NATURAL TREATMENT SYSTEMS –

A WATER QUALITY MATCH FOR OREGON'S CITIES AND TOWNS

A report on Natural Treatment Systems prepared jointly by Oregon Department of Environmental Quality and the Oregon Association of Clean Water Agencies

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EXECUTIVE SUMMARY

The use of natural treatment systems, including wetlands, tree farms, wastewater lagoon systems, recycled water programs, indirect discharge, and water quality trading, is a perfect match for meeting the wastewater treatment needs of many Oregon communities. Natural processes are effective in treating wastewater to Oregon's environmental standards - - often times at a lower cost to the community, due to lower ongoing maintenance costs and lower operating costs, including reduced chemical and energy costs.

For many Oregon communities - - especially in rural Oregon - - tree farms, treated water reuse for crops such as hay and pasture, and treatment ponds, build on the natural resource management expertise resident in the community.

Water quality trading is another innovative regulatory strategy that can build on the success of soil and water conservation districts, watershed councils, and other non-profit partnerships, to substitute more effective natural systems for steel-and-concrete systems. Water quality trading also often provides substantial savings to the community while providing multiple environmental benefits.

A variety of Oregon communities currently use natural treatment systems to meet water quality requirements, almost always at a cost substantially less than conventional steel-and-concrete systems, while also providing amenities to the community such as recreational access, open space, and opportunities for environmental education. A selection of Oregon communities using natural treatment systems include:

- Wetland treatment systems in Salem, and Albany
- Recycled water irrigation systems in Cottage Grove, Silverton, Myrtle Creek, Newberg, and Prineville, and Bend
- Tree farms in Woodburn, Eugene/Springfield, Harrisburg, and Veneta
- Indirect discharge at Roseburg Urban Sanitary Authority (RUSA)
- Water quality trading programs for Clean Water Services and Medford
- Wastewater treatment ponds in Dufur, LaGrande, and Condon

Match Natural Treatment Systems to Water Quality Challenges

Many Oregon cities and towns face strict water quality discharge requirements to meet stringent limits set to protect fish populations. Every community should insist that natural systems are evaluated and considered along side traditional concrete-and-steel solutions. Oregon communities with experience in using natural treatment systems have found the natural systems to be lower in costs to operate and maintain due to reduced energy and chemical expenses. Some natural treatment systems can be designed to require only a State water quality permit, not a federal water quality permit, lowering permit fees, lessening regulatory requirements and reducing risk. Many systems can provide additional community benefits such as irrigating ball fields and providing outdoor recreation opportunities in a park-like setting.

The table below summarizes the types of natural treatment systems that perform best to meet specific types of water pollution control restrictions:

Water Quality Treatment Target	***Wetland Treat-ment***	***Phyto Treat-ment Recycled Water***	***Phyto Treat-ment Tree Farms***	***Indirect Discharge***	***Water Quality Trading***	***Wastewater Pond Systems***
Nutrient Restrictions	√	√	√	√	√	√
Temperature Restrictions	√	√	√	√	√	√
Toxic water quality limits	√	√	√	√		√
Ammonia	√	√	√	√		
Chlorine	√	√	√	√		√

For many communities, linking a variety of natural treatment systems, or linking a traditional mechanical treatment system followed by a variety of natural treatment systems is the best wastewater treatment match for the community.

Natural Treatment Systems Can Cost Less

Designing and installing natural treatment systems can reduce costs. For instance,

- The City of Medford program to use water quality trading to reduce its temperature impacts on the Rogue River is costing $6 million, compared to $16 million and additional O & M costs for chillers.
- The Roseburg Urban Sanitary Authority natural treatment system was installed at a cost of $9 million - - compared to $100 million for a conventional treatment system that also had much higher operating costs.
- In the 10 years Clean Water Services has operated its temperature water quality trading program, it has saved ratepayers $100 million. Clean Water Services is meeting its DEQ permit at a 95% cost savings compared to conventional wastewater treatment technologies.

Additional Details Available

A complete report reviewing the performance of Natural Treatment Systems in Oregon has been compiled by a task force of Oregon DEQ and municipal treatment system experts. A copy of the report, dated July, 2014) is available at http://www.oracwa.org/r-studies-reports.html.

Oregon communities considering an expansion or upgrade of their wastewater treatment plants should take the time to read the report, and work with their consulting engineer to tour nearby communities using Natural Treatment Systems, and consider how best to incorporate these systems into the overall wastewater treatment facility planning process.

The report on Natural Treatment Systems was prepared jointly by Oregon Department of Environmental Quality and the Oregon Association of Clean Water Agencies

For Additional Information

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PURPOSE

This report summarizes the national performance of natural treatments and highlights specific installations in Oregon as a tool to assist Municipal Councils and District Commissions, along with Public Works Directors and their consulting engineers, in fully considering natural treatment systems as part of any community Wastewater Facility Plan and options analysis for treatment plant expansion or upgrade.

The Oregon Department of Environmental Quality and the Oregon Association of Clean Water Agencies partnered to produce this summary report.

TECHNICAL ADVISORY COMMITTEE

The technical advisory committee guiding this research and report included:

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The report was researched and completed by Amelia Yeager for Oregon Association of Clean Water Agencies.

NATURAL TREATMENT SYSTEMS

All wastewater treatment systems utilize natural processes. For example, gravity is used to remove particulates and bacterial decomposition reduces organics. In conventional treatment systems, these natural processes are supported by a complex array of energy-intensive mechanical equipment.

Natural treatment systems, by contrast, utilize biological and physical/chemical processes to accomplish a wide range of treatment objectives, with minimal dependence on energy inputs and mechanical assistance. These systems can also go beyond simply providing treatment services; many provide an aesthetic benefit, and some include opportunities for wildlife viewing, environmental education, and outdoor recreation.

Natural wastewater treatment systems have been used for centuries, but a serious resurgence in interest in the United States occurred after the passage of the Clean Water Act in 1972. At first, wastewater treatment managers focused on advanced mechanical treatment methods to meet the new, more stringent water quality standards, but the high energy requirements and costs of these methods soon became apparent and the natural treatment systems were taken into consideration as more sustainable and cost-effective alternatives.[i]

While natural treatment systems can be used to treat a variety of media, including industrial wastewater and contaminated soils, this report focuses on the use of these systems to treat domestic wastewater, either working in tandem with or taking the place of a conventional municipal wastewater treatment system.

DEFINITION OF NATURAL TREATMENT SYSTEMS

Natural treatment systems are engineered systems that have a minimal dependence on mechanical elements to support the wastewater treatment process, instead using plants, soil, bacteria, and other natural processes to break down and treat pollutants in wastewater. Natural treatment systems use - - rather than dispose of - - water, minimize the use of chemicals, and require limited energy to operate. These systems clean contaminated water in a sustainable, low cost, low impact manner, and can be designed to have a long life.

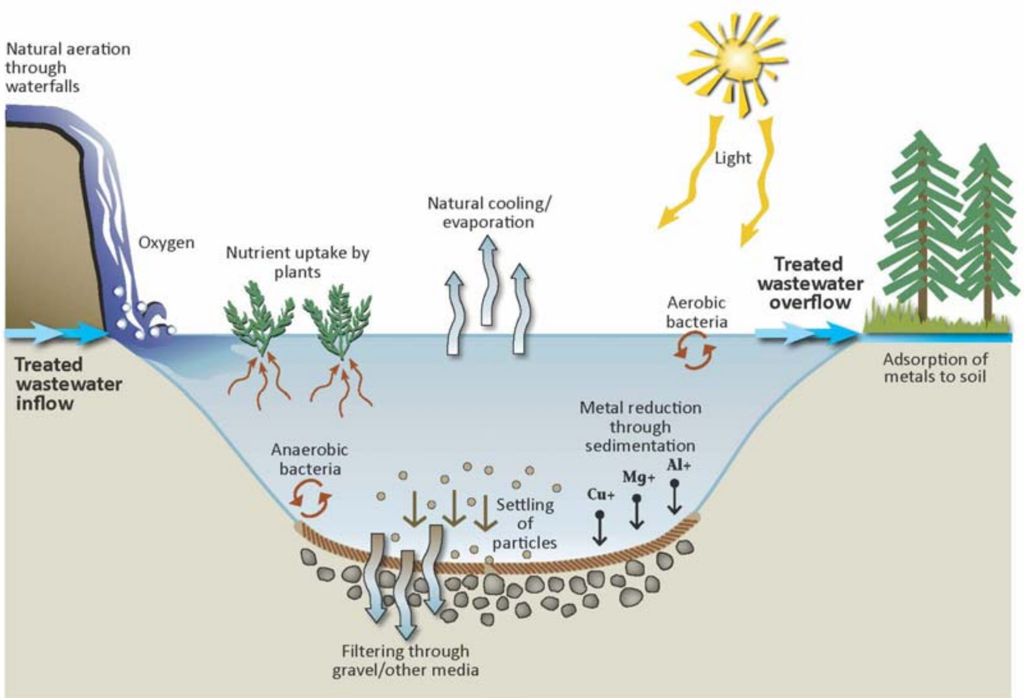
SCIENTIFIC SUMMARY OF NATURAL TREATMENT SYSTEM PROCESSES

Natural treatment systems utilize a variety of natural processes to achieve pollutant reduction goals. Most of these natural systems are intended to treat wastewater that has already gone through primary or secondary treatment, providing further treatment and polishing. Depending on the type of natural treatment system, some or all of the following processes may be utilized in a given natural treatment system.

Scientific processes at play in the natural treatment system include:

- Bacterial decomposition (aerobic and anaerobic) of organic wastes
- Natural aeration through waterfalls
- Settling of particles
- Natural cooling, especially at night
- Nutrient uptake by plants
- Metals reduction through sedimentation
- Adsorption of metals to soils, and
- Filtration through gravel or other media

The chart below illustrates the scientific basis for wastewater treatment in natural systems. A more detailed description of natural treatment system processes can be found in Appendix 3.



Natural Treatment System Process

TYPES OF NATURAL TREATMENT SYSTEMS REVIEWED IN THIS REPORT

Five major types of natural treatment systems are examined in this report:

- Wetland treatment
- Phyto treatment, including both water recycling and tree farms
- Water quality trading
- Indirect discharge, and
- Wastewater pond systems.

Each type of natural treatment system is suitable for addressing different pollutant reduction goals and requires different amounts of investment in terms of land, money, and energy. Many times, a variety of natural treatment systems may be used in sequence to provide effective wastewater treatment and community amenities at an affordable price.

The case studies reviewed in this report utilize all five of these natural treatment approaches. The systems examined include:

- City of Albany – treatment wetlands
- City of Bend – water recycling
- Clean Water Services – water quality trading
- City of Cottage Grove – water recycling
- City of Harrisburg – poplar farm and wastewater ponds
- City of Junction City – water recycling and wastewater ponds
- City of Medford – water quality trading
- Metropolitan Wastewater Management Commission (MWMC) – poplar farm and water recycling
- City of Myrtle Creek – water recycling
- City of Newberg – water recycling
- City of Prineville – water recycling and wastewater ponds
- Roseburg Urban Sanitary Authority (RUSA) – wetland treatment and indirect discharge
- City of Salem – wetland treatment
- City of Silverton – wetland treatment
- City of Veneta – poplar farm, water recycling, and wastewater ponds
- City of Woodburn – poplar farm

Natural treatment systems are more effective for treating some types of pollutants; less for other types of pollutants. The table below summarizes the types of natural treatment systems that are likely to be most effective in treating specific classes of pollutants. Remember that for some communities, linking a variety of natural treatment systems, or linking a mechanical treatment system to be followed by a natural treatment system, is an effective treatment train combination.

For the table below, subject areas marked with a check (√) are good candidates for reducing the listed pollutant to acceptable water quality standards. For those natural treatment systems that can eliminate the need to discharge treated wastewater effluent - - for instance by land applying all the treated wastewater effluent to a tree farm - - in stream water quality standards are no longer a concern.

For toxic water quality limits, Oregon has the nation's most stringent water quality standards for toxics related to human health. There are no known technologies able to meet the very low levels of toxics set in the Oregon water quality standards.[1]

WATER QUALITY TREATMENT TARGETS

Natural treatment systems are effective at treating a variety of water quality treatment targets. The table below summarizes systems by the types of water quality pollutants they can effectively target.

Water Quality Treatment Target	***Wetland Treatment***	***Phyto Treatment Recycled Water***	***Phyto Treatment Tree Farms***	***Indirect Discharge***	***Water Quality Trading***	***Wastewater Pond Systems***
Nutrient Restrictions	√	√	√	√	√	√
Temperature Restrictions	√	√	√	√	√	√
Toxic water quality limits	√	√	√	√		√
Ammonia	√	√	√	√		
Chlorine	√	√	√	√		√

DESIGN CONSIDERATIONS

Each natural treatment system is unique and each system should be evaluated to determine how it matches with the local situation. The table below summarizes some of the general design conditions for using natural treatment systems.

Type of System	***Design Considerations***	***Benefits***
Wetland Treatment	Need available appropriate land near treatment plant Polishing effluent treated by a mechanical plant could reduce land needed	Bird watching Park-like community amenity

[1] Treatment Technology Review and Assessment, Association of Oregon Business, Association of Washington Cities, Washington State Association of Counties, HDR, Dec. 2013

Type of System	*Design Considerations*	*Benefits*
Phyto Treatment Recycled Water	Match recycled water by Class to nearby water uses (rock crushing, fire suppression, cleaning, etc.) Identify critical temperature seasons to match to irrigation seasons Diverting recycled water can reduce discharges in critical low flow periods when permit restriction are most stringent Water distribution costs could be high Recycled water must be applied an the appropriate agronomic rate	
Phyto Treatment Tree Farms	Need available appropriate land near treatment plant Recycled water must be applied an the appropriate agronomic rate	Good match for rural communities with tree growing expertise Wood might be useful in rural communities
Indirect Discharge	Need geological and geographical match Detailed site analysis will be needed, including impacts on fish and aquatic life populations Biological processes transfer ammonium to nitrate and absorb phosphorus, along with other metals Provides cooling if designed so that the system does not come to temperature steady state (i.e., seasonal indirect discharge or cycling through multiple infiltration basins	Provides additional treatment for a variety of water quality pollutants
Water Quality Trading	Identify trading potential in your watershed Consider if the utility would manage the trading program itself or use a contractor Good match for rural community with strong Soil & Water Conservation District to construct and oversee trading program	
Wastewater Pond Systems	Need available land Evaluate if water can be used in summer and stored in winter	

	Summer storage and winter discharge allows higher stream flows for permitting calculations Consider if discharge can be eliminated by storing in the winter and recycling in the summer; eliminating the discharge and moving to State only WPCF permit has many benefits over federal/state NPDES permit	

NATURAL TREATMENT SYSTEMS CAN COST LESS

Designing and installing natural treatment systems can reduce costs. For instance,

- The City of Medford program to use water quality trading to reduce its temperature impacts on the Rogue River is costing $6 million, compared to $16 million and additional O & M costs for chillers.
- The Roseburg Urban Sanitary Authority natural treatment system was installed at a cost of $9 million - - compared to $100 million for a conventional treatment system that also had much higher operating costs.
- The City of Salem wetland treatment system treats for ammonia and temperature at an operating cost of $80 per day.
- In the 10 years Clean Water Services has operated its temperature water quality trading program, it has saved ratepayers $100 million. Clean Water Services is meeting its DEQ permit at a 95% cost savings compared to conventional wastewater treatment technologies.

