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Short communication

Policy adoption of ecosystem services for a sustainable community: A case study of wetland assimilation using natural wetlands in Breaux Bridge, Louisiana

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A B S T R A C T

Academicians and government officials have advocated incorporating ecosystem services into environmental policy-making processes. The State of Louisiana has adopted policy guidelines for using natural wetlands to assimilate nutrients in secondarily treated municipal effluent, thus utilizing ecosystem services of natural wetlands. We describe a case study for the city of Breaux Bridge, Louisiana, to discuss policy guidelines and assess ecological and financial benefits of this approach. In addition to water quality improvement, wetland assimilation provides additional ecosystem services, including increased vegetative productivity, surface accretion, and carbon sequestration. Financially, using wetland assimilation at Breaux Bridge generated an economic savings of $1.8 million in capital costs and annual savings of $72,116 for operation and maintenance costs, resulting in nearly $3 million savings over the lifetime of the project, due to its low capital expenditures and high energy efficiency, compared with a sand filtration method. When considering rapidly depleting non-renewable resources (e.g., fossil fuels) and challenging financial situations of small communities across the nation, wetland assimilation can be an important factor in designing sustainable communities.

1. Introduction

Incorporating ecosystem services into the policy-making process has been advocated by government officials (e.g., Environmental Protection Agency, http://www.epa.gov/ecology/; National Oceanic and Atmospheric Administration, http://www.csc.noaa.gov/; Forest Service, http://www.fs.fed.us/ecosystemservices/) and academicians (e.g., Daily and Matson, 2008; Fisher et al., 2008; Batker et al., 2010). State governments have responded to federal environmental regulations by developing innovative approaches over the past three decades (Fiorino, 2001). We use a wetland assimilation project in Louisiana to demonstrate how the current regulation system allows state governments to take initiatives in adopting innovative approaches to utilizing ecosystem services in compliance with the Clean Water Act.

In Louisiana, there are numerous municipalities that use natural wetlands for tertiary (advanced) treatment by following the State's wetland assimilation policy and complying with the federal National Pollutant Discharge Elimination System (NPDES) regulations (Table 1).

In addition to improving water quality with lower financial costs than conventional methods, wetland assimilation can provide additional ecosystem services including increased vegetative productivity and surface accretion, both of which help restore and sustain the natural wetland environment (Breaux and Day, 1994; Rybczyk et al., 2002; Day et al., 2004, 2006). In this paper, we outline the development of policy regarding the use of natural wetlands for assimilation of secondarily treated municipal effluent. First, we examine the current legal and administrative guidelines of utilizing natural wetlands for assimilation of secondarily treated municipal effluent within an intergovernmental framework. Second, we discuss nutrient removal, ecological impacts of the assimilation on receiving wetlands, and associated financial benefits.

2. An overview of regulation for wetland assimilation in Louisiana

The current regulations that apply to wetland assimilation come under three broadly defined governmental regulations: wastewater treatment, water quality maintenance, and wetlands protection.

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Table 1
Municipalities using natural wetlands assimilation in Louisiana.

NPDES permit no.	Municipality	Parish	Design capacity (m^3/day – MGD[a])
LA0115487	Amelia	St. Mary	3400 (0.90)
LA0120243	Mandeville	St. Tammany	2300 (0.60)
LA0020613	Broussard	Lafayette	2800 (0.75)
LA0032131	Luling	St. Charles	12,100 (3.20)
LA0032948	Thibodaux	Lafourche	15,100 (4.00)
LA0033014	Breaux Bridge	St. Martin	4800 (1.27)
LA0038288	Mandeville	St. Tammany	15,100 (4.00)
LA0040185	Riverbend Oxidation Pond	St. Bernard	1700 (0.47)
LA0040941	City of St. Martinville	St. Martin	5700 (1.50)
LA0049379	Tchefuncta Club Estates	St. Tammany	600 (0.16)

[a] Million-gallon-per-day.

2.1. National pollutant discharge elimination system

The basic federal regulations for wastewater treatment are based on the Clean Water Act (CWA) whose objective is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. §1251 *et seq.*). The NPDES program requires a permit for the discharge of pollutants from any point source into the waters of the United States. The provisions of the CWA mandates that jurisdictional responsibility for administering the NPDES program are to be delegated to those states with an EPA-approved NPDES program, as is the case for Louisiana.

Sections 301(b) and 306 of the CWA require a minimum of secondary treatment for discharges from publicly owned treatment works (POTWs) to waters of the United States using best practical control technology currently available (BPT). Section 304(b)(1)(B) requires the EPA to consider costs and benefits associated with proposed technologies in determining BPT. Wastewater treatment is mainly regulated by section 402 of the law, which specifies the NPDES program for permitting the discharge of pollutants into waters of the United States. Further, NPDES permits may be issued to POTWs for up to five years. If effluent limits or water quality standards are modified after a permit is issued, subsequent alterations to permit requirements may also be made.

2.2. Water quality standards: total maximum daily loads

Sections 301(b)(1)(c) and 302(a) of the CWA require more stringent tertiary treatment, when secondary treatment of wastewater at POTWs would not be sufficient to improve impaired waterbodies (e.g., rivers, lakes and streams) that receive treated effluent. Section 303(d) of the CWA requires all states to develop a list of their impaired waterbodies, consisting of those waterbodies that would not meet state regulatory water quality standards even with the current control of point sources of pollution from POTWs. For those waterbodies that are identified as not being able to achieve water quality standards by means of effluent limitations, the state is required to calculate 'total maximum daily load (TMDL)' for the waterbodies. TMDL is the sum of allowable pollutant loads from point and nonpoint sources, and a margin of safety for specific pollutants, taking into account background conditions and all other sources of pollution along a designated segment of a waterbody.

Further, section 304(a)(2) requires EPA to identify those pollutants suitable for TMDL calculations, and to correlate various water qualities with such load levels. The identified pollutants and load calculations, made by the state and approved by the EPA regional administrators, are required to be incorporated into a NPDES program by section 303(e). A properly functioning wetland assimilation system should not contribute to the TMDL for waterbodies because regulated constituents are reduced to background levels.

2.3. Wetlands protection

Section 404 of the CWA on dredge and fill is relevant to wetland discharges, because alterations in the wetlands might be needed as part of a wastewater management system. Section 404(b)(1) provides that the permit decision is to be made using guidelines developed by the EPA in conjunction with the U.S. Army Corps of Engineers (Corps), and section 404(c) authorizes the EPA to veto any permit issued by the Corps that does not meet the goals of the law. The Corps and EPA review proposed modifications to natural wetlands to (1) prevent wetlands degradation due to inflowing wastewater, (2) minimize unavoidable impacts, and (3) mitigate the impacts through practicable compensatory actions (US EPA, 1987, p. 11).

2.4. EPA review and guidelines

The EPA considers wetland assimilation as an approach to "provide certain communities, especially small communities, with alternatives to more costly and complex advanced treatment plants" (An EPA Office of Water Guidance to supplement the October 1987 Burdick "Report on the Use of Wetlands for Municipal Wastewater Treatment and Disposal, dated on September 20, 1988; is available at US EPA, 1987). The EPA regional administrators reserve the right to authorize and approve state programs to insure compliance with federal guidelines and goals. The EPA regional officers review the following items based on information provided by permit applicants:

(1) All pollutants that may be present within a wastewater stream and which must comply with water quality requirements;
(2) Average and maximum quantities of wastewater to be discharged, and the frequency and volume of discharge;
(3) Individual state requirements, treatment facility size, location and type of discharge;
(4) Assessment of requirements for additional treatment after secondarily treatment;
(5) Report of ecological baseline study (EBS), which provides information for evaluating existing uses of affected wetlands, baseline water quality, and ecological data before effluent is discharged to a proposed site.

2.5. Louisiana state regulations

Currently the State of Louisiana is granted delegation of the NPDES program. With this delegation, the Louisiana Department of Environmental Quality (LDEQ) holds responsibility for administering the permitting, compliance and enforcement activities of the NPDES program under the oversight of the regional EPA administrator. The two major regulations relevant to municipal wastewater

Table 2
Current discharge limits vs. permit limits without wetland assimilation.

	Current permit		Limits without wetland assimilation	
	Monthly average	Weekly average	Monthly average	Weekly average
Items				
BOD_5 (mg/L)	30	45	10	15
TSS (mg/L)	90	135	15	23
Fecal coliform (colonies/100 mL)	200	400	200	400
NH_3–N			5	10

Other items included in the current discharge permit are pH, priority pollutants, and wetland monitoring.

treatment are the Louisiana Environmental Quality Act (La. R.S. 30:2001 *et seq.*) and the Louisiana Water Pollution Control Regulations (LAC 33:IX. 311).

