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Article

A Point Source of a Different Color: Identifying a Gap in United States Regulatory Policy for "Green" CSO Treatment Using Constructed Wetlands

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Abstract: Up to 850 billion gallons of untreated combined sewer overflow (CSO) is discharged into waters of the United States each year. Recent changes in CSO management policy support green infrastructure (GI) technologies as "front of the pipe" approