Construction of a wetland to accept tertiary treated wastewater at the University of California, Davis Experimental Ecosystem

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PURPOSE:

The University of California, Davis is always striving to be on the cutting edge of research. It is one of the only self-contained universities. With over 26,000 students and 9,500 faculty/staff members on the campus, UC Davis generates approximately 1.8 million gallons of wastewater each day. The University operates its state-of-the art tertiary treatment plant in the south campus to treat this wastewater. A sanitary sewer collection system across the campus carries wastewater from office buildings, housing laboratories, food service facilities, and other support facilities to the wastewater treatment plant.

Much of the wastewater generated on the campus is normal domestic sewage (from those who live on campus or from campus restrooms). However, wastewater from laboratory drains and other non-domestic wastewater sources also drains into the sanitary sewer.

The University operates its wastewater treatment plant (WWTP) under a permit issued by the State Regional Water Quality Control Board (RWQCB). The permit specifies how much treated wastewater can be discharged into Putah Creek, where and when monitoring samples are to be collected, and what analyses are to be run. Samples are collected many times each week to monitor the treated wastewater before it is discharged in Putah Creek. Samples are also collected directly from Putah Creek, both upstream and downstream of the treatment plant outfall, to monitor for negative impacts to water quality (UC Davis Wastewater Treatment Plant Environmental Impact Report (EIR), 2001).

Currently, the UC Davis WWTP is allowed to dispose 20 $g/m^{3.}$ Although the university stays well below the permit limits of discharged BOD and other wastewater effluents, past problems with low dissolved oxygen in Putah Creek due to increased levels of Biochemical Oxygen Demand (BOD) effluent threaten fish populations (Fan, 2003). By decreasing the amount of remaining BOD in UC Davis wastewater treatment plant effluent pumped into the south fork of Putah Creek, UC Davis will improve overall down stream water quality, improve fish stocks, and improve the quality of downstream riparian corridors. Moreover, the UC Davis campus expansion project, including a new vet center, aquatics center, recreation retrofitting, various academic buildings, student housing, and increased agricultural runoff, levels of BOD may increase. This project aims lower the BOD in the campus effluent, while also contributing to the research community by building a wetland that receives wastewater inputs from the UC Davis wastewater treatment plant and outputs cleaner, oxygen-rich water to Putah Creek. Furthermore, this new wetland will be a site for wildlife research.

STUDY SITE:

Currently, a site is being investigated for this construction at the University of California, Davis Experimental Ecosystem. The Experimental Ecosystem is west of campus, east of UC Davis airport, off hwy 98, approximately 130 meters north of the Putah Creek. The Experimental Ecosystem serves campus and the community as an ecosystem preserve and restoration project. Many songbirds, water fowl, raptors, reptiles, and mammals use the ecosystem for brooding, foraging, and nesting (Elliot-Fisk, 2003) The proposed wetland site sits on 6.3 acres of land north of the wild deer preserve, southwest of UC Davis landfill, and east of Coyote Gulch (all afore mentioned areas are within the Experimental Ecosystem). Further expansion lies directly north of the proposed wetland site.

OVERALL DESIGN STRUCTURE:

The next step is to design the size and aspects of the wetland to accommodate the release of remaining BOD from the wastewater treatment plant on campus. This project will cut costs by using an area already set aside for wetland construction, provide mitigation for campus development, and reuse the campus' tertiary treatment water such that cleaner, oxygen rich water is discharged into the south fork of Putah Creek.

The design of the wetland will: allow for the most efficient uptake of BOD, be within the spatial confinements of the study site area, closely mimic natural historic wetlands of Putah Creek riparian areas. The area will be designed in such a way that expansion is feasible should expansion studies be investigated.

WASTEWATER EFFLUENT AND LIMITS:

The campus releases approximately 1.6 million gallons of effluent into the South Fork of Putah Creek with BOD levels ranging from 2 g/m^3 to 5 g/m^3 (Fan, 2003). The maximum intake of BOD allowed by the NPDES permit for the Campus WWTP effluent water quality limits is 20 g/m^3 (Permit No. CA0077895, CVRWQCB Order No. 92-040).

WETLAND DESIGN:

This proposed project is not trying to substitute for the any of the primary, secondary, or tertiary treatment processes. Instead, the wetland proposed will continue to reduce BOD effluent discharged by UC Davis, and provide overflow BOD removal for future urban growth and agricultural on campus.

Because BOD is the pollutant requiring the largest area for removal, it is the *limiting design parameter* (LDP) and thus controls the dimensions of the wetland (Reed, et. al., 1995). Since the maximum inflow of BOD and the desired outflow of BOD have been determined, working backwards from concentrations of pollutants to the spatial dimensions of the proposed wetland.

Specific parameters for wetland dimensions utilizing BOD as the LDP and outflow parameters of UC Davis Wastewater Treatment Plant:	
Slope gradient ($\Delta H/\Delta L$)	$\Delta H/\Delta L$ = 1/10 Best if in a flat area to allow for maximum hydraulic retention time (day^{-1}) (Mitsch, et.al., 2000). The shallow gradient allows for appropriate rooting ground for emergent plants, allows for plants develop more quickly and create a wide band of plant species, and for plants to migrate uphill (Reddy and Smith, 1984).
Aspect Length (L) x Width (W)	L:W = 3:1 Aspect described by Mitsch, et. al, (2000).
Average Depth (m)	y = 0.35 m Average depth of WWTP run from 0.01 m to 1.0 m, with BOD limiting ponds averaging from 0.3 m to 0.4 m (Reed, et.al, 1995)
Porosity (n)	n = 0.70 Porosity for a surface flow wetland with medium to medium-high density vegetation biomass and average depth 0.3m ≤ y ≤ 0.4m is 0.60 to 0.75 (Reed, et.al., 1995).
Maximum inflow to wetland (m^3/day)	(2.0×10^6 gal/day) x (0.003785 m^3/day) = Q_{in} Q_{in} = 7570.0 m^3/day.
Maximum outflow to Putah	For preliminary calculations, assume $Q_{in} = Q_{out}$ (Reed, et.al., 1995).

Creek (m^3/day)	Q_{out} = 7570.0 m^3/day.
Maximum daily loading of BOD (g/m^3)	BOD_{max} = 10.0 (g/m^3) Maximum inflow is half of the permitted effluent yet above the BOD effluent already discharged (this provides for expansion of BOD loading without affecting the BOD effluent to Putah Creek).

Fowler (2003)

SUBSTRATE:

The underlying substrate of a constructed wetland with tertiary treated water as the main inflow source is described by Hammer (1988). The bottom most layer is composed of native soils and is contiguous with the surrounding ground. The next layer up is the clay liner. This highly impermeable liner is approximately 50 cm thick and surrounds the entire basin of the wetland and prevents ground water from seeping into or treatment water from seeping out of the wetland. The third layer is a thin layer of crushed limestone. This layer helps to remove excess phosphate (PO_4^-), heavy metals, and helps to raise the pH of the system. The fourth layer is composed of 60 cm of medium to coarse sand and acts as a filter for the system, the final layer is 50 cm of organic soil for plant growth and establishment.

Water (Average ~35 cm)
Organic soil (50 cm)
Medium – coarse grained sand (60 cm)
Crushed limestone (30 cm)
Clay liner (50 cm)
Native soils

HYDROLOGIC RETENTION TIME (t):

The hydrologic retention time ($t = day^{-1}$) is the amount of time in days the water must remain in the wetland for adequate BOD removal:

$$C_e/C_o = e^{-(K(T) * t)}$$

C_e = BOD effluent out of wetland (1.5 g/m^3).

C_o = BOD input to wetland (BOD_{max} = 10 g/m^3).

K_t = temperature-dependant first-order decay reaction constant,

~ $K_{20} = 0.678 * 1.06^{(5)}$ g/day.

t = hydrologic retention time ($t = day^{-1}$).