As a way to utilize the ecosystem service of water quality improvement by natural wetlands, Louisiana allows the use of natural wetlands for assimilation of secondarily treated effluent (LAC 33:IX. §1109(J); §1113(B)(12)(b)). Specifically, the LDEQ allows 'the discharge of the equivalent of secondarily treated effluent into wetlands for the purposes of nourishing and enhancing those wetlands' (Louisiana Water Quality Management Plan, Vol. 3, Sec. 10; http://www.deq.state.la.us/portal/DIVISIONS/WaterQuality-Assessment/WaterQualityManagementPlanContinuingPlanning.aspx). Secondarily treated effluent must be disinfected and cannot have unacceptable levels of toxic materials. When an application for wetland assimilation of secondarily treated municipal effluent is submitted, LDEQ assesses the feasibility of a proposed project based on: (1) the suitability of wetlands (e.g. vegetation type) for assimilation; (2) the area of wetlands available for assimilation compared to the area of wetlands required based on long-term nutrient loading rates; (3) the hydrology of the project area; (4) the existing land uses of the area; (5) landowners' easement agreements, and (6) the locations of proposed sampling plots. After an initial feasibility analysis is completed that indicates the potential for assimilation, and prior to effluent discharge, an EBS for the proposed wetlands is conducted to analyze (1) vegetation structure and productivity, (2) wetland hydrology, (3) soil and water chemistry, and (4) soil accretion rates (LDEQ, wetlands assimilation projects, http://www.deq.state.la.us/portal/Divisions/WaterPermits/WetlandAssimilationProjects.aspx).

3. Case study of Breaux Bridge, Louisiana

3.1. A chronology of the Breaux Bridge facility

The city of Breaux Bridge, Louisiana, has been using natural wetlands for assimilation of secondarily treated municipal effluent under a state LPDES discharge permit. The wetland is located in the Cypriére Perdue Swamp in St. Martin Parish, Louisiana (latitude: 30°16′N; longitude: 91°54′W). The TMDL for dissolved oxygen in the Vermilion-Teche River Basin, into which the treated water from the treatment facility ultimately flows, was developed in 1987. During the early and mid-1990s, the facility was cited by the EPA for violating their water permit, primarily for TSS and BOD_5, but also NH_3 and pH less frequently. In order to come into compliance, the city searched for the most cost-effective method to improve water quality and meet permit conditions. The utilization of natural forested wetlands adjacent to the treatment plant was assessed at a series of meetings with city officials, LDEQ, EPA, civil engineers, and researchers at Louisiana State University. The continued use of the forested wetlands for wetland assimilation was suggested. Although the treated effluent had been discharged into the forested wetlands since about 1950, it had never been officially permitted. In order to be officially permitted, it was necessary to carry out a Use Attainability Analysis (UAA, now termed an Ecological Baseline Study), which included a feasibility analysis and an EBS for the wetlands. After completion of the UAA in 1994 (Day et al., 1994), the adjacent forested wetlands were permitted for treated effluent discharge under a NPDES permit (LA 0033014), effective November 7, 1997.

The present sewage treatment system for the city of Breaux Bride has a 4800 m^3/day (1.27 million-gallon-per-day (MGD)) capacity, consisting of three oxidation ponds and a chlorination/dechlorination system, with treated effluent discharged to the adjacent forested wetland (1475 ha) for further nutrient assimilation. The effluent is discharged through one of five discharge pipes on a rotating basis to ensure that the effluent spreads over the whole wetland. The average monthly discharge of treated effluent into the receiving wetlands was 3600 m^3/day (0.95 MGD) for the period from 2000 to 2007. Table 2 shows a comparison of the current water quality criteria of treated effluent and criteria that would be applicable without the wetland assimilation. The LDEQ recognized the benefits of utilizing ecosystem services in complying with the NPDES regulation. The LDEQ issued the water quality criteria for the wastewater treatment plant after assessing the potential impacts of wetland assimilation on the wetlands surrounding the wastewater plant. The without wetlands criteria were calculated based on an assumption in which a conventional tertiary treatment approach was adopted. When the LDEQ issued the permit, they also required vegetative and other environmental monitoring for the receiving wetlands (Table 3). A number of studies have been conducted on nutrient removal, forest structure and productivity, surface hydrology, and nutrient biogeochemistry, for the Breaux Bridge site (Breaux and Day, 1994; Delgado-Sanchez, 1995; Hess et al., 1998; Blahnik and Day, 2000; Day et al., 2004; Ko et al., 2004; Hunter et al., 2009a,b).