WETLAND TREATMENT

Wetland treatment involves utilizing existing wetlands or constructing engineered wetlands to treat wastewater. Many processes that occur naturally in wetlands, such as uptake of water by plants, microbial breakdown of organics, sedimentation and passive cooling, can help reduce common pollutants in wastewater including Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), metals, and temperature. Wetlands used for wastewater treatment typically have engineered structures to control flow direction, detention time, and water level, but otherwise rely solely on natural processes to treat wastewater. Specific pollutants may be targeted through careful engineering and management of a treatment wetlands system.

There are two basic types of wetland treatment systems:

- Free Water Surface (FWS) wetlands, and
- Vegetated Submerged Bed (VSB) wetlands.

Free water surface wetlands visually resemble natural wetlands because they contain aquatic plants that grow in the soil layer on the bottom of the wetland and water flows through the stems and leaves of the plants. Vegetated submerged bed wetlands do not resemble natural wetlands because they have no visible water. Instead, they consist of a bed of media such as crushed rock, small stones, sand, or soil which has been planted with aquatic plants. Water flows beneath the surface of the media and comes in contact with the roots of the plants but is not visible at the surface.

Treatment wetlands can also provide additional community benefits including the creation and preservation of wildlife habitat, environmental education, and recreation opportunities for the local community including hiking and bird watching.

PHYTO TREATMENT

Phyto treatment includes many types of natural treatment systems, including systems using rooted plants, floating aquatic plants, and algae. In these types of plant-based treatment systems, treated effluent passes through a vegetated medium, allowing for further polishing of the effluent. Nitrogen and phosphorus in the wastewater are utilized as nutrients by the plants. The plants uptake the treated wastewater and absorb the nutrients along with other pollutants such as metals.[ii] Further polishing occurs as the effluent filters through the soil medium in which the plants grow before flowing to groundwater or surface water.[iii]

This report focuses on two key types of phyto treatment systems most often used in Oregon:

- Water recycling, and
- Tree farms.

WATER RECYCLING

Treated wastewater can be recycled and used as a substitute for potable water for many environmentally-sound water uses. Using recycled water reduces the amount of water that must be discharged to a river and stream, making permit compliance easier, may conserve potable water for uses such as drinking.

Recycled treated wastewater can be used for:

- Irrigation on crops such as firewood, Christmas trees, animal pasture, fodder, golf courses, parks, and playgrounds,
- Irrigation on orchards and vineyards if the water is applied directly to the soil,
- Industrial and commercial uses such as industrial cooling, rock crushing, street sweeping, commercial car washing, and dust control, and
- Impoundments such as a water supply for golf course water ponds, restricted recreational impoundments, and artificial groundwater recharge.

Water recycling project examples in Oregon include:

- Golf course irrigation in Bend, Prineville, and Newberg
- Park irrigation in Washington County by Clean Water Services

TREE FARMS

In some situations, phyto treatment systems can be used to grow trees, such as poplars. Several tree farms in Oregon that are irrigated with wastewater use hybrid poplars to absorb nutrients, beneficially reuse biosolids, and grow wood, while eliminating any discharge to rivers and streams in summer, low-flow conditions.

Treated wastewater is used to irrigate tree farms, and often times, biosolids are land applied as a fertilizer.

In Oregon, tree farms must be harvested within 12 years to avoid being regulated under Oregon's Forest Practices Act (see definition of '*operation*' at OAR 629-600-0100(46) available at http://www.oregon.gov/odf/privateforests/docs/guidance/oardiv600.pdf . Communities could decide to grow higher value wood products, even cedar or redwood, but must ensure compliance with the Oregon Forest Practices Act and assorted harvest taxes.

Water and nutrient use is relatively low during the first establishment year and builds over the first three years of growth as the tree stand matures. By the fourth growing season, the tree stand canopy is typically closed and water and nutrient use stabilize at their peak rate until harvest. [iv] In Western Oregon poplar tree stands, the expected maximum nitrogen uptake rate of a mature stand is approximately 240 pound per acre per year.[v]

Acreage needed for a plantation depends on site soil and drainage conditions, , tree planting density and cover crop management, intended rotation age, setback requirements from site boundaries and waterways, irrigation methods utilized, and volumes of treated wastewater water and biosolids to be applied. A number of hybrid poplar varieties are available for use. The ideal poplar tree variety for a particular site depends on the local soil attributes, wastewater characteristics (including salinity and nutrient concentration), tree stand management plans (e.g. short rotation dense plantings for biomass or pulp vs. longer rotation less dense plantings for solid wood products), and common local pests and diseases.[vi]

INDIRECT DISCHARGE

Indirect discharge involves additional treatment of secondary-level treated wastewater through the soil matrix in the subsurface flow environment. This soil matrix may be saturated all the time or part of the time by this infiltration, and the soil and associated microbial and chemical/physical activity further treats the wastewater. Indirect discharge processes can also reduce the effect of wastewater discharge temperatures on receiving waters by delaying the arrival time of the flow and heat into surface waters to cooler less temperature sensitive periods and by intermixing with cooler groundwater to create a more diffuse discharge. Indirect discharge mimics the natural processes of side channel and floodplain discharges in a river system.

Indirect discharge allows for natural physical, biological, and chemical processes present in groundwater to further treat the wastewater before it reaches the surface water.[vii]

Discharge of municipal wastewater treatment plant effluent by indirect discharge to surface water via groundwater water may be environmentally beneficial if planned, installed, and operated correctly, and if located under the right geographic, hydrogeologic, and environmental conditions. The type of indirect discharge system should be matched to the specific conditions of the site.

Systems that could be used for indirect discharge of treated municipal wastewater include:

- Rapid and moderate rate infiltration systems
- Constructed wetlands designed for evaporation/transpiration and minimal seepage
- Constructed wetlands designed for infiltration
- Surface spray irrigation applied at greater than agronomic rates

- Subsurface drip irrigation applied at greater than agronomic rates
- Exfiltration galleries, drainfields, mounds, and bottomless sand filters
- Evaporation ponds with infiltration components
- Injection wells discharging above the water table

Indirect discharge systems should have each of the following characteristics:

- The intent of the system design is to route wastewater through shallow unsaturated soils and/or groundwater for additional polishing and diffusion before it discharges to surface water. This would include situations where wastewater is discharged to hyporheic water.
- Site conditions (geology or hydrology) and system design are such that (effectively) all the wastewater and affected groundwater will discharge to surface water after leaving the waste management area.
- As required by the DEQ Groundwater Quality Protection rules (see OAR 340-040), groundwater outside the waste management area will not be adversely affected by the system.
- Conditions in the waste management area and the quality of discharge are such that long term contamination would be unlikely following termination of the discharge.
- A local government or special district owns or otherwise controls the property containing the waste management area.
- Water supply wells do not exist and cannot be placed (or are reasonably unlikely to be placed) within the waste management area.

WATER QUALITY TRADING

Water quality trading is a flexible approach to achieving water quality goals in a cost effective manner, often with greater environmental benefit than concrete-and-steel approaches. Credits are generated through the conservation or restoration of natural ecosystems beyond levels required by state and federal regulations. A regulated entity then buys these credits as a way to meet its regulatory obligations. Water quality trading can reduce compliance costs while providing additional benefits to overall watershed health.[viii]

Water quality trading can be used to offset a variety of pollutant parameters, including temperature and nutrients. Permittees can obtain pollutant reduction credits by taking action to create or restore wetlands, streamside riparian areas, floodplains, aquatic habitat, or other stream-related areas similar to that discharged by the permittee. For instance, this could involve sponsoring the planting of trees to increase riparian shading which in turn reduces stream temperatures.

The permittee can also trade credits with other permittees or non-permitted entities to offset its pollutant impacts. Some permittees are better equipped than others to treat their effluent to a high level. If they exceed the level of pollutant reduction required by their permit, they can sell the excess reduction as credits to nearby permittees looking to offset their own pollutant loads. Non-permitted entities such as farms and logging operations can also implement pollutant-reducing practices that extend beyond the current regulatory requirements, and those can be sold as credits to permittees. [ix]

Nutrient trading is often carried out in this manner. For example, the Long Island Sound National Estuary Program has developed a nitrogen credit trading program to reduce nitrogen discharges from Connecticut point sources, such as wastewater treatment plants, to Long Island Sound. Nitrogen reductions help increase dissolved oxygen levels and improve the overall health of the water body. The Connecticut program focuses on reducing nitrogen output from 84 municipal wastewater treatment discharges. Each municipality is charged with making a 70% reduction in their total nitrogen load. Municipalities that reduce nitrogen beyond the 70% reduction requirement can sell their credits to other municipalities that cannot meet reduction requirements through treatment technology alone. Nonpoint sources, including agricultural activities and forestry operations, can also generate credits by employing pollutant-reducing practices beyond that required by current environmental regulations. These credits can then be sold to NPDES permittees.

WASTEWATER POND SYSTEMS

Wastewater ponds are large ponds where wastewater is held for a period of days or months. These ponds are designed to mimic a natural pond environment, encouraging the growth of aerobic and anaerobic bacteria that can reduce BOD, TSS, and pathogens levels. Pond systems can be used alone or in combination with other wastewater treatment processes.

There are two main types of wastewater pond systems:

- **Facultative wastewater ponds** are the most common type of pond system. These systems are usually used to treat raw municipal wastewater but may also be used for primary or secondary effluent treatment. They contain an aerobic layer of water overlaying an anaerobic layer. Aerobic bacteria provide odor control along with nutrient and BOD removal, while anaerobic bacteria aid in sludge digestion, denitrification, and some BOD removal. The system relies on oxygen production by photosynthetic algae and/or re-aeration at the surface to maintain the aerobic processes.
- **Aerobic pond systems** are shallower ponds that maximize aerobic processes. High light penetration and re-aeration at the surface allow aerobic bacteria to biochemically stabilize the wastewater. Advantages of this system include short detention time with low land and energy requirements, but their operation is more complex and the effluent can contain high levels of TSS if the algae are not removed prior to discharge.[x]

EFFLUENT PERFORMANCE

Natural treatment systems can be utilized to treat a wide variety of pollutants, including :

- Biological Oxygen Demand (BOD)
- Total Suspended Solids (TSS)
- Nutrients
- Temperature
- Toxics
- Ammonia
- Chlorine
- Metals, and
- Emerging contaminants, including solvent related-compounds such as benzene

Different types of natural treatment systems are best suited to treat different pollutants. In considering the use of a natural treatment system, utility managers should consider the water quality needs of the local river and stream. Consider both water quality standards that are currently not being met, along with examining the available data to determine what regulations and restrictions might affect the utility system in the future.

While there are many published studies and statistics about the performance of individual natural treatment systems, pollutant removal performance varies for each system based on factors such as wastewater influent flow, pollutant load, characteristics of the sediment and/or vegetation in place, local climatic conditions, and others. In some cases, consultation with other jurisdictions that are operating under similar conditions may be helpful in determining what type of natural treatment system may meet a community's needs. Performing pilot studies is an effective way to gather data that describes how a particular natural treatment system might be expected to perform under specific local conditions. These types of studies are especially important if the system is intended to treat an emerging contaminant or if the influent includes an unusual source, such as treated industrial wastewater.

Based on both Oregon and national natural treatment systems, this type of pollution removal effectiveness can generally be predicted:

WETLAND TREATMENT SYSTEMS

A variety of factors will influence each treatment systems performance.

Wetland treatment systems demonstrate post-treatment water discharges with a wide range of parameter concentrations, as reported in the most recent comprehensive international compilation *Treatment Wetlands 2nd Edition* (Kadlec and Wallace, 2009). These discharge chemistries are the result of a number of factors, including but not limited to: influent parameter concentrations and loadings; regional parameter background concentrations in similar natural wetlands; hydraulic loading rate; residence time; water depth; vegetation density and type; media/sediment composition and chemistry; system age; climate and seasonal factors such as temperature, precipitation, snow cover depth, and snow melt; internal erosion (e.g. wave activity) and wildlife use (especially waterfowl). All of these factors are addressed in design to optimize outcomes, but some can also be managed during the treatment system life, while some remain fixed. These factors lead to variability in discharge concentrations from a wetland treatment system seasonally and annually, and the range of discharge concentrations summarized below for selected treatment wetland types.

FREE WATER SURFACE WETLANDS

For free water surface wetlands, the final effluent characteristics are likely to be:

- BOD values in the range of 4.8 – 14.1 milligrams per liter (mg/l)
- Total Suspended Solids in the range of 2.8-29.7 mg/l
- Temperature reduction of 0.3 – 11.1° F
- Phosphorus reduction to 0.01-4 mg/l
- Total Kjeldahl Nitrogen in the range of 1.35-11 mg/l
- Ammonia reduction to 0.1-56.9 mg/l

- Nitrate in the range of 0.05-48 mg/l
- Metals concentrations reductions for aluminum, copper, iron, manganese and zinc

VEGETATED SUBMERGED BED WETLANDS

For vegetated submerged bed wetlands, the final effluent characteristics are likely to be:

- BOD values in the range of 2.2 – 55.4 mg/l
- Total Suspended Solids in the range of 4-35 mg/l
- Phosphorus reduction to 3.2-3.9 mg/l
- Metals concentrations reductions for aluminum, copper, iron, manganese and zinc

The most comprehensive resource on the subject of wetland effluent performance is *Treatment Wetlands* by Kadlec & Wallace.

WETLAND TREATMENT OF PRIORITY PERSISTENT POLLUTANTS

Due to the extended interaction the soil and a variety of natural processes, natural treatment systems are effective at reducing emerging contaminants. Some of these pollutants have associated Oregon water quality criteria, while others do not. The table below summarizes some wetland treatment system performance data on reduction in concentrations of a variety of complex organic pollutants:

Chemical	Constructed Wetlands Performance (% removal)
Benzene	81
Biphenyl	96
Chlorobenzene	81
Dimethyl-phthalate	81
Ethylbenzene	88
Naphthalene	90
p-Nitrotoluene	99
Toluene	88
p-Xylene	82
Bromoform	93
Chloroform	69
1,2-Dicholorethane	49
Tetrachloroethylene	75
1,1,1-Trichloroethane	68

INDIRECT DISCHARGE

For treatment plants employing an indirect discharge, additional removal can be anticipated, including:

- Temperature reduction
- Removal of metals will be influenced by the types of soils in the area, but the majority of the heavy metals are removed within the first six inches of soil through which the treated wastewater percolates [xi]
- For example, indirect discharge in Flushing Meadows, Arizona obtained zinc reductions to 0.035 mg/l, copper to 0.016 mg/l and cadmium to 0.072 mg/l

WASTEWATER PONDS

Wastewater treatment pond performance will vary, but generally, this type of performance can be anticipated:

- BOD reduction ranging from 50 – 95% reduction
- Phosphorus removal in the range of 30 – 90%
- Total Kjeldahl nitrogen reduction to 5-23.6 mg/l
- Ammonia in the range of 1.3-22.9 mg/l
- Nitrate reduction to 0.9-2.96 mg/l

Phyto treatment systems including recycled water and tree farms, along with non-discharging wastewater ponds. beneficially reuse the treated water, eliminating the need to meet strict in-stream water quality standards.

ADDITIONAL RESEARCH OR TESTING NEEDS

While there has been extensive research done on natural treatment systems, there are still areas that need to be investigated further. Chief among these issues is the challenge of emerging contaminants. As water quality standards become more stringent, additional research into the treatment effectiveness of natural systems on emerging contaminants would be useful information.

Additional research and 'best practices' for maintaining and operating natural treatment systems is an additional area of potential research.

REGULATORY FRAMEWORK

BACKGROUND

This section summarizes the DEQ regulations that apply to natural treatment systems. DEQ Regional permit writers can answer questions about specific, detailed permitting requirements.

In considering a natural treatment system, some additional regulatory requirements should also be considered including:

FEDERAL

- US Federal Aviation Administration will be interested in wetland and pond systems if there are nearby airports, or the project is near a flight path or important air space.
- US Army Corps of Engineers regulates fill and removal within waters of the U.S., in concert with the Department of State Lands.
- US Fish and Wildlife Services and National Marine Fisheries Service consult with the US Army Corps of Engineers on projects requiring a Biological Assessment (sometime associated with projects where constructed wetlands are used in floodplains or associated with relocated outfalls and there is a federal nexus).

STATE

- Department of State Lands regulates fill and removal within waters of the state, in concert with the US Army Corps of Engineers.
- Oregon Department of Fish and Wildlife consult with Department of State Lands on projects requiring a Biological Assessment.
- DEQ and the Oregon Health Authority will want precautions to protect any underground source of water used for drinking water withdrawals.

LOCAL

- All actions must be in accordance with the adopted comprehensive plan and the Statewide Land Use Planning Goals and Guidelines.

REVIEW OF DEQ PERMITTING REQUIREMENTS

Diagram the DEQ permitting requirements to ensure you have a complete understanding of the various elements. Working with your consulting team, develop a schedule for completing and filing the various necessary plans and applications. Review the diagram and time frame with DEQ staff to get their review, input, and agreement.

Remember that all DEQ permit applications must be accompanied by a Land Use Compatibility Statement – a form signed by the local land use agency that indicates your project is consistent with the locally adopted land use plan and zoning requirements. Local land use approval is necessary prior to applying to DEQ for permits.

Many permit actions require public notice. Permitting decisions can be extended if, at the end of the public notice period, an organization requests a public hearing. The public hearing will likely require an additional time for public notice.

The DEQ permitting requirements for these natural treatment systems are summarized below:

1. Wetland Treatment
2. Phyto Treatment, including water recycling and tree farms
3. Indirect Discharge
4. Water Quality Trading
5. Wastewater Pond Systems

WETLAND TREATMENT

A constructed wetland built outside of a natural wetland, waterway, or flood plain, is considered part of the wastewater treatment system and not subject to EPA, Army Corps of Engineers, or the Oregon Department of State Lands wetlands regulations.

An important regulatory permitting consideration for wetland treatment systems is the point- of-compliance for achieving the applicable water quality standards. Determining the point-of-compliance with a standard discharge pipe and its associated mixing zone can be more straightforward; communities designing a wetland treatment system will want to work with their consulting team and Oregon DEQ permit writer to determine the exact point-of-compliance. The point-of-compliance may vary by pollutant parameters.

Some Oregon wetland treatment systems have restored and expanded natural wetlands using the Department of State Lands inventory and permitting system, and have generated wetland mitigation credits to use in future projects.

Most wetland systems do not have a liner and are designed to use the soils beneath the wetland for additional treatment, while still protecting groundwater.

Permit holders (NPDES and WPCF) would apply to DEQ to incorporate the wetland treatment system as an additional treatment train described in the water quality permit. DEQ will incorporate specific monitoring and reporting requirements for the wetland treatment system.

Groundwater monitoring wells may be required as part of a permitted treatment wetland project. If a DEQ hydrogeologist concluded that there was a likely adverse groundwater quality impact, monitoring may be required (see OAR 340-040-0030(2).

Communities will want to check the Water Resources Department well logs to ensure no wells are close to the wetland treatment system and might be impacted by it.

REGULATORY TIPS FOR WETLAND TREATMENT SYSTEMS

- Gather adequate background hydraulic, geomorphic, and soil information to fully characterize the area where the wetland treatment system is planned
- Map area wells
- Consider the point-of-compliance
- Work with DEQ to bring the wetland treatment system into the appropriate NPDES or WPCF permit

PHYTO TREATMENT

Phytoremediation is a broad term that has been used since 1991 to describe the use of plants to reduce the volume, mobility, or toxicity of contaminants in soil, groundwater, or other contaminated media, including wastewater (USEPA, 2000). The focus on this paper is on phyto treatment systems that feature treated water recycling and tree farms.

WATER RECYCLING

Treated wastewater can be recycled as a substitute for potable water for many environmentally-sound water uses. Using recycled water reduces the amount of water that must be discharged to a river and stream, making permit compliance easier, and may conserve potable water for uses such as drinking.

Recycled treated wastewater has many uses, such as:

- Irrigation of crops, Christmas trees, animal pasture, fodder, golf courses, parks and playgrounds, and orchards and vineyards if the water is applied directly to the soil
- Industrial and commercial uses such as industrial cooling, rock crushing, street sweeping, commercial car washing, and dust control
- Impoundments recharge such as water supply for golf course water ponds, restricted recreational impoundments, and artificial groundwater recharge

Oregon DEQ regulates the use of recycled water from a wastewater treatment plant (see OAR Chapter 340, Division 55). In summary, these regulations:

- Set quality standards for four classes of recycled water: Class A, Class B, Class C, and Class D. Specific recycled water uses are allowed depending on the class of water produced.
- A recycled water management plan will be required. The plan will detail the water treatment programs, recycled water use, systems to meet the DEQ requirements, and monitoring and reporting requirements.
- Recycled water with high public access requires greater levels of treatment.
- Recycled water can only be used for beneficial purposes.
- Groundwater must be protected.

Water recycling project examples in Oregon include:

- Golf course irrigation in Bend, Prineville, and Newberg
- Park irrigation in Washington County by Clean Water Services

Additional information on DEQ's recycled water regulations and a 'fillable' form for completing a model recycled water management plan is available at http://www.deq.state.or.us/wq/reuse/recycled.htm

REGULATORY TIPS FOR WATER RECYCLING PROJECTS

- Partner with large volume agricultural, industrial, and commercial water users near the treatment plant; learn how treated wastewater can be substituted for potable water uses
- Match the recycled water use with the necessary treatment standards in the DEQ regulations

TREE FARMS

Trees, such as fast-growing hybrid poplars, can provide both a nutrient sink for wastewater and a means to produce a harvested wood product. The wastewater tree farms in Oregon use hybrid poplars to absorb nutrients, beneficially reuse biosolids, and grow wood.

Tree farms irrigated with recycled water are regulated under the same rules described above for water recycling projects (see OAR Chapter 340, Division 55).

Like water recycling projects, use of tree farms for applying treated wastewater can avoid stringent water quality limits for surface water discharge often imposed in the summer, low flow season.

In Oregon, tree farms must be reviewed and approved by Oregon DEQ. If biosolids are to be incorporated in the plantation, the appropriate Biosolids Management Plan must be revised. Strict practices will be required to ensure that treated wastewater is not applied at greater than agronomic rates and that there will be no runoff to nearby streams and rivers.

In Oregon, tree farms that are located on Exclusive Farm Use zoned land must be harvested within 12 years to avoid being regulated under Oregon's Forest Practices Act (see definition of '*operation*' OAR 629-600-0100(46) available at http://www.oregon.gov/odf/privateforests/docs/guidance/oardiv600.pdf. Communities could decide to grower higher value wood products, even cedar or redwood, but must ensure compliance with the Oregon Forest Practices Act, and assorted harvest taxes.

REGULATORY TIPS FOR TREE FARMS

- Get professional foresters involved in planning and operating the tree farm
- Consider the possible end uses of the harvested wood products and select trees and a tree farm management plan that match the targeted use
- Match the amount of treated wastewater to be applied to the agronomic needs of the tree crop and soils
- Ensure there is no opportunity for runoff from the irrigation system

INDIRECT DISCHARGE

Disposal of municipal wastewater treatment plant effluent by indirect discharge to surface water via groundwater water may be environmentally beneficial if planned, installed, and operated correctly, and if located under the right geographic, hydrogeologic, and environmental conditions. The type of indirect discharge system should be matched to the specific conditions of the site.

The following are potential benefits of using indirect discharge:

- Wastewater temperature may be reduced in the groundwater water to meet in-stream temperature standards and therefore stream flow volumes may be maintained;
- Some "polishing" of the wastewater, such as reducing total metals or removing residual chlorine through natural geochemical processes, may occur within the soils and aquifer containing groundwater water; and
- If a land application component is used in the design, nutrients in wastewater may be beneficially reused by plants and therefore reducing the nutrient load for a mandated Total Maximum Daily Load (TMDL).

There are many methods for land discharge of treated municipal wastewater that could be used for indirect discharge to surface water. These include:

- Rapid and moderate rate infiltration systems

- Constructed wetlands designed for evaporation/transpiration and minimal seepage
- Constructed wetlands designed for infiltration
- Surface spray irrigation applied at greater than agronomic rates
- Subsurface drip irrigation applied at greater than agronomic rates
- Exfiltration galleries, drainfields, mounds, and bottomless sand filters
- Evaporation ponds with infiltration components
- Injection wells discharging above the water table

An indirect discharge system should have each of the following characteristics:

- The intent of the system design is to route wastewater through shallow unsaturated soils and/or groundwater for additional polishing and diffusion before it discharges to surface water.
- Site conditions (geology or hydrology) and system design are such that (effectively) all the wastewater and affected groundwater will discharge to surface water after leaving the waste management area.
- As required by the Groundwater Quality Protection rules in OAR 340-040, groundwater outside the waste management area will not be adversely affected by the system.
- Conditions in the waste management area and the quality of discharge are such that long term contamination would be unlikely following termination of the discharge.
- A local government or special district owns or otherwise controls the property containing the waste management area.
- Water supply wells do not exist and cannot be placed within the waste management area.

Groundwater quality in Oregon is protected from pollution in Oregon Revised Statutes (ORS) 468B.025 and ORS 468B.050, and reflected in the Oregon Groundwater Quality Protection rules, OAR 340-040.

With the use of an indirect treated effluent discharge system, treated wastewater may reach the waters of the state, so NPDES permits are needed for this type of natural treatment system.

Permittees planning and designing indirect discharge systems will want to ensure that salmon spawning or rearing areas will not be affected, and the existing cold water is protected (see OAR 340-41-0028(11).

DEQ's policy for indirect discharge of treated effluent entitled *Disposal of Municipal Wastewater Treatment Plant Effluent by Indirect Discharge to Surface Water via Groundwater or Hyporheic Water (2/07)* is available at http://www.deq.state.or.us/wq/pubs/imds/indirectdischarge.pdf.

REGULATORY TIPS FOR INDIRECT DISCHARGE

- Adequately map the soils and underlying geology of the possible indirect discharge in order to have adequate information to predict the pathway of the treated wastewater
- Be able to demonstrate that groundwater outside the project boundary will not be impacted
- Consider the point-of-compliance

- Ensure the indirect discharge will not adversely impact salmon and steelhead populations or other aquatic species. Get the local Oregon Department of Fish and Wildlife fish biologist involved in the program.

WATER QUALITY TRADING

Water quality trading is an innovative program that allows facilities that discharge wastewater to a stream or river to meet regulatory obligations by:

- Purchasing equivalent or larger pollution reductions from another source; or
- Taking action to protect or restore riparian areas, wetlands, floodplains, and aquatic habitat to reduce the impact of pollutants.

Trading is based on the fact that dischargers in a watershed can face very different costs to control the same pollutant. Trading programs allow facilities facing higher pollution control costs to meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions from another source at lower cost, thus achieving the same water quality improvement at lower overall cost. Trading may also allow Oregon water quality permit holders to achieve water quality improvements more quickly and more cost effectively than would otherwise be possible.

For many communities, using water quality trading will meet pollution reduction targets at a lower cost than traditional steel and concrete solutions, while providing greater environmental benefit. Examples of successful water quality trading projects used in Oregon are planting trees and restoring riparian areas rather than constructing chillers for wastewater effluent that exceeds temperature limits.

NATIONAL TRADING MODELS

EPA has developed a water quality trading tool kit for permit writers, available at http://water.epa.gov/type/watersheds/trading/WQTToolkit.cfm. A variety of trading programs are outlined, including trading programs among water quality permit holders, and trading programs between water quality permit holders and non-point sources such as agriculture or forestry.

The tool kit provides specific fact sheets describing a number of successful trading programs nationally including:

- Lower Boise River (Idaho)
- Long Island Sound (Connecticut)
- Neuse River (North Carolina)
- Clean Water Services (Oregon)
- Rahr Malting (Minnesota)

The tool kit is based on EPA's 2003 national water quality trading policy – see also available at http://water.epa.gov/type/watersheds/trading/WQTToolkit.cfm.

OREGON TRADING MODELS

Since 2001, Oregon has had a state law supporting the use of water quality trading (see ORS 468B.555 – available at http://www.oregonlaws.org/ors/468B.555). Oregon DEQ uses this state law to implement water quality trading in Oregon. There are no water quality trading rules, at this time.

Oregon DEQ has a policy in place to guide water quality trading programs, *Water Quality Trading in NPDES Permits - Internal Management Directive (12/09 updated 8/12)* available at http://www.deq.state.or.us/wq/pubs/imds/wqtrading.pdf.

Oregon DEQ typically requires a trading ratio of 2 credits traded for each 1 credit needed to compensate for the time it takes to implement natural systems. DEQ can, however, consider a lower trading ratio for certain situations. For instance, work on a smaller stream may not generate as many credits as work on a larger stream. However, the smaller stream may be more ecologically important than the larger stream.

A variety of water quality trading program resources are available on the DEQ web site at http://www.deq.state.or.us/wq/trading/trading.htm#Pro

In Oregon, two municipal water quality NPDES permits have incorporated water quality trading to date:

- Clean Water Services – Watershed Permit
- Medford Regional Water Reclamation Facility

There are two models for undertaking water quality trading: a utility-managed trading program such as the program run by Clean Water Services and a third party contracted program as chosen by the City of Medford and its contractor, The Freshwater Trust.

