	Lagoon
Ridgway	FWS	1.5	0.015	0.015	290	Yes	2.8	Yes	1994	Septic Tanks
Rocky Mountain Shambhala Center	SF	0.23	0.05	0.05	200-500	Yes	1.5	Yes	1996	Septic Tanks
Silt	FWS	0.830	0.236	0.110	1700	No	2.3	No	1992	Lagoon
Valmont	SF	0.03	0.50	0.25	100	Yes	2.1	No	1993	Septic Tanks

Conclusion

Chapter 8

OEMC's Phase II will incorporate the 'Lessons Learned' documented in this report into the design of a 'showcase' treatment wetland.

Results of the site visits and data review were presented to the Task Force Members by the project team.

Lessons Learned

During the inventory of Colorado constructed treatment wetlands, the project team recorded practices and features that proved to be effective. The team also recorded 'lessons learned' from the first generation of Colorado treatment wetlands. It is the goal of this report to disseminate this collected data for the purpose of recording the current status of treatment wetlands and providing some guidance for future developments.

In order to refine design and management strategies, wetland professionals must have the ability to build on what has already been accomplished. Colorado has many treatment wetlands that are operating as intended, and in some cases, they are operating above expectations.

Design Methods

The primary objective of a treatment wetland is to remove key pollutants before discharging the system effluent. Often, BOD is considered the limiting pollutant and the wetland is designed to meet associated permit limitations.

Rule-of-thumb size ratios should only provide guidance for wetland design. Each wetland site should incorporate a comprehensive engineering study to determine wastewater characteristics, growth requirements, and climatological factors. Reaction kinetics of the top pollutants (typically BOD and TSS) of concern should be studied for maximum and minimum flow conditions.

Pretreatment

Constructed wetlands are one component of a treatment facility. It is imperative that all the system components are designed and operated to provide adequate treatment. Pretreatment of wastewater is especially important for successful wetland functioning. Influent requirements for the wetland must be considered when selecting pretreatment components.

Hydraulics

Treatment wetlands should be designed to implement simple hydraulic systems. These systems should minimize mechanical and electrical components wherever possible. The designer should address maintenance issues during the layout of the piping systems. Components of a successful hydraulic system are discussed below.

- **Gravity flow** – the wetland system should be designed with adequate slope and head to allow gravity flow through the entire system.
- **Simple hydraulics** – the plumbing should consist of pipes no smaller than 2”, with a minimum of appurtences in order to prevent plugging.
- **System redundancy** – piping should be provided to allow wetland cells to be bypassed and dried out.
- **Adjustable water depth –** operators should be able to easily vary water level.
- **Cell drains –** the wetland cells should have the ability to be completely drained.
- **Designed for maintenance** –an easy method of cleaning pipes should be incorporated into the wetland design. Easily accessible pipe clean-out features, and 45° angles facilitate the use of hydrojets and other pipe cleansing mechanisms.
- **Hardy Materials –** in the selection of materials used in the wetland cells, consideration should be given to long-term operation and maintenance needs. Wood is susceptible to water wear, and destruction by muskrat and other wildlife. In addition, wood requires extra care during seasonal burning of the wetland cells. PVC pipe stub-outs may also create problems during burning of the wetland cells. Materials should be selected during the design of the wetland to withstand saturated conditions, as well as to fit into the long-term maintenance plans (i.e. harvesting and/or burning of wetland vegetation).

Site Selection

Constructed wetlands are land intensive treatment options. When selecting a site for implementation of a wetland system, the following factors should be considered.

- **Soils** – several sites in Colorado experienced significant settling (up to 18”) of the entire wetland system, resulting in failure of the system hydraulic systems. This was the result of constructing the wetland on top of soils that could not support the weight of the wetlands.
- **Land Value** – consideration should be given to the ‘best use’ of intended land at build-out conditions.

Biological Perspective

Treatment wetland design requires input from biologists and botanists in order to develop high quality sites. It was noted that wetlands that scored high based on a biological perspective also consistently met discharge requirements. Conversely, wetlands that scored low from a biological perspective tended to have problems with wastewater treatment. The wetland should be designed to provide a high quality habitat that will thrive in its ecological siting.

- **Plant selection** - use of native plants is desirable, exotics should not be used.

- **Habitat design** - incorporate features that provide habitat for desired species, while minimizing nuisance species. Providing protection of berms and exclosures around pipe outlets will prevent muskrat destruction and discourage infestation. Designing a wetland to encourage a balance of species will minimize the potential for one species to dominate and thus become a nuisance.
- **Sizing for habitat value** - over-sizing wetland to encourage plant diversity
- **Irregular boundaries and shapes**– wetlands that have niches, islands, and other natural features will provide a higher quality wetland. Incorporate shapes, other than rectangles, that conform to available land and provide borders to improve habitat value.