Solving for t ($days^{-1}$):

$$\ln (C_e/C_o) = -K_T * t \quad =$$

$$t = [\ln (C_e/C_o)] / -K_T$$

Hydraulic Retention time for this wetland:

$t = \text{Ln} (1.5 \text{ g/m}^3 / 10 \text{ g/m}^3) / -(0.678 \text{ g/day} * 1.06^5)$

t = 2.01 days.

AREA OF WETLAND:

The area of the wetland is determined by the amount of BOD released into the system and is a function of BOD used by organisms (Reed, et.al., 1995). Once the hydraulic retention time is found, and the input water flow into the wetland is known, the surface area can be estimated.

$$A_s = [Q(\ln C_o - \ln C_e)] / K_T(y)(n)$$

A_s = surface area (m).

Q = flow into wetland (7570 m^3/day).

C_e = BOD effluent out of wetland (1.5 g/m^3).

C_o = BOD input to wetland (BOD_{max} = 10 g/m^3).

K_t = temperature-dependant first-order decay reaction constant,

~ $K_{20} = 0.678 * 1.06^{(5)}$ g/day.

y = average design depth of water in the system (0.35 m).

n = porosity (0.70).

A_s = [7570 m^3/day (ln10 g/m^3 – ln 1.5 g/m^3)] / (0.90732 g/d* 0.35 m* 0.70)

A_s = 34,045.77 m^2.

A_s = 8.41 acres = 3.40 ha.

VOLUME:

The volume of water held by the wetland is equal to the surface area time the average depth of the water. Depths less than 0.2 m allows for quick establishment and growth of vegetation and provides good foraging ground for insects, reptiles, and water foul. Depths greater than 0.6 m allows for fish populations to grow, foraging for water foul, and establishment and growth of water hyacinths.

$$\text{Volume} = A_s * y$$

A_s = surface area (34,045.77 m^2).

y = depth (0.35 m)

Volume = 34,045.77 m^2 * 0.35 m

Volume = 17,586.89 m^3.

ASPECT:

The aspect of the proposed wetland is the dimensions of length and width that are multiplied yielding the surface area. The given ratio of the aspect (L:W) is equal to 3:1.

$$A_s = 3W * L, \quad (3W = 1L)$$

$$A_s = 3W * W$$

$$A_s = 3W^2$$

A_s = surface area (34,045.77 m^2).

L = length

W = Width

Aspect of this wetland:

34,045.77 m^2 = $3W^2$

W = (34,045.77 m^2 / 3)$^{-1/2}$ = 106.529 m

L = 3W = 3(106.529) 319.8 m

L = 319.8 m, W = 106.5 m.

FLORA SPECIES FOR WETLAND:

Among the plants that are able to remove high levels of BOD are shallow water (≤ 30 cm) emergent macrophyte stems: cattails (*typha spp.)*, bulrushes *(Schoenoplectus spp., Scirupus spp.)*, and reed grass *(Phragmites australis)*. Free-floating macrophyte emergent species that prefer deeper water (≥ 30 cm) include: duckweed (*Lemna spp.)* and water hyancinths *(Eichhornia crassipes)* (Reddy and Smith, 1987). Vegetation will be established by planting roots and rhizomes directly into the soil and by seeding. Native plant species suggested will thrive in this wetland, provide valuable habitat for fish and wildlife, and add cultural aesthetics to the Experimental Ecosystem.

MONITORING THE WETLAND:

Monitoring of the flow rate into and out of the system will be done daily using a Hobo data logger attached to the inflow pump and the outflow. Monitoring will be conducted on an monthly basis and include the amount of BOD entering and exiting the system, the change in biomass of the plants, and sediment samples to analyze the deposition rates of sediments.

Many UC Davis students and staff can take advantage of the opportunities to practice monitoring and data collection as well as conducting personal research during the construction of the wetland and upon completion.

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