The Willamette Partnership has developed water quality trading protocols and practices, including its Counting on the Environment accounting system. More information is available at http://willamettepartnership.org/

REGULATORY TIPS FOR WATER QUALITY TRADING PROGRAMS

- Carefully review the DEQ guidance on trading programs and the details included in the City of Medford Regional Water Reclamation Facility permit and trading program evaluation for the City of Medford
- Learn from the two water quality trading programs currently in place in Oregon
- Discuss trading program options with DEQ staff early in the development of the program.

WASTEWATER POND SYSTEMS

There are generally three types of wastewater pond systems used in Oregon:

- Ponds that discharge to public waters under a National Pollutant Discharge Elimination System permit,
- Ponds that do not discharge to public waters, but irrigate treated recycled water under a Water Pollution Control Facility permit, or

- Ponds that neither discharge to public waters nor irrigate recycled water. These ponds rely exclusively on evaporation for wastewater disposal and are also permitted under a WPCF permit.

DISCHARGING PONDS

These facilities must demonstrate that the effluent meets all applicable water quality standards at the edge of the mixing zone during times of discharge – often in the winter during high flows. The Oregon water quality standards are found in OAR 340, Division 41 – see http://www.deq.state.or.us/wq/standards/standards.htm

NON-DISCHARGING PONDS WITH RECYCLED WATER USE

Non-discharging ponds are regulated by the State Water Pollution Control Facility (WPCF) permits. No discharge is allowed and the ponds must be properly engineered and managed to ensure no discharge is needed, even in times of high precipitation. Many non-discharging ponds beneficially reuse treated effluent as recycled water. DEQ's recycled water regulations (OAR 340, Division 55) set specific water quality standards for different types of recycled water uses. Recycled water with high public access requires greater levels of treatment. A Recycled Water Use Plan must be developed, including monitoring and reporting.

NON-DISCHARGING EVAPORATION PONDS

These ponds are also regulated by the State Water Pollution Control Facility (WPCF) permits. No discharge is allowed and the ponds must be properly engineered and managed to ensure no discharge is needed, even in times of high precipitation. These ponds are almost exclusively for smaller systems (schools, rest stops, small RV parks, etc) and in the drier parts of the Oregon, such as Eastern Oregon and the Southwestern interior valleys.

REGULATORY TIPS FOR WASTEWATER PONDS

- Design a series of natural treatment systems possibly including a wastewater pond and recycled water so that the treated water can be used, not discharged. Non-discharging systems qualify for an Oregon Water Pollution Control Facility (WPCF) permit - - a permit with lower fees, reduced requirements, and less legal risk.

IMPORTANT DESIGN CONSIDERATIONS AND CHALLENGES

Natural treatment systems are complex tools that require significant preparation and planning. This section outlines the most important considerations to keep in mind when designing a natural treatment system. These tips can help system planners avoid unexpected problems and be prepared for the challenges that come with operating a natural treatment system.

GENERAL

When designing a natural treatment system, it is important to understand the regulatory targets specific to the community in which the system is to be built. The planners must consider future pollutant concerns as well as current ones, collaborating with the Department of Environmental Quality to gain guidance and insight. Thinking in the context of the overall facility plan is also important: population growth and other changes can affect hydraulic loading rates and wastewater constituents in the future. Life cycle costs such as energy, chemicals, and operation and maintenance costs must be considered, as well as the appropriate level of wastewater pretreatment prior to entering the natural treatment system.

The climate and geography of the local area can affect the natural treatment system design and performance considerably. Topography, rainfall, soils, and average seasonal temperatures should all be considered when determining site suitability. Land availability is another important factor, since natural treatment systems are usually located outside of wastewater treatment plant grounds. Existing local economic activities such as hay production, forestry, or farming should also be analyzed for their potential to be incorporated into the natural treatment system plan. This provides a depository for the treated wastewater and a resource for the established economic entities.

Natural treatment systems are not built in a vacuum. It is important to understand the values of the community under consideration and to look for ways to cater to the public's values such as bird watching and outdoor recreation. Public access, outreach, and education will help the natural treatment system gain support while communicating the purpose, benefits, and potential challenges of the natural treatment system and help manage the expectations of decision makers and the public. When utilizing a natural treatment system, treatment system managers and the community must be flexible and expect surprises. These are natural systems that combine a variety of interconnected factors to treat wastewater, and not every challenge can be predicted and planned for.

While there are published studies and many anecdotal statistics about the performance of individual natural treatment systems, pollutant removal performance varies for each system based on many factors including influent flow and pollutant load, characteristics of the sediment and/or vegetation in place, local climatic conditions, and others. In some cases, consultation with other jurisdictions that are operating under similar conditions may be helpful in determining what type of natural treatment system may meet a community's needs. Performing pilot studies is a more effective way to gather data that describes how a particular natural treatment system might be expected to perform under specific local conditions. These types of studies are especially important if the system is intended to treat an emerging contaminant or if the influent includes an unusual source such as treated industrial wastewater.

WETLAND TREATMENT

Before constructing a wetland treatment system, a comprehensive analysis of soil types and groundwater hydrology of the selected area must be performed. This includes mapping all drinking water wells in the immediate area, since leakage from the wetland system could have impacts on these wells. Background and ongoing groundwater monitoring should be an integral part of the system management plan, and floodplain impacts should also be considered.

The design of the wetland treatment system starts with determining what level of pretreatment is needed for the system to operate successfully. A comprehensive evaluation of influent water quality and chemistry is necessary. Planners must also determine whether a lined or unlined system is better for their community. What level of seepage to groundwater is acceptable? What should be done if the liner is damaged?

Other important design considerations include:

- Plant selection
- Flow control and measurement
- Target ratio of subsurface to surface flow
- System detention time, and
- Water depth

Coordinate carefully with your DEQ permit writer about the exact compliance points and associated monitoring. In some cases, DEQ may work with you to establish an additional compliance point for the effluent from the treatment wetlands. The design should allow for the inclusion of the necessary monitoring equipment at the permitted compliance point(s). If the wetland will be hydraulically connected to the treatment facility, a comprehensive model should be done.

As with traditional wastewater treatment technologies, monitoring of the processes that are occurring within the treatment wetlands is critical to its successful operation. Thought should be given to how and where monitoring should occur within the individual treatment wetland cells. It is common to provide monitoring equipment for data collection at the inflow and outflow points of each cell, for instance.

Wetland treatment systems are often open to the public, so it is important to consider how to handle and accommodate public use of the area. Important factors include signage, trail maintenance, restroom facilities, seating, tours, and security. Outreach materials help educate visitors about how the natural treatment system works. It is also important to consider unforeseen consequences of public use such as duck feeding and litter. Other challenges can include destructive wildlife such as muskrat and nutria, invasive species, and vector control of mosquitoes. Published studies can provide information on design strategies to minimize these negative impacts. For example, organic loading, nutrients, and emergent vegetation can have a significant effect on mosquito production and therefore should be taken into consideration when designing a wetland system. [xii]

PHYTO TREATMENT

WATER RECYCLING

Land application of treated wastewater involves a variety of considerations. Before initializing a water reuse system, system planners must determine the most suitable type of irrigation system (drip, spray, etc.) for the particular area. Water balance, seasonality, and salinity limits (especially in drier climates) must also be considered. A recycled water plan is essential to ensure proper record keeping. Since the type of recycled water use determines the level of wastewater pretreatment required, it is important to identify how the treated effluent will be used before commencing irrigation.

Challenges for water reuse systems can include aerosol or spray drift and cooperation with partners that are not affiliated with the wastewater treatment facility, such as golf course managers and farmers. Contracting with such entities requires training and poses risks such as over-irrigation and lack of monitoring.

TREE FARMS

Communities considering a tree farm system should be familiar with agricultural and forestry regulations that could apply to their tree farm, especially the Oregon Forestry Practices Act, which can have tax implications for tree farm operations. It is also important to ensure that the tree farm is congruent with local land use planning regulations.

While there is potential to generate and sell saw logs from a tree farm harvest, the market for wood is not robust or predictable, so plant managers should be prepared to not make a profit on their tree crop. Hiring forestry expertise to help analyze the market and gear forestry practices to market potential can be very beneficial.

The selection of the most suitable tree species for a particular system is essential. Pest and weed management plans need to be developed, along with a plan for soil monitoring. Labor needed to run the operation should be considered, as trees require maintenance and oversight. The farm should be laid out to allow for access for forestry equipment for maintenance and harvest.

INDIRECT DISCHARGE

A minimum of secondary-level treatment is required for indirect discharge systems. If improperly designed, indirect discharge can have negative impacts on drinking water supplies and fish populations. Therefore, it is important to consider fish use in a proposed indirect discharge area and map cold water refugia for sensitive fish populations. Working with the local Oregon Fish & Wildlife biologist is important to avoid negative impacts on fish and other wildlife.

Groundwater flow and characterization, including ongoing monitoring and consideration of seasonal variations in the groundwater table, can help prevent unexpected complications. Planners must coordinate closely with DEQ to map the waste management area, which must be owned and controlled by the wastewater treatment authority. Soil percolation modeling and testing are essential to determine appropriate flow rates and prevent plugging issues. DEQ's groundwater protection regulations are included in OAR 340, Division 40.

WATER QUALITY TRADING

Using water quality trading to meet strict temperature requirements is cheaper and more environmentally sound than other compliance options, such as installing chillers.

Utilities interested in water quality trading should look for local partnerships to build upon existing programs for agricultural practices pollution control, such as the incentives included in the national Farm Bill.

The potential for water quality trading within the basin must be assessed. Utilities will want to consider if they have the capacity to manage a water quality trading program or want to use a contract for generating credits, such as the City of Medford agreement with The Freshwater Trust.

WASTEWATER POND SYSTEMS

Wastewater pond systems need adequate available land. Some system can be designed for irrigation in the summer growing season, and discharge during the winter when stream flows are greater and there is increased dilution.

Attempt to design a system where the water can be stored and recycled and not discharged. Non-discharging systems can qualify for a State Water Pollution Control Facility permit. The WPCF permit has lower fees, fewer regulatory requirements, and less enforcement risk.

PUTTING IT ALL TOGETHER

The advantage of using natural treatment systems is that they are very flexible. Many systems, such as the system utilized by the Roseburg Urban Sanitary Authority (RUSA) , employ several natural treatment approaches that work in tandem to achieve treatment goals and maximize the utility of the overall system. Therefore, municipalities and districts interested in natural treatment systems should consider using a number of components to meet their wastewater treatment needs. For instance, can a wetland treatment system be installed that treats some of the flow, while a portion of the flow is applied to a tree farm? Or, can a nearby field used to grow hay during the summer months be partnered with a nutrient trading partnership with a local soil and water conservation district? Since different treatment approaches can be used to meet different performance standards, a combination of systems can provide a more complete treatment solution.

LESSONS LEARNED

Through the experience of designing, operating, and maintaining the natural treatment systems detailed above, the system operators have gained valuable insight and experience. The following is a summary of the lessons they learned throughout this process.

GENERAL

- Know your community's values. Are nature and natural spaces a value? Is energy conservation a value?
- Hire knowledgeable experts for assisting with the planning, design, and construction of these systems
- Tour similar facilities and ask questions when deciding whether a natural treatment system is right for your municipality
- Involve the operations team in planning and design
- Involve the appropriate regulatory authorities early in the process
- Carefully consider how you will conduct monitoring to know the system is performing as predicted
- Do not over-promise on performance of the system
- Educate public and elected officials as early as possible
- Be up front and foster community relationships
- Make sure neighbors understand the benefits and potential challenges of having a natural system nearby

- Invest effort in using as little energy as possible or even produce energy if possible
- Every year is different – change one operation at a time and give the system time to react

WETLAND TREATMENT

- Local topography is important. Wetlands need ample flat land.
- Identify jurisdictional wetlands and floodplains
- If you want to open the facility to the public, plan for considerations such as restrooms and litter
- Establish a plan and budget for vegetation and wildlife control at the outset
- Be aware of specific criteria for preserving the natural environment and the hydrological cycle
- Time of planting is important
- Be prepared for unexpected challenges such as weeds and birds that eat seeds/seedlings
- How to control and monitor flow between wetland cells and monitoring performance within each cell is important

WATER RECYCLING

- Talk to local agricultural users. How do producers in your area feel about recycled water?
- Match the recycled water use with the level of treatment
- Put contingency plans in place for handling spills
- Communicate with nearby neighbors and institute a process for responding to any concerns or complaints

TREE FARMS

- Know you are in it for the long haul – cannot just plant trees and forget about them
- Maintenance will vary depending on the type(s) of tree selected and the end wood product goals
- Additional soil supplements or pest control may be needed
- Consider responses to wind damage and seasonality
- Understand that this is first and foremost a treatment system, not a monetary investment
- Monetary gains can vary due to system operation costs and wood products market fluctuations

WATER QUALITY TRADING

- Conduct a survey to learn what water quality trading opportunities are available
- Analyze the impact of the existing or increased wastewater discharge against chronic or lethal conditions, especially if fish are present in the receiving stream
- Be transparent about the types of credits being generated and document progress towards meeting environmental goals
- Consider how you will monitor and report on the effectiveness of the trading system

WASTEWATER PONDS

- Involve the public in siting decisions
- Carefully calculate the water storage needs of the system, including winter rainfall

SYSTEM INVENTORY

There are a variety of natural treatment systems in use in Oregon. The summary below highlights some of the Oregon systems. Communities interested in natural treatment systems can contact these communities and learn about their experiences, along with touring the facilities.

CITY OF ALBANY

The City of Albany's 9.6 MGD average dry weather flow water reclamation facility operates under an NPDES permit. In 2010, the City installed Talking Water Gardens, a system of 38.3 acres of treatment wetlands that operates year-round. The initial design was for an average dry weather flow of 11.6 MGD. This system was designed to meet the temperature reduction requirements of the Willamette Total Maximum Daily Load, developed by DEQ and approved by EPA. [xiii] Albany's treatment wetlands are also somewhat unique in that a local industrial facility also discharges its treated wastewater directly to the wetlands. Design and construction costs were $10.7 million with an additional $5.6 million for land acquisition. Operations and management costs average about $300,000 per year.

The City of Albany is currently gathering additional information on the effectiveness of the system in meeting its targeted pollution reduction goals. This system provides additional benefits to the community including walking trails, bird watching, wildlife habitat, and environmental education.

CITY OF BEND

The City of Bend Water Reclamation Facility was installed in 1981. Located near the Deschutes River, the City of Bend beneficially reuses all its treated wastewater. No wastewater is discharged to the River. The 6 MGD wastewater treatment facility uses both secondary treatment and nutrient treatment processes, along with anaerobic digesters, including a substantial Class A water reuse program. The water reuse program is used from April to October to treat secondary effluent under a WPCF permit. The system meets its pollutant reduction goals of 20 mg/l of BOD and 20 mg/l Total Suspended Solids with a 10.0 mg/l total nitrogen content in the effluent.

The Bend Water Reclamation Facility is currently being expanded to meet the population needs into 2030.

The City of Bend beneficially reuses all its treated effluent on a 1600-acre area that includes grounds around the treatment plant and at nearby golf courses. Using treated effluent as a substitute for potable water for irrigation conserves water and reduces chemical fertilizer use. A significant portion of the treated effluent is used to irrigate landscaping and greens at the Pronghorn Resort. The Pronghorn Resort includes two 18-hole golf courses – the Jack Nicklaus Signature Course and the Tom Fazio Course.

It cost $4 million to design and construct the natural treatment system and ongoing operation and maintenance costs average $25,000-$50,000 per year. Energy requirements to treat the wastewater to applicable standards averages 500,000 kilowatt hours per year. Additional system amenities include bird watching.

CLEAN WATER SERVICES

Clean Water Services (District) is a special service district that serves more than 536,000 customers mostly in the urban portion of Washington County. The District owns and operates four wastewater treatment plants in the Tualatin River basin. The District, along with its 12 member cities and Washington County, also implements the Municipal Separate Storm Sewer System (MS4) program in urban Washington County. The wastewater treatment plants and MS4 are permitted by the Oregon Department of Environmental Quality (DEQ) under a single watershed-based National Pollutant Discharge Elimination System (NPDES) permit.

The 2001 Temperature Total Maximum Daily Load (TMDL) for the Tualatin River included strict thermal load allocations for the District's Rock Creek and Durham Advanced Wastewater Treatment Facilities (AWTFs). The thermal load allocations were later incorporated into the District's watershed-based NPDES permit. The District evaluated technological and source control options to meet the thermal load limits. Ultimately, the District concluded that the technology-based approach, which would require mechanical cooling, was resource intensive and cost prohibitive, and would do little to improve watershed health. The District adopted a strategy to offset the thermal load from the two AWTFs with riparian planting and flow augmentation. The District concluded that this approach was not only cost-effective, but would provide an opportunity to improve overall watershed health.

The District's watershed-based NPDES permit included provisions to develop and implement a Temperature Management Plan (TMP) which specified the District's approach to offsetting the thermal load from the Rock Creek and Durham AWTFs. The TMP included programs that the District would implement to offset the thermal load from the AWTFs. Since 2004, the District has implemented a trading program to offset the thermal load from the Rock Creek and Durham AWTFs. The thermal load trading program consists of augmenting stream flow in the Tualatin River with its stored water releases and riparian planting in the Tualatin River watershed.

The District augmented stream flow in the Tualatin River using its stored water in Hagg Lake (Scoggins Reservoir) and Barney Reservoir. From 2004-13, the District released an average of 35.2 cubic feet per second (cfs) of its stored water during the critical months of July and August to augment flows in the Tualatin River. Thermal credits for flow augmentation are based on the temperature benefits of the augmentation water at the Rock Creek and Durham AWTFs.

A riparian planting program was implemented in the urban and rural areas of the Tualatin River basin. In urban areas, the District implemented the riparian planting program. The projects in the urban areas included riparian planting and, on a site specific basis, stream enhancement activities such as stream bank stabilization, channel reconfiguration, large wood placement, floodplain reconnection, and off-channel habitat. From 2004-13, a total of 48 projects were implemented in urban areas of the watershed, which resulted in over 18 stream miles being planted. In rural areas of the watershed, the District contracted with the Tualatin Soil and Water Conservation District to provide incentives for enrolling landowners in an enhanced version of the U.S. Department of Agriculture's Conservation Reserve Enhancement Program (CREP) and Vegetated Buffer Areas for Conservation and Commerce (VEGBACC) programs. From 2004-13, a total of 45 projects were implemented in rural areas of the watershed, which resulted in 24.9 stream miles being planted. In all, the urban and rural riparian planting programs resulted in 43 miles of planting in the Tualatin River watershed. A 2:1 trading ratio is used to calculate the thermal credits from the riparian planting program.

CITY OF COTTAGE GROVE

The Cottage Grove facility conducts land application of its treated secondary effluent. Cottage Grove operates a 1.8 MGD dry weather/3.5 MGD wet weather plant under an NPDES permit. Installed in 2007, the facility irrigates a 75-acre golf course and driving range, along with hospital grounds, in the summer. The system was designed to help meet a 75% pollutant reduction goal. Test results show that the system is meeting the goal.

CITY OF HARRISBURG

The City of Harrisburg's 0.49 MGD wastewater treatment system includes a 58-acre poplar farm that is irrigated during the months of May to October with treated recycled water. The City grows four varieties of poplars that were planted in 2005. As of April 2013, the poplar trees were eight years old, and are intended to be harvested on a 12-year rotation, consistent with the Oregon Forest Practices Act. The trees are managed by the City of Harrisburg Public Works Department.

Harrisburg also utilizes a series of wastewater ponds, installed in 1992 and expanded in 2004. The ponds cover an area of 26 acres with two acres of rock filter. Both the wastewater ponds and the poplar tree farm are regulated under an NPDES permit.

CITY OF JUNCTION CITY

Constructed in 1966/1967, the City of Junction City's 0.8 MGD dry weather sewage treatment plant operates under an NPDES permit. The system includes 50 acres of wastewater ponds that are used during the wet season, from November to April, to treat secondary effluent. During the dry season, treated wastewater is land applied at agronomic rates using sprinkler systems on adjacent agricultural land. Actual average flow over the past two years has been 0.62 MGD during the dry season and 2.06 MGD during the wet season.

CITY OF MEDFORD

The Medford Regional Water Reclamation facility treats wastewater from the cities of Central Point, Jacksonville, Phoenix, Talent, Eagle Point, and other unincorporated Jackson County areas. The 20 MGD average dry weather flow facility is an activated sludge treatment plant, with a trickling filter. A biogas generator fuels the facility by combusting waste gas from the digester.

The City of Medford Regional Water Reclamation Facility discharges to the Rogue River, near important steelhead and salmon spawning beds. Strict temperature requirements were included in the Medford water quality permit. Temperatures at wastewater treatment plants are elevated due to hot water from households washing clothes and dishes and taking showers.

The City and DEQ staff evaluated a number of alternatives, including water quality trading, to meet the stringent water quality temperature limits, including:

1. Internal plant changes
2. Evaporative cooling
3. Effluent recycling and reuse
4. Effluent chillers
5. Effluent storage
6. Temperature trading.

The three feasible alternatives, chillers, effluent storage, and trading, were further evaluated based on operability, effectiveness, reliability, flexibility, energy consumption, public and regulatory acceptability, regulatory compliance, and risk control. Using these criteria, effluent chillers scored the lowest, with the highest energy consumption and lowest perceived public acceptance. While effluent storage offers improved flexibility by allowing the plant to divert flows to storage, it is a higher energy consumption alternative to temperature trading.

Temperature trading had the lowest estimated cost at $6 million, versus $16 million for effluent chillers.   Based on this information, the City of Medford entered into a contract with The Freshwater Trust to develop and implement a water quality trading program to restore streamside vegetation to meet the City's temperature obligations.

Medford also utilizes a thermal credit trading program to meet standards that require an effluent temperature reduction of 1 degree Celsius, an equivalent of about 300 million kilocalories. Instead of paying $16 million to build and operate an effluent chilling system, the City developed an $8 million trading program. It pays for the eradication of non-native species in riparian areas and replaces them with native trees and plants that shade the stream. It also pays stream-side landowners $100-$300 per acre per year to host these restoration projects. The City will create projects to offset 600 million kilocalories of heat output in alignment with a 2:1 ratio that helps offset possible project failures. Over the next 20 years, the City will monitor these sites for success.[xiv]

More about the Medford trading program is available at http://www.thefreshwatertrust.org/fixing-rivers/water-quality-trading/

METROPOLITAN WASTEWATER MANAGEMENT COMMISSION (MWMC)

The Metropolitan Wastewater Management Commission treats sewage from the City of Eugene, the City of Springfield, and the urbanized areas of Lane County. The 49 MGD treatment plant is located on the banks of the Willamette River in the City of Eugene. The treatment plant uses an innovative natural treatment system for biosolids recycling and recycled water application.

MWMC's Eugene/Springfield Water Pollution Control Facility currently produces approximately 5,000 dry tons of biosolids annually from three anaerobic digesters. The solids are processed at the Biosolids Management Facility (BMF), located 5.5 miles north of the treatment plant. For the majority of biosolids produced, MWMC relies on voluntary cooperative agreements with farmers to utilize biosolids as a source of nutrients for agricultural crops.

In addition, in 1997, MWMC adopted a Biosolids Citizens Advisory Committee's (CAC) recommendation to diversify the biosolids program, which included a dedicated application site growing hybrid poplar trees. Hybrid poplars are a great option for biosolids application and recycling because these trees combine a long growing season with significant water and nutrient uptake capacity due to their rapid growth rate.

In order to ensure the availability of land for environmentally-sound application of biosolids, MWMC purchased land, called the Biocycle Farm and began planting poplar trees in 2004. By 2010, MWMC had completed phased implementation of the farm, with a total area of nearly 400 acres containing 88,000 trees. On average, 750 dry tons of Class B biosolids and 70 million gallons of Class D recycled water is irrigated on the poplar farm annually. By owning and operating its own farm connected by pipelines to the WPCF, MWMC furthers its sound management practices and achievement of high environmental standards.

CITY OF MYRTLE CREEK

The City of Myrtle Creek's 1.8 MGD dry weather/2.4 MGD wet weather wastewater treatment process includes the use of recycled water for golf course irrigation. Their system was installed in 1996 and upgraded in 2003. The 120-acre facility is used seasonally, from May 1 to October 31, to reduce nutrient discharge to the South Umpqua River during the summer season.

CITY OF NEWBERG

The City of Newberg's 4 MGD wastewater treatment plant was installed in 1989 and is in the process of being upgraded. Operating under an NPDES permit, the facility was designed to meet an 85% pollutant reduction goal, which it succeeds in meeting. Secondary effluent is discharged to the Willamette River year-round. During the dry season, the City further treats a portion of its wastewater and provides this water to the local golf course for recycled water irrigation purposes.

CITY OF PRINEVILLE

The City of Prineville's municipal wastewater treatment system utilizes water recycling and wastewater ponds as part of its system. The treatment plant was installed in the 1960s, and has gone through multiple upgrades, the last of which was in 2005. This latest upgrade brought the dry weather design flow to 1.6 MGD. Operating under an NPDES permit, the City of Prineville land applies secondary effluent during the dry season on the 123-acre Meadow Lakes Golf Course and more recently on farmland adjacent to the wastewater treatment facility. This system was designed to help the municipality meets its pollutant reduction goals of CBOD to 25 mg/L and TSS to 40 mg/L. For the most part the facility meets these goals although algal blooms can cause suspended solids issues during the months of February and March.

The 2005 facility upgrade cost approximately $8 million dollars. Operations and management costs average $1450 per million gallons treated, or approximately $500,000 per year. Energy usage averages 4640 kilowatt hours per million gallons treatment, or 1,598,000 kilowatt hours per year. Additional benefits of the system include wildlife habitat.

ROSEBURG URBAN SANITARY AUTHORITY (RUSA)

The Roseburg Urban Sanitary Authority (RUSA) provides sanitary sewer service to the City of Roseburg and the area within the Roseburg Urban Growth Boundary. The 7.9 MGD dry weather/15 MGD wet weather Roseburg Regional Wastewater Treatment Facility (WWTF) was installed in 1985-87 and utilizes treatment wetlands and indirect discharge under an NPDES permit to seasonally polish treated secondary effluent.

The complex natural treatment system, constructed in 2009-2012 on a private farm near the WWTF that RUSA owns, contains hydraulic management, treatment, and ecosystem services components. This includes a reuse pump station at the WWTF, an irrigation pond and treatment wetlands, land application as agronomic and high-rate irrigation, indirect discharge, mitigation wetlands, and restoration of historic natural wetlands on the farm.[xv] The system utilizes farm crops, soil organisms, and soil chemical reactions to uptake, absorb, and transform target constituents in the treated effluent. The drainage waters from these natural processes then percolate through the soil and discharge to the nearby surface waters in compliance with the water quality criteria of the river.[xvi]

The 340-acre facility is used seasonally, from May 1 to October 31, to treat 8 MGD dry weather WWTF-treated effluent flow. It was designed to meet the 2006 Temperature TMDL for the South Umpqua River and to reach effluent phosphorus levels of less than 3.4 pounds per day, a 97% reduction from normal levels. According to system managers, the system achieves that goal, offering a cost-effective alternative to conventional treatment systems while meeting stringent water quality standards. In the summer of 2013, the natural treatment system's first full summer of operation, the NTS removed 96.2 percent of the total phosphorus, releasing only 603 pounds to the South Umpqua River. The DEQ/RUSA target of no more than a 1 mg/L decrease in dissolved oxygen from upstream to downstream sample points was met 100 percent of the time, and dissolved oxygen in the downstream sample point was above the statewide cold water standard of 8 mg/L 100 percent of the time.[xvii]

The surface flow wetland cells at Salem have also been monitored for temperature treatment and have shown to be effective in lowering effluent temperatures from the WWTP. Data from the constructed wetland cell showed that with 6 to 13 days of hydraulic retention time, the average temperature reduction was 3 ^{o}C in July to 8.3 ^{o}C in December .

Construction costs were approximately $8.5 million while ongoing operations and maintenance costs average about $200,000 per year. This represents enormous savings compared to a conventional treatment plant, which would have cost $100 million to design and construct and $6 million in annual operation and maintenance costs. [xviii] The system also provides additional community benefits such as tours for diverse groups such as middle school classes, engineers, the Audubon Society, and civic groups.

CITY OF SALEM

The City of Salem operates the 35 MGD Willow Lake Treatment Plant, serving Salem and Keizer. The treatment process includes a 1.0 MGD Natural Reclamation System, a treatment wetlands system that was installed in 2002. Design and construction costs were $3.5 million and operations and maintenance costs are $20,000 per year. The treatment area covers 10 acres with 20 acres of non-process native habitat and is used year-round to treat secondary effluent. The facility operates under a state-only WPCF permit and achieves its design goals of temperature and ammonia reduction. According to system managers, the system has been a success and provides a great learning environment that can be used for furthering knowledge of natural treatment systems for both facility operators and the public. Additional benefits of the system include walking trails, bird watching, wildlife habitat, and environmental education.