Operation and Maintenance

Colorado's treatment wetlands scatter across the State. Some pockets of wetlands have been established as a result of 'word-of-mouth' discussions among towns operating treatment wetlands and those seeking treatment solutions. The project team found that there was a loose knit network of wetland operators state-wide. During the course of this project, a contact list was assembled to aid in the development of a network among every wastewater treatment operator currently using wetlands in Colorado.

- **Network** – operators of wetland facilities should develop a network in order to build on the experiences and knowledge in this field.
- **Sampling locations** - sampling ports should be provided to monitor water quality throughout the wetland. This gives the operator the ability to isolate treatment in the wetland from other treatment components
- **Design** – the long-term operation and maintenance scheme for the wetland should be determined during the initial design of the system.
- **Start-up period** – an operation plan should include a strategy for allowing the plants to mature. This may require operating the system at lower or higher water levels. In addition, consideration should be given to the planting schedule in order to allow slower growing plants to become established before introduction of more dominant species.

Energy

Constructed treatment wetlands can be designed to operate with minimal energy inputs. In order to take full advantage of this low energy treatment method, all components used at the wastewater treatment facility should be low energy consuming. Communities seeking low energy treatment methods should consider pairing a wetland system with other low energy using treatment components.

- **Gravity flow –** the treatment facility should be located at the lowest point in the community. Where available, sufficient elevation differences should be provided across the treatment facility to allow complete gravity flow.
- **Low Energy Primary Treatment –** selection of low energy treatment components should be considered.

- **Alternative Energy Sources –** energy requirements at a treatment facility could be completely satisfied by wind, solar, or other alternative energy sources.
- **Operation schedules –** energy consumption can be minimized by operating mechanical systems, such as lagoon aerators, on efficient schedules.

Human Use

Constructed treatment wetlands have great potential for providing ancillary benefits at minimal additional costs. Some of these potential benefits are discussed below.

- **Educational programs –** wetlands can be used as 'outdoor laboratories' to teach schoolchildren and adults about natural treatment processes.
- **Recreational activities -** trails, possibly connected to existing trails, can be incorporated to maximize public exposure to the wetlands. Other outdoor activities, such as bird and wildlife viewing can be enjoyed at the wetland site.
- **Public exposure** - interpretive centers can be provided to facilitate tours of the treatment wetland.

Added-Value Features

In addition to providing wastewater treatment, constructed treatment wetlands can also be designed as inviting areas for human and wildlife interaction. The following are components that should be included in a treatment wetland designed to encourage public visitation.

- Shape that blends into the natural setting
- Educational value, use of interpretive centers, educational displays
- Trails around wetland, with stops at interpretive centers
- Safety issues – need to protect public from raw waste, deep water
- Located off of major road, or in other heavily traveled area
- Handicap accessible
- Signage to facilitate self-touring
- Operator with interests in conducting tours, or local volunteer with interest and experience sufficient to conduct tours for educational purposes
- Use of alternative energy sources on site
- System design that provides nutrient removal (alternating open and vegetated water zones).

Conclusion

The project team visited constructed treatment wetlands that were functional in all regions of Colorado. Historical effluent monitoring reports indicate that the majority of these wetland systems have been able to consistently treat wastewater within permit limitations. Ancillary benefits, such as scenic views, and habitat viewing areas, were often provided as an unplanned component of the system.

List of Colorado Constructed Wetlands Contacts

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References

Colorado School of Mines. 1992. Passive mine drainage treatment in a bioreactor: the significance of flow, area, and residence time. Golden, CO.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services Program. FWS/OBS-79/31. 131 pp.

De Forest, G., J.C. Emerick, and E.A. Howard. 1985. Passive mine drainage treatment systems: A theoretical assessment and experimental evaluation. Dep't of Environmental Sciences and Engineering Ecology Colorado School of Mines Golden, CO.

Huskie, Wm W. 1987. The Pennsylvania mine drainage study: Evaluation of an existing high mountain wetland for passive treatment of metal laden acid mine drainage in Colorado. Master's thesis, Colorado School of Mines.

Kadlec, R.H., and Knight, R.L. 1996. Treatment Wetlands. CRC Press, Boca Raton, FLA.

Mitsch and Gosselink, 1993. Wetlands. Van Norstrand Reinhold. New York.

Montana Department of Transportation. 1996. Montana Wetland Field Evaluation Form and Instructions. Helena, MT.

U.S. Army Corps of Engineers Environmental Laboratory. 1987. Corps of Engineers Wetland Delineation Manual. Technical Report 7-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Walton-Day, K. 1996. Iron and zinc budgets in surface water for a natural wetland affected by acid mine drainage, St. Kevin Gulch, Lake County, Colorado. U.S. Geological Survey Toxic Substances Hydrology program—Proceedings of the technical meeting, Colorado Springs, CO. USGS Water Resources Investigation Report 94-4015. Vol. 2, p. 759-764.

Weber, W. and R. Wittman. 1996. Colorado Flora, Eastern Slope, revised edition. University Press of Colorado. Niwot, Colorado.