3.2. Nutrient removal

Natural wetlands remove nutrients in treated effluent by utilizing natural energies that drive multiple functions and mechanisms of effluent assimilation in wetlands, including physical settling, chemical precipitation, adsorption, and biogeochemical processes such as uptake, burial, and denitrification (Day et al., 2004; Reddy and DeLaune, 2008; Hunter et al., 2009a).

At the Breaux Bridge wetlands, for the period of 1993–1995, the average nutrient removal efficiencies were 92% for NO_3, 91% for NH_4, and 68% for PO_4 (Fig. 1; Hunter et al., 2009b). These removal rates reduced the nutrients to concentrations at or below the levels of the receiving waters. Mean NO_3 concentrations from 1993 to 1995 were 0.57 mg/L at the discharge pipe and of 0.05 mg/L at the outlet of the wetlands. During the period of 2001–2007, mean NO_3 concentration was 0.69 mg/L at the discharge pipe, and 0.23 mg/L at the outlet. Mean NH_4 concentrations from 1993 to 1995 were 1.22 mg/L at the discharge pipe and 0.11 mg/L at the outlet, while they were 2.02 mg/L at the pipe and 0.73 mg/L at the outlet site

Table 3
Monitoring requirements for a typical wetland assimilation project in Louisiana.

Parameter	Wetland component			
	Flora	Sediment	Surface water	Effluent
Species classification	P			
Percentage of whole cover (for each species)	P			
Growth studies	A			
Water stage			M	
Metals: Mg, Pb, Cd, Cr, Cu, Zn, Fe, Ni, Ag, Se	P	P	P	S
Metals analysis: Hg, As		P		
Nutrient analysis I: TKN, TP	P	P	S	
Nutrient analysis II: NH_3N, NO_2N, NO_3N, PO_4		P	S	
Others: BOD5, TSS, pH, dissolved oxygen			P	
Accretion rate		P		

P: Periodically – Sampling must be made once during March through May and once during September through November in the fourth year of the permit period. A: Annually – Sample once per year. M: Monthly – Samples should be taken each month. S: Semi-annually – Sample twice per year. Once during September through February and once during March through August. Monitoring work is mandated for three sites from the wastewater management area and one site from the control area.

from 2001 to 2007. Mean PO_4 concentrations from 1993 to 1995 were 1.0 mg/L at the discharge pipe and 0.32 mg/L at the outlet site, and during the 2001–2007 period, mean PO_4 concentrations were 1.58 mg/L at the pipe site and 0.17 mg/L at the outlet site (For more nutrient information, see Hunter et al., 2009b). Monitoring data from more than twenty-years clearly shows that natural wetlands contribute to significant nutrient removal even after 60 years of discharge.