The City of Salem Natural Reclamation System can treat up to 1 million gallons per day (mgd) of secondary effluent. The City's main treatment plant (Willow Lake Water Pollution Control Facility) does not have the capacity to perform nutrient removal in its current process and can send secondary treated wastewater to the wetlands with ammonia levels as high as 25 mg/l, which at 1 MGD equals 208.5 pounds of ammonia. The wetlands treatment system is capable of removing most of the ammonia and can routinely reduce ammonia concentrations to less than 1 mg/l at the end of the process. Total Kjeldahl Nitrogen (TKN) is also reduced to a range of 1 to 2 mg/l. The Salem wetland treatment system is effective in removing most of the nitrogen from the water. The only cost for this system is the pumping of the water from the main plant out to the wetlands. Now that the system is fully established and operational, ongoing operations and maintenance costs for this nutrient treatment system is approximately $80.00 per day.

CITY OF SILVERTON

The 2.25 MGD Silverton Wastewater Treatment Plant utilizes a 17-acre treatment wetland system that was installed in 1999 and operates under an NPDES permit. Operations and maintenance costs average $46,000 per year. These treatment wetlands are classified as warm water refugia and receive high-temperature secondary wastewater treatment plant effluent during the summer months (May 1 – October 31). The wetland water is also used to irrigate the Oregon Gardens, an ornamental botanical garden. Energy costs to irrigate the Oregon Gardens average about $1,100 per year.

This natural treatment system was designed to help the City of Silverton meet the thermal load limit of less than 5.2 kilocalories per day for Silver Creek. Facility managers report that the system performs very well, meeting the temperature reduction design goals while offering additional amenities including botanical garden irrigation, walking trails, wildlife habitat, bird watching, and environmental education.

CITY OF VENETA

The City of Veneta's 1.25 MGD wastewater treatment plant was installed in 1970. Originally consisting of a single facultative lagoon system, the City expanded to two lagoons in 1976. In 1982, due to increasing flows, the lagoons could no longer hold all of the effluent during the summertime, so the City began conducting irrigation on City-owned fields during the summer season, usually during the months of May to October. After undergoing primary and secondary treatment in the activated sludge treatment facility, the effluent is disinfected and sent to the effluent holding lagoon. From there, irrigation pumps move the effluent to city-owned fields located to the north of the city. A mixture of poplar trees and hay are grown in these fields.

CITY OF WOODBURN

The City of Woodburn's 3.3 MGD dry weather/4.8 MGD wet weather wastewater treatment facility was installed in 1999. As part of the wastewater treatment system, the City utilizes secondary effluent to irrigate an 88-acre poplar farm that provides phyto treatment services. The poplar farm system is operated during the dry season (June-October) under an NPDES permit. Biosolids are also applied on the poplar farm during the summer months. The system was designed to reduce ammonia loading to the receiving stream. According to system operators, the system is straightforward and effective, meeting ammonia reduction requirements and while providing additional benefits to the community including environmental education.

SYSTEMS USED BY OREGON MUNICIPALITIES

Facility	Wetland Treatment	Recycled Water	Tree Farms	Indirect Discharge	Water Quality Trading	Wastewater Ponds
City of Albany	X					
City of Bend		X				
Clean Water Services		x			X	
City of Cottage Grove		X				
City of Harrisburg			X			X
City of Junction City		X				X
City of Medford					X	
MWMC (Eugene/Springfield)		X	X			
City of Myrtle Creek		X				
City of Newberg		X				
City of Prineville		X				X
RUSA	X			X		
City of Salem	X					
City of Silverton						
City of Veneta		X	X			X
City of Woodburn			x			

RECYCLED WATER SYSTEMS

This list was generated by Oregon Department of Environmental Quality staff.

Facility	***Recycled Water Use***						
	Tree Farms	*Golf Courses*	*Other Landscapes (Cemeteries, City Parks, etc.)*	*Forest Lands*	*Fodder (e.g Hay)*	*Nursery*	*Other*
City of Albany							X
Camp Rilea			X				
OHSU – Center for Health & Healing							X

Facility	***Recycled Water Use***						
	Tree Farms	*Golf Courses*	*Other Landscapes (Cemeteries, City Parks, etc.)*	*Forest Lands*	*Fodder (e.g Hay)*	*Nursery*	*Other*
Nehalem Bay					X		
City of Amity					X		
City of Arch Cape				X			
City of Aumsville					X		
City of Aurora	X						X
City of Bend		X			X		
City of Bly							X
City of Bonanza					X		
City of Brownsville					X		
City of Burns/Hines					X		
City of Butte Falls				X			
City of Cave Junction		X					
Clean Water Services		X			X		X
City of Cottage Grove		X					
City of Creswell					X		
City of Culver					X		
City of Donald					X		
City of Drain					X		
City of Dufur					X		

Facility	***Recycled Water Use***						
	Tree Farms	*Golf Courses*	*Other Landscapes (Cemeteries, City Parks, etc.)*	*Forest Lands*	*Fodder (e.g Hay)*	*Nursery*	*Other*
City of Gervais	X				X		
City of Harrisburg	X						
City of Junction City					X		
City of Lakeside				X			X
City of Lakeview					X		
City of Madras					X		
City of Malin					X		
MWMC/Eugene	X				X		
City of Merrill					X		
City of Metolius					X		
City of Molalla					X	X	
City of Monmouth					X		X
City of Monroe							X
City of Moro					X		
City of Myrtle Creek		X					
City of Newberg		X					
City of Oakland					X		
City of Oakridge				X	X		
City of Paisley							X
City of Philomath					X		

Facility	Recycled Water Use						
	Tree Farms	*Golf Courses*	*Other Landscapes (Cemeteries, City Parks, etc.)*	*Forest Lands*	*Fodder (e.g Hay)*	*Nursery*	*Other*
City of Prineville		X			X		
RUSA							X
City of Redmond					X		
City of Saint Paul					X	X	
City of Salem		**X**					**X**
City of Sandy						**X**	
City of Silverton							**X**
City of Sisters					**X**		
City of Sheridan					**X**		
City of Sutherlin		**X**					
City of Tangent							**X**
City of Veneta	**X**				**X**		
City of Wamic					**X**		
City of Wasco					**X**		
City of Woodburn	**X**						

PENDING SYSTEMS

ASHLAND

The City of Ashland's 2.1 MGD secondary wastewater treatment plant uses oxidation ditch technology, with an anoxic zone. During the summer months, Ashland uses membrane filtration to treat wastewater and remove phosphorus. The City of Ashland is one of only a handful of facilities in Oregon that are required to treat wastewater to remove phosphorus. Ashland is now planning further improvements to its treatment plant by relocating its outfall to a larger nearby stream, while constructing wetlands to provide temperature reductions to address near field temperature issues. The City is also working to incorporate water quality trading into its water quality permit compliance plans to address far field temperature issues. The combination of these natural treatment approaches would build on the success of other communities that have demonstrated that natural solutions can be more cost effective for ratepayers, while providing greater environmental gains than their mechanical alternatives.

HOODLAND

The Hoodland Wastewater Treatment Plant, located in Welches, Oregon, serves a mountain community of 4000 customers. Treated wastewater from the Hoodland plant is discharged to the nearby Sandy River via a traditional in-river outfall structure. The beauty of the Hoodland area is matched by the intensity of rain events and the Sandy River is well-known for being dynamic and destructive during high river flows. Hoodland's river outfall structure was destroyed during a flood event in 1996, rebuilt in 1998, and destroyed again in 2011.

Clackamas Water Environment Services (WES), in coordination with regulatory agencies and consultants, is evaluating the possibility of using an indirect discharge system adjacent to the river channel. WES has facilitated meetings with the local community on the project goals and status. Several meetings and phone conferences have taken place with DEQ and other agency staff to update them on project development and to obtain feedback on the project approach. Stakeholder reactions to the project concepts have been positive.

The following studies have been conducted thus far:

- Soil sampling and depth to groundwater monitoring through test pit installation – Test pits were installed in January 2012 and data indicated that the Sandy River was a gaining stream in this area.
- Installation of three monitoring wells and a pump test to assess hydraulic conductivity and direction of groundwater flow at the site and refine groundwater hydrology modeling.
- A wetland delineation study with an assessment of Sandy River Ordinary High Water Elevation Survey and a Rare Plants Survey. The study concluded that no wetlands or rare plants are present within the study area.
- An evaluation of the geomorphology of the upper Sandy River in the vicinity of the preferred indirect discharge site.
- A fisheries survey conducted at the preferred discharge location. The study showed that spawning habitat is limited due to the large substrate size. The preferred discharge location was chosen in part because spawning habitat is limited in the immediate vicinity.

The project is anticipated to provide a more resilient system that is less likely to be damaged during subsequent Sandy River flood events while at the same time improving receiving water quality as a result of improved and more dispersed dilution into the river.

CLEAN WATER SERVICES – FERNHILL

The Fernhill Natural Treatment System in Forest Grove is planned to be built in 2015-2016. It will include 95 acres of treatment wetlands. It is planned for year-round use but the primary benefit is anticipated to be achieved during the dry season. It is designed to achieve temperature reduction goals under an NPDES permit while offering additional amenities to the community including walking trails, bird watching, wildlife habitat, and environmental education.

The initial design flow rate of the facility is 5 MGD. By 2025, the system is anticipated to have a flow of 6.3 MGD, with an increase to 9 MGD and finally 18 MGD further in the future. The following table summarizes the system's predicted temperature changes based on these different flow rates.

Table 5-9 Summary of average predicted temperature changes in Celsius through wetlands at various flows. Negative numbers imply cooling of water relative to influent.

	Average Predicted Degree Change from Inflow for Four Flow Rates (negative reflects cooling)			
Month	5 MGD	6.3 MGD	9 MGD	18 MGD
Jan	-4.7	-4.3	-3.8	-2.6
Feb	-4.8	-4.5	-4.0	-2.8
Mar	-4.9	-4.5	-4.0	-2.9
Apr	-3.8	-3.6	-3.2	-2.5
May	-3.4	-3.2	-2.8	-2.1
June	-1.4	-1.3	-1.2	-0.9
Jul	-1.0	-1.0	-0.9	-0.7
Aug	-2.8	-2.7	-2.4	-1.8
Sep	-5.0	-4.6	-4.0	-2.8
Oct	-5.8	-5.4	-4.6	-3.1
Nov	-6.4	-5.9	-5.2	-3.6
Dec	-5.7	-5.3	-4.6	-3.2
Annual	-4.1	-3.8	-3.4	-2.4

The following table summarizes predicted removal rates for other selected pollutants:

Pollutant	***Influent (mg/l)***	***Effluent (mg/l)***
BOD	6	3
TSS	12	6
Ammonia	2	0.2
Phosphorus	0.5	0.3

WOODBURN

In response to a 2008 Pudding River Total Maximum Daily Load (TMDL) issued for temperature, the City of Woodburn plans to develop a constructed wetlands partially within an existing unused effluent lagoon and on adjacent City-owned floodplain land to provide passive cooling. This approach would provide a cost effective alternative to expensive and high energy demand chillers otherwise required to meet the temperature requirements. Planned improvements to the wastewater treatment facility include improved aeration and disinfection, emergency back-up generators, road improvements, and increased pumping capacity along with an expansion to the poplar tree system and construction of a 10 million gallon irrigation regulating reservoir and 26 acres of constructed wetlands with a new outfall into the Pudding River.

CONCLUSION

Natural treatment systems, including wetlands, recycled water systems, tree farms, indirect discharge, water quality trading, and wastewater treatment ponds are a sustainable, and affordable wastewater treatment system for Oregon communities, especially rural Oregon communities. All communities should incorporate evaluation and consideration of natural treatment systems as part of on-going facility planning and treatment system updates and expansions.

The reduced operation, chemical, and energy costs of natural treatment systems make them more sustainable. Although planning a successful natural treatment system may take more planning up front, the investment will pay off later for the community. Communities should be evaluating a number of different natural treatment systems combined into one holistic system.

Additional community benefits can include recreation, environmental education, and open space.

APPENDICES

APPENDIX 1: DISCHARGING AND NON-DISCHARGING LAGOON SYSTEMS IN OREGON[xix]

DISCHARGING LAGOON SYSTEMS

ALPINE COMMUNITY	AMITY STP	ASTORIA STP
AUMSVILLE STP	AURORA STP	BAKER CITY WWTP
BAY CITY STP	BORING STP	BROOKS STP
BROWNSVILLE STP	CARLTON STP	COUNTRY VIEW MOBILE HOME ESTATES
CRESWELL STP	DAYTON STP	CITY OF DAYVILLE
DUFUR STP	DUNDEE STP	ECHO STP
ELGIN STP	GERVAIS STP	GOSHEN ELEMENTARY SCHOOL STP
GRAND RONDE STP	HALFWAY STP	HALSEY STP
HARRISBURG LAGOON TREATMENT PLANT	HUNTINGTON STP	INDEPENDENCE STP
JOSEPH STP	JUNCTION CITY STP	KNOLL TERRACE MHC
LA GRANDE STP	LAKEVIEW STP	LANE COMMUNITY COLLEGE
MOLALLA STP	MONMOUTH STP	MONROE STP
MT VERNON STP	NEHALEM BAY STP	NORTH POWDER STP
ONTARIO STP	PHILOMATH WWTP	PRINEVILLE STP
RICE HILL EAST LAGOON	RICE HILL WEST LAGOON	SCIO STP
SHERMAN BROS. TRUCKING	SHERIDAN STP	SILETZ STP
SOUTH SUBURBAN STP	TANGENT STP	TILLAMOOK INDUSTRIAL PARK STP
VENETA STP	VERNONIA STP	WALLOWA STP
WARRENTON, CITY OF STP	WILLAMINA STP	YONCALLA STP

NON-DISCHARGING LAGOON SYSTEMS

ADRIAN STP	ANANDA LAURELWOOD	BLY STP
BOARDMAN SAFETY REST AREA	BOARDMAN STP	BONANZA STP
BURNS STP	CAMP RILEA STP	COMFORT INN AND SUITES
CARLTON, MARK W	CONDON STP	COVE STP
CRANE HIGH SCHOOL	CULVER STP	DEVLIN, LEW & JOAN
DIKESIDE MOORAGE	DONALD STP	EAGLES HOT LAKE RV PARK (ABN)
EMERALD VALLEY RESORT	EMIGRANT LAKE RECREATION AREA STP	FOSSIL STP
GILCHRIST SEWER COMPANY, LLC	HAINES STP	HEARD FARMS
HINES STP	HOWARD PRAIRIE RECREATION AREA	ILLAHE ESTATES WATER SYSTEM
JOHN DAY STP	JORDAN VALLEY STP	CITY OF LA PINE
LEHMAN HOT SPRINGS RESORT	MADRAS STP	MALIN STP
MERRILL STP	METOLIUS STP	MILO ACADEMY, INC.
MILTON-FREEWATER STP	MONUMENT STP	MORO STP
MORROW COUNTY OHV PARK	NORTH VALLEY HIGH SCHOOL STP	NYSSA STP
OCHOCO WEST SUBDIVISION	OLSON ROAD FACILITY	ODOT - COW CREEK REST AREA, DOUGLAS COUNTY
ODOT - DEADMAN'S PASS REST AREA	OPRD - BEVERLY BEACH STATE PARK	OPRD - STEWART STATE PARK
OPRD - SUNSET BAY STATE PARK STP	OREGON WATER WONDERLAND UNIT II STP	OYA – RIVERBEND
PGE PROMONTORY PARK STP	PAISLEY STP	PILOT ROCK STP
PIONEER VILLA	PIRATE'S COVE MARINA LLC	PORT OF TILLAMOOK BAY
PRAIRIE CITY STP	RVS	RADAR HOLDING LLC
RAINEY'S CORNER MARKET	REXIUS	RICHARDSON POINT PARK STP
RICHLAND STP	RIVER MEADOWS	ROCKY POINTE MARINA
ROUND LAKE SEWER	RUFUS STP	SENECA STP
SILVER FOX RV PARK	SILVER SPUR RV PARK	SISTERS WASTEWATER TREATMENT IMPROVEMENTS
SOUTH VALLEY RESOURCE & TRUCK SHOP	SPACE AGE TRAVEL CENTER	SPRAY STP
ST. PAUL STP	STANFIELD HUTTERIAN BRETHREN	SUMPTER RAILROAD PARK
SUMPTER STP	TRAPPIST ABBEY OF O.L. OF GUADALUPE	USNPS - CRATER LAKE NATIONAL PARK
USFS - MALHEUR NATIONAL FOREST; ALLISON GUARD STATION	USFS - ROGUE RIVER NATIONAL FOREST, APPLEGATE R.D.;HART-TISH PARK STP	USFS - UMATILLA NATIONAL FOREST; DALE WORK CENTER

USFS - UMPQUA NATIONAL FOREST; DIAMOND LAKE STP	USACOE - COTTAGE GROVE LAKE STP	USBLM - OREGON TRAIL CENTER INTERPRETIVE CENTER
USBLM - SHOTGUN CREEK RECREATION PARK	UKIAH STP	UNITY STP
VALE STP	WAMIC WATER AND SEWER AUTHORITY	WASCO STP
WEDDERBURN STP	WESTON STP	WILLOW LAKE RECREATION AREA STP
YOUNG LIFE	ZIG ZAG VILLAGE STP	

APPENDIX 2: USEFUL RESOURCES

These resources will be most useful in assisting communities in exploring natural treatment systems. A short descriptor of each reference is included.

Austin, D. (2006). Influence of cation exchange capacity (CEC) in a tidal flow, flood and drain wastewater treatment wetland. *Ecological Engineering*, *28*(1), 35-43.

> *This article discusses how the cation exchange capacity of aggregate can dramatically affect treatment performance in flood and drain wastewater wetland treatment systems, especially in reference to wetland plants that are utilized as part of the treatment process.*

Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006).*Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.

> *This book provides an in-depth examination of all types of natural wastewater treatment systems, including wastewater pond systems, free water surface constructed wetlands, subsurface and vertical flow constructed wetlands, land treatment, sludge management, and onsite wastewater systems. The book illustrates the practical aspects of these systems through case studies and includes a broad range of data on costs, performance, and constraints of these systems.*

Dong, Z., & Sun, T. (2007). A potential new process for improving nitrogen removal in constructed wetlands—promoting coexistence of partial-nitrification and deammonification. *Ecological Engineering*, *31*(2), 69-78.

> *This document examines the potential for nitrogen removal via microbial pathways based on partial-nitrification of ammonia. Recent experiments show that this process can achieve higher nitrogen removal in constructed wetlands than conventional nitrification methods and that this process could lead to significant improvements to constructed wetland performance.*

Gasik, J. Oregon Department of Environmental Quality. (2012). *Preparation of operations and maintenance manuals for domestic wastewater treatment facilities* (DEQ 12-WQ-056). Retrieved from website: http://www.deq.state.or.us/wq/rules/div052/guidelines/stpommanuals.pdf

> *This document is a practical guide that is intended to help domestic wastewater plant owners write operations and maintenance (O&M) manuals. Tips are provided to help improve the*

quality and usefulness of these manuals and reduce review time. This document applies primarily to mechanical wastewater treatment systems that discharge treated water to surface waters under a National Pollutant Discharge Elimination System (NPDES) permit.

Kadlec, R., & Wallace, S. (2009). *Treatment wetlands*. (2nd ed.). CRC Press.

This book provides a comprehensive resource for the planning, design, and operation of wetland treatment systems. It addresses the design, construction, and operation of wetlands for water pollution control, presents the best current procedures for sizing these systems, and describes the intrinsic processes that combine to quantify the performance of these systems.

Molle, P., Lienard, A., Boutin, C., Merlin, G., Iwema, A. (2005). How to treat raw sewage with constructed wetlands: an overview of the French systems. Water Science Technology 51(9):11-21.

This document examines the use of vertical flow wetlands used to treat raw sewage in France, which has proved to be very successful. A survey of 80 treatment plants provides insight into important design considerations and pollutant removal performance of these systems, with a focus on nitrogen removal.

Oregon Department of Environmental Quality. (2007). *Disposal of municipal wastewater treatment plant effluent by indirect discharge to surface water via groundwater or hyporheic water*. Retrieved from website: http://www.deq.state.or.us/wq/pubs/imds/indirectdischarge.pdf

This internal management directive describes treatment municipal wastewater discharge systems and the rules that govern them, including groundwater protection, water quality standards, and underground injection control. A discussion of NPDES and WPCF permits and permitting of indirect discharges is included.

Oregon Department of Environmental Quality. (2012). *Water quality trading in NPDES permits*. Retrieved from website: http://www.deq.state.or.us/wq/pubs/imds/wqtrading.pdf

This internal management directive discusses minimum provisions for water quality trading, mechanics of credit trading, and incorporating trades into NPDES permits. Appendices include protocols for temperature trading, BOD and ammonia trading, and nutrient trading.

Reed, S. C., Crites, R.W, & Middlebrooks, E. J. (1998). *Natural systems for waste management and treatment.* McGraw-Hill Professional.

This book helps anyone involved in the process of planning, designing, building, upgrading or operating waste management facilities evaluate and adopt one or more natural treatment systems. The book includes performance data and design procedures (with example) while providing a thorough working background in wastewater stabilization ponds, aquatic treatment systems, feasibility assessment, land treatment systems, wetland systems, site selection, planning, sludge management and treatment and on-site wastewater management.

Reed, S. US Environmental Protection Agency, Office of Water. (1993). *Subsurface flow constructed wetlands for wastewater treatment, a technology assessment* (EPA 832-R-93-008). Retrieved from website: http://water.epa.gov/type/wetlands/restore/upload/2003_07_01_wetlands_pdf_sub.pdf

This document provides an assessment of the technologies used in subsurface flow constructed wetlands, including performance evaluations, design considerations, and construction details. It focuses on on-site subsurface flow constructed wetland systems but also discusses other potential applications for the technology and areas where further research is needed.

Kuhn, G. (2000). USDA National Agroforestry Center. *Wastewater management using hybrid poplar.* Retrieved from website: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1015&context=agroforestnotes.

This concise document outlines the major planning and engineering considerations for a short-rotation woody crop wastewater application system. System design considerations including permitting, effluent quality and quantity, irrigation and nutrient loading rates, and irrigation system options are discussed. Specific issues such as species choice, site conditions, site preparation, planting, and maintenance are also included.

US Environmental Protection Agency, Center for Environmental Research Information. (1998). *Constructed wetlands and aquatic plant systems for municipal wastewater treatment, design manual (*EPA/625/1-88/022). See EPA web site.

*This design manual provides detailed information on the design of constructed wetlands and aquatic plant systems. It also includes an overview aquatic treatment systems and a discussion of environmental and public health considerations associated with constructed wetlands***.**

US Environmental Protection Agency. *Constructed wetlands handbooks (volumes 1-5): A guide to creating wetlands for agricultural wastewater, domestic wastewater, coal mine drainage and stormwater in the Mid-Atlantic region* (1993-2000). Retrieved from website: http://water.epa.gov/type/wetlands/restore/upload/constructed-wetlands-handbook.pdf (Volume 1)

This series of five manuals discusses general constructed wetland design considerations and provides details on specific topics such as hydrology, soils, and vegetation. Construction, operation, maintenance, and monitoring considerations are also included.

US Environmental Protection Agency. (2000*). Constructed wetlands treatment of municipal wastewaters*. (EPA/625/R-99/010). Retrieved from website: http://water.epa.gov/type/wetlands/restore/upload/constructed-wetlands-design-manual.pdf

This document discusses the capabilities of constructed wetlands, both free water surface wetlands and vegetated submerged bed wetlands. It outlines removal mechanisms and modeling performance, associated costs of these systems, and case studies for both types of constructed wetlands including lessons learned.

US Environmental Protection Agency. (1993). *Constructed wetlands for wastewater treatment and wildlife habitat, 17 case studies* (EPA832-R-93-005). Retrieved from website: http://water.epa.gov/type/wetlands/upload/constructed-wetlands.pdf

This compilation of constructed treatment wetlands case studies provides descriptions of 17 systems from 10 US states. Each case study examines a variety of topics including design, construction, system performance, operation and maintenance costs, and additional benefits such as wildlife habitat.

US Environmental Protection Agency. (2000). *Guiding principles for constructed treatment wetlands: Providing for water quality and wildlife habitat* (EPA 843-B-00-003). Retrieved from website: http://water.epa.gov/type/wetlands/constructed/upload/guiding-principles.pdf

This user's guide provides guiding principles for planning, siting, design, construction, operation, maintenance, and monitoring of constructed treatment wetlands. It also includes information on current EPA policies, permits, regulations, and resources, and provides answers to common questions.

US Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory. (2011). *Principles of design and operations of wastewater treatment pond systems for plant operators, engineers, and managers* (EPA/600/R-11/088). Retrieved from website: http://nepis.epa.gov/Adobe/PDF/P100C8HC.pdf

This updated version of the wastewater treatment ponds manual includes basic design recommendations while discussing innovations in pond design and additional processes that have been added to address new nutrient requirements. A troubleshooting section and appendices from several states, directed at providing training for operators, emphasize the importance of pond operations and maintenance.

US Environmental Protection Agency, Office of Wastewater Management. (2013). *Rural and small systems guidebook to sustainable utility management* (EP-C-11-009). Retrieved from website: http://www.rurdev.usda.gov/SupportDocuments/GUIDEBOOK TO SUSTAINABLE MANAGEMENT OF RURAL AND SMALL SYSTEMS FINAL.pdf

This guidebook is designed to help address rural and small water and wastewater system management concerns and improve system operations. The guidebook identifies ten key management areas and outlines how to conduct a system assessment process based on these principles. It also describes how to prioritize areas for improvement while developing measures to assess progress that help these small systems improve overall performance.

US Environmental Protection Agency, Office of Water, Office of Wastewater Management. (2012.) *Stormwater Wetland.* Retrieved from website: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=74

This document provides an overview of constructed wetlands for stormwater treatment. Topics discussed include applicability, siting and design considerations, limitations, maintenance considerations, effectiveness, and cost considerations.

APPENDIX 3: ADDITIONAL DISCUSSION OF NATURAL TREATMENT SYSTEM PROCESSES

BOD/CBOD

Dissolved oxygen is a key element to water quality that is necessary to support aquatic life. Organics and ammonia in wastewater are often decomposed by aerobic bacteria that require oxygen as part of their metabolic process. Therefore, the existence of organics and ammonia in wastewater places a demand on the natural supply of dissolved oxygen in water, called biochemical oxygen demand (BOD) or carbonaceous biological oxygen demand (CBOD). If there are high levels of these pollutants in the effluent then the effluent will demand more dissolved oxygen from the water and leave less for the fish and other aquatic life that depend on this oxygen for survival.[xx]

Natural treatment systems such as treatment wetlands and ponds create an environment where the natural breakdown of organics by bacteria can occur before the wastewater is released to surface water. The large surfaces of these systems encourage the re-aeration of water, stimulating the activity of aerobic bacteria. BOD/CBOD can also be reduced through the anaerobic breakdown of organics, which is facilitated by other types of bacteria that do not use oxygen as part of their metabolic processes.[xxi]

PARTICULATES

The amount of particulates in treated effluent determines its clarity, which can have adverse effects on water quality when it is discharged to surface water. Particulate level is usually measured in terms of Total Suspended Solids (TSS). Clay, silt, sand, algae, organic matter, and sewage are common sources of particulates in wastewater. Sediments are a natural part of all water bodies, but if the particulate levels are too high, the water loses its ability to support aquatic organisms. Particulates decrease light penetration, which limits plant growth and decreases oxygen production. The death and subsequent decomposition of these plants further decreases oxygen availability and imposes more negative impacts on fish and other aquatic organisms. Water with high TSS also usually becomes warmer because the suspended sediment darkens the water and causes it to absorb more heat from sunlight.[xxii]

Particulate levels can be reduced through decomposition, sedimentation, and filtration. Since much of suspended sediment is organic, it will be broken down by bacteria in the natural treatment system. Sedimentation can occur in wetlands or ponds that slow down water flow and allow for particles to settle out through gravitational forces. Particulate levels can also be decreased through filtration, when the wastewater passes through natural mediums such as soil and gravel.[xxiii]

TEMPERATURE

Heat reduces water's capacity to retain oxygen. Because dissolved oxygen is essential for the survival of fish and other aquatic life, effluent that enters surface water at an elevated temperature can have serious negative impacts for sensitive species such as salmon. Elevated temperatures reduce salmon's ability to successfully reproduce and for their offspring to survive and grow. There is increased incidence of disease, reduced survival rate of eggs, increased competition for limited resources, and reduced ability to compete with other species that are better adapted to higher water temperatures. The incidence of these impacts increases as the water temperature increases and can seriously alter the ecology of the water body.[xxiv]

Natural conduction and advection processes help achieve temperature reductions in wastewater. Conduction involves the transfer of heat from wastewater to a solid substance. For example, filtering treated wastewater through a cooler solid medium such as soil can decrease temperature through conduction. Advection involves the transfer of heat to another liquid. When wastewater is pumped through hyporheic water before reaching surface water, the cooling process is defined as advection.[xxv]

PHOSPHORUS

Phosphorus is an essential nutrient for all living things and is one of the most common nutrients found in water; but excessive phosphorus in wastewater can have detrimental effects. When effluent containing high levels of phosphorus is released to surface water, it can create a condition called eutrophication which is caused by the rapid growth of algae. High phosphorus levels stimulate this excessive algal growth, preventing sunlight from penetrating the water and choking out other plant life. When the algae die and decompose, the BOD/CBOD of the water increases significantly, further decreasing dissolved oxygen levels and depriving fish and aquatic plants of oxygen.[xxvi]

Microbes living in natural treatment system environments convert insoluble forms of phosphorus into soluble forms that are available for plants to use. Aquatic plants and terrestrial plants that grow in or around natural treatment system environments naturally uptake phosphorus and remove it from the effluent before it is released to surface water.[xxvii] Phosphorus can also be absorbed and retained by soil through a process known as adsorption.[xxviii]

NITROGEN

Nitrogen is another essential nutrient that can also create a significant oxygen demand if released to surface water at high concentrations. Nitrogen, in the form of ammonia, can also be toxic to fish. Due to nitrogen's various oxygen states, this pollutant is present in wastewater in a variety of forms. Nitrogen can change quickly from one state to another depending on the physical and biochemical conditions present in the wastewater.