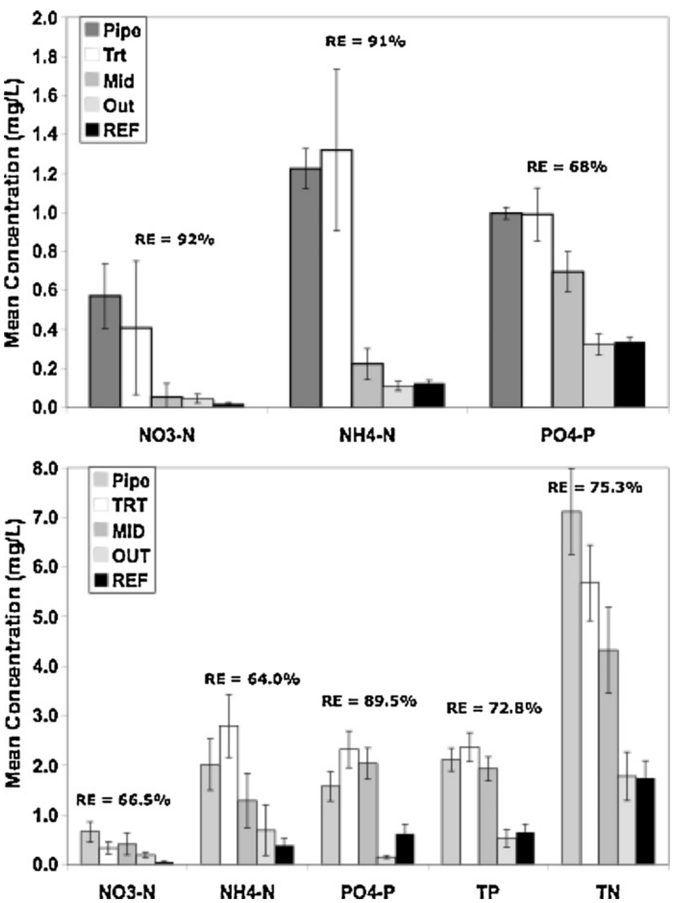

Fig. 1. Mean nutrient concentrations measured in surface water of assimilation and reference wetlands from 1993 to 1995 (upper figure) and from 2001 to 2007 (lower figure). RE is removal efficiency calculated as the difference between the nutrient concentration in the effluent compared to that in the OUT site (from: Hunter et al., 2009b, permission granted).

3.3. Ecological impacts of effluent assimilation

Secondarily treated effluent delivers nutrient-rich water to the permitted wetlands, enhancing vegetation productivity, organic matter deposition, and surface elevation gain in numerous wetlands in Southern Louisiana (Rybczyk et al., 2002; Day et al., 2004, 2006; Brantley et al., 2008; Hunter et al., 2009b).

At the Breaux Bridge treatment facility, the effluent discharge point is periodically changed to one of five outlets to ensure wide distribution of the effluent. Forest productivity is monitored along a gradient, with sites located near, intermediate and far from the discharge point, as well as at a comparable reference site. Hunter et al. (2009b) reported on forest productivity at the Breaux Bridge assimilation wetlands between 1993 and 2006. Mean litterfall was higher near the effluent discharge point compared to sampling sites further away, or to the reference site. Mean tree growth was also lower at the site furthest from the discharge point compared to the other sites.

3.4. Economic assessment

Ko et al. (2004) estimated the economic benefits of the Beaux Bridge site. Discharging secondarily treated effluent into nearby wetlands of adequate size for assimilation eliminates the needs for constructing facilities for sand filtration, and maintenance costs including electricity, labor, chemicals, and sludge disposal. Using the replacement cost method of comparing costs associated with building and operating a conventional recirculating sand filtration system to the wetland assimilation system currently used at Breaux Bridge, they estimated that there was economic savings of $1.8 million in capital costs and $72,116 in annual operation and maintenance costs. Over the 20-year lifetime of the project, the total savings would be nearly $3 million.

4. Discussion and conclusions

Wetlands have been used for water quality improvement for decades in many parts of the world and there is an extensive body of literature on the subject (e.g., Godfrey et al., 1985; Reddy and Smith, 1987; Kadlec and Knight, 1996; Mitsch and Jorgensen, 2003; Kangas, 2004; Mitsch and Gosselink, 2007; Kadlec and Wallace, 2009). In particular, well-designed assimilation wetlands can achieve tertiary treatment while significantly relieving financial burdens on local communities and perform well over decades (60 years for Breaux Bridge).

The State of Louisiana recognized the water quality improvement and associated ecological benefits of natural wetlands, and adopted wetland assimilation as an option for appropriate dischargers. The successful use of natural wetland assimilation in Louisiana is the result of a close working relationship among wetland scientists, Louisiana state and local officials, and US EPA, allowing for the development of a science-based innovative approach that complies with state and federal regulations.

Non-renewable energy sources, especially oil, are being rapidly exhausted than commonly perceived, and many have projected that the world is currently at peak oil production (e.g., Campbell and Laherrere, 1998; Day et al., 2009; Hall and Day, 2009; Hirsch et al., 2010). It is known that conventional wastewater treatment is very energy intensive, while wetland assimilation is very energy efficient and can lead to significant carbon sequestration. Incorporation of ecosystem services should be considered in developing sustainable community planning.

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