Nitrogen reduction can be achieved by plant or algal uptake, nitrification and denitrification by aerobic and anaerobic bacteria, and loss of ammonia gas to the atmosphere (volatilization). Some forms of nitrogen can be also adsorbed onto soil particles and retained in the soil.[xxix]

METALS

Trace metals that enter the food chain or the water supply can create serious health problems for both humans and wildlife. The primary metals of concern are copper, nickel, lead, zinc, and cadmium.

Metals are primarily reduced through adsorption onto organic matter and precipitation. Natural treatment systems that utilize plants can also reduce wastewater through the bioaccumulation of trace metals in plant tissues. Some metals may be toxic to plants, however, so it is important to evaluate the types of metals in the influent before choosing to utilize bioaccumulation methods for metals removal.[xxx]

CONTAMINANTS OF EMERGING CONCERN AND PRIORITY PERSISTENT POLLUTANTS

According to the US Environmental Protection Agency, an emerging contaminant (EC) is any chemical or material characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards. A contaminant also may be "emerging" because of the discovery of a new source or a new pathway to humans.[xxxi] Emerging contaminants comprise a wide array of chemicals including pharmaceuticals, personal care products, steroids, hormones, flame retardants, and pesticides.[xxxii] These pollutants are being increasingly detected in the environment. Due to daily activities, there is a concern that municipal wastewater may be a significant source of these pollutants. Many of these chemicals are harmful to fish and other aquatic life and some may be harmful to humans. The synergistic effects created by these chemicals in combination are not well known.[xxxiii]

The State of Oregon has implemented efforts to address a related category of pollutants: priority persistent pollutants. These substances are toxic and either persist in the environment or accumulate in the tissues of humans, fish, wildlife or plants. In 2007, the Oregon State Legislature passed Senate Bill 737, which required the Oregon Department of Environmental Quality to work with all interested parties to develop a list of priority persistent pollutants. This Oregon-specific category of bioaccumulative toxics includes 118 substances that have a documented effect on human health, wildlife and aquatic life. The bill also required Oregon's 52 largest municipal wastewater treatment plants to screen wastewater effluent for the presence of priority persistent pollutants, and to develop pollution reduction plans if levels were over threshold quantities.

FDA approval is not required for the commercial use of many emerging contaminants and priority persistent pollutants, making it difficult to prevent them from entering the water system. Many of these chemicals are not regulated under traditional environmental regulations and are not covered under state or federal water quality standards or limits.[xxxiv]

Natural treatment systems have a complex set of microenvironments that can remove a wide range of emerging contaminants and priority persistent pollutants under aerobic, anaerobic, and anoxic conditions.[xxxv] Some contaminants can also be adsorbed to other particles and settle out.[xxxvi]

APPENDIX 4: REFERENCES

Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006).*Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.

Environmental Quality Commission presentation (October 2013). Williamson, Ken. *The Science of Natural Treatment.*

Freeman, M. (2013, June 14). Cool waters. *Mail tribune*. Retrieved on April 8, 2014 from http://www.mailtribune.com/apps/pbcs.dll/article?AID=/20130714/NEWS/307140331&cid=sitesearch

Jenkins, P. Washington Department of Environmental Quality. (2007). *Methods to reduce or avoid thermal impacts to surface water*. (WA DEQ 07-10-088). Retrieved on January 15, 2014 from website: https://fortress.wa.gov/ecy/publications/publications/0710088.pdf.

Kuhn, G. (2000). USDA National Agroforestry Center. *Wastewater management using hybrid poplar.* Retrieved on March 14, 2014 from website: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1015&context=agroforestnotes.

LakeSuperiorStreams.org. *Turbidity & TSS*. Retrieved on January 30, 2014 from website: http://www.lakesuperiorstreams.org/understanding/param_turbidity.html

Ludlow, A. (2011). US Environmental Protection Agency. *Overview of natural systems for wastewater treatment.* Retrieved on January 9, 2014 from website: http://www.epa.gov/osp/presentations/PhytoWBC11/ph_Ludlow.pdf.

Oregon Department of Environmental Quality. *Senate Bill 737: Development of a Priority Persistent Pollutant list for Oregon.* http://www.deq.state.or.us/wq/SB737/docs/P3LrepExecutiveSum.pdf

Oregon Department of Environmental Quality. (2007). *Disposal of municipal wastewater treatment plant effluent by indirect discharge to surface water via groundwater or hyporheic water*. Retrieved on January 8, 2014 from website: http://www.deq.state.or.us/wq/pubs/imds/indirectdischarge.pdf

Oregon Department of Environmental Quality. (2013). *Implementation of methylmercury criterion in NPDES permits.* Retrieved on January 30, 2014 from website: http://www.deq.state.or.us/wq/pubs/imds/IMDmethylmercuryCriterion.pdf

Oregon Department of Environmental Quality. (1997). *The scientific basis for Oregon's stream temperature standard: Common questions and straight answers.* Retrieved on February 18, 2014 from website: http://www.deq.state.or.us/wq/standards/docs/temperature/tempstdccibasis1996.pdf

Oregon Department of Environmental Quality. (2012). *Water quality trading in NPDES permits*. Retrieved on January 8, 2014 from website: http://www.deq.state.or.us/wq/pubs/imds/wqtrading.pdf

Oregon DEQ. (2006). *Willamette Basin TMDL*. Retrieved on April 7, 2014 from http://www.deq.state.or.us/wq/tmdls/willamette.htm

Oregon Department of Environmental Quality. (2006). *Willamette basin mercury TMDL*. Retrieved on January 30, 2014 from website: http://www.deq.state.or.us/wq/tmdls/docs/willamettebasin/willamette/chpt3mercury.pdf

Oregon State University. (2005). *Investigation of the temperature impacts of hyporheic flow: Using groundwater and heat flow modeling and GIS analyses to evaluate temperature mitigation strategies on the Willamette River, Oregon.* Retrieved on January 14, 2014 from website: http://www.deq.state.or.us/wq/trading/docs/hyporheicreport.pdf

RUSA. (2014). *Natural treatment system*. Retrieved on April 8, 2014 from http://www.rusa-or.org/index.cfm?nav=natural

US Environmental Protection Agency. (2000). *Constructed wetlands treatment of municipal wastewaters.* (EPA/625/R-99/010). Retrieved from website: http://water.epa.gov/type/wetlands/restore/upload/constructed-wetlands-design-manual.pdf

US EPA. (2013). *Emerging contaminants fact sheets.* Retrieved on March 14, 2014 from website: http://www.epa.gov/fedfac/documents/emerging_contaminants.htm

US Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory. (2011). *Principles of design and operations of wastewater treatment pond systems for plant operators, engineers, and managers* (EPA/600/R-11/088). Retrieved on January 9, 2014 from website: http://nepis.epa.gov/Adobe/PDF/P100C8HC.pdf

US Environmental Protection Agency. Office of Water. Office of Wastewater Management. (2004). *Primer for municipal wastewater treatment systems*. (EPA 832-R-04-001) Retrieved on January 14, 2014 from website: http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf

US Environmental Protection Agency. *Publicly owned treatment works (POTW) wastewater sampling study.* Retrieved on January 30, 2014 from website: http://water.epa.gov/scitech/swguidance/ppcp/potw.cfm

US Environmental Protection Agency. Water recycling and reuse: The environmental benefits. (EPA 909-F-98-001). Retrieved on January 16, 2014 from website: http://www.epa.gov/region9/water/recycling/brochure.pdf

Water Environment Research Foundation. (2000). *Nitrogen Credit Trading in the Long Island Sound Watershed.* (Project #97-IRM-5B). Retrieved on March 8, 2014 from website: http://ww2.werf.org/AM/CustomSource/Downloads/uGetExecutiveSummary.cfm?FILE=ES-97-IRM-5B.pdf&ContentFileID=3418

Willamette Partnership. *What is an ecosystem services marketplace?* Retrieved on February 6, 2014 from website: http://willamettepartnership.org/about-markets/what-is-an-ecosystem-marketplace

---

[i] Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006). *Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.

[ii] US Environmental Protection Agency. Office of Water. Office of Wastewater Management. (2004). *Primer for municipal wastewater treatment systems*. (EPA 832-R-04-001) Retrieved on January 14, 2014 from website: http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf

[iii] Jenkins, P. Washington Department of Environmental Quality. (2007). *Methods to reduce or avoid thermal impacts to surface water.* (WA DEQ 07-10-088). Retrieved on January 15, 2014 from website: https://fortress.wa.gov/ecy/publications/publications/0710088.pdf.

[iv] Smesrud, Jason. (2014). Digital communication. *Poplar farm maturity.*

[v] Washington State Department of Ecology. 1999. *Managing Nitrogen for Biosolids*. Publication 99-508.

[vi] Kuhn, G. (2000). USDA National Agroforestry Center. *Wastewater management using hybrid poplar.* Retrieved on March 14, 2014 from website: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1015&context=agroforestnotes

[vii] Oregon DEQ. (2007). *Disposal of municipal wastewater treatment plant effluent by indirect discharge to surface water via groundwater or hyporheic water*. Retrieved on January 8, 2014 from website: http://www.deq.state.or.us/wq/pubs/imds/indirectdischarge.pdf

[viii] Willamette Partnership. *What is an ecosystem services marketplace?* Retrieved on February 6, 2014 from website: http://willamettepartnership.org/about-markets/what-is-an-ecosystem-marketplace

[ix] Oregon DEQ. (2012). *Water quality trading in NPDES permits*. Retrieved on January 8, 2014 from website: http://www.deq.state.or.us/wq/pubs/imds/wqtrading.pdf

[x] US Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory. (2011). *Principles of design and operations of wastewater treatment pond systems for plant operators, engineers, and managers* (EPA/600/R-11/088). Retrieved on January 9, 2014 from website: http://nepis.epa.gov/Adobe/PDF/P100C8HC.pdf

[xi] Santa Rosa CH2M Hill report

[xii] Walton, W. (2012, June). Design and management of free water surface constructed wetlands to minimize mosquito production. *Wetlands Ecology and Management, 20. 173-195.*
[xiii] Oregon DEQ. (2006). *Willamette Basin TMDL*. Retrieved on April 7, 2014 from http://www.deq.state.or.us/wq/tmdls/willamette.htm
[xiv] Freeman, M. (2013, June 14). Cool waters. *Mail tribune*. Retrieved on April 8, 2014 from http://www.mailtribune.com/apps/pbcs.dll/article?AID=/20130714/NEWS/307140331&cid=sitesearch
[xv] Girts, M. (Spring 2014). RUSA natural treatment system: Water quality and more. *Pacific Northwest Clean Water Association Newsletter*. *16-17.*
[xvi] RUSA. (2014). *Natural treatment system*. Retrieved on April 8, 2014 from http://www.rusa-or.org/index.cfm?nav=natural
[xvii] Girts, M. (Spring 2014). RUSA natural treatment system: Water quality and more. *Pacific Northwest Clean Water Association Newsletter*. *16-17.*
[xviii] RUSA. (2014). *Natural treatment system*. Retrieved on April 8, 2014 from http://www.rusa-or.org/index.cfm?nav=natural
[xix] Oregon Department of Environmental Quality. Water Quality Source Information System. Accessed on November 12, 2013.
[xx] US Environmental Protection Agency. Office of Water. Office of Wastewater Management. (2004). *Primer for municipal wastewater treatment systems*. (EPA 832-R-04-001) Retrieved on January 14, 2014 from website: http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf
[xxi] Environmental Quality Commission presentation (October 2013). Williamson, Ken. *The Science of Natural Treatment.*
[xxii] LakeSuperiorStreams.org. *Turbidity & TSS*. Retrieved on January 30, 2014 from website: http://www.lakesuperiorstreams.org/understanding/param_turbidity.html
[xxiii] Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006).*Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.
[xxiv] Oregon Department of Environmental Quality. (1997). *The scientific basis for Oregon's stream temperature standard: Common questions and straight answers.* Retrieved on February 18, 2014 from website: http://www.deq.state.or.us/wq/standards/docs/temperature/tempstdccibasis1996.pdf
[xxv] Oregon State University. (2005). *Investigation of the temperature impacts of hyporheic flow: Using groundwater and heat flow modeling and GIS analyses to evaluate temperature mitigation strategies on the Willamette River, Oregon.* Retrieved on January 14, 2014 from website: http://www.deq.state.or.us/wq/trading/docs/hyporheicreport.pdf
[xxvi] US Environmental Protection Agency. Office of Water. Office of Wastewater Management. (2004). *Primer for municipal wastewater treatment systems*. (EPA 832-R-04-001) Retrieved on January 14, 2014 from website: http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf
[xxvii] US Environmental Protection Agency. (2000*). Constructed wetlands treatment of municipal wastewaters*. (EPA/625/R-99/010). Retrieved from website: http://water.epa.gov/type/wetlands/restore/upload/constructed-wetlands-design-manual.pdf
[xxviii] Ludlow, A. (2011). US Environmental Protection Agency. *Overview of natural systems for wastewater treatment.* Retrieved on January 9, 2014 from website: http://www.epa.gov/osp/presentations/PhytoWBC11/ph_Ludlow.pdf.
[xxix] Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006).*Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.
[xxx] Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006).*Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.
[xxxi] US EPA. (2013). *Emerging contaminants fact sheets.* Retrieved on March 14, 2014 from website: http://www.epa.gov/fedfac/documents/emerging_contaminants.htm
[xxxii] US EPA. *Publicly owned treatment works (POTW) wastewater sampling study.* Retrieved on January 30, 2014 from website: http://water.epa.gov/scitech/swguidance/ppcp/potw.cfm
[xxxiii] US Environmental Protection Agency. Office of Water. Office of Wastewater Management. (2004). *Primer for municipal wastewater treatment systems*. (EPA 832-R-04-001) Retrieved on January 14, 2014 from website: http://water.epa.gov/aboutow/owm/upload/2005_08_19_primer.pdf

---

[xxxiv] Oregon DEQ. *Senate Bill 737: Development of a Priority Persistent Pollutant list for Oregon.* Retrieved on March 14, 2014 from website: http://www.deq.state.or.us/wq/SB737/docs/P3LrepExecutiveSum.pdf
[xxxv] Environmental Quality Commission presentation (October 2013). Williamson, Ken. *The Science of Natural Treatment.*
[xxxvi] Crites, R. W., Middlebrooks, E. J., & Reed, S. C. (2006).*Natural wastewater treatment systems*. Boca Raton, Florida: CRC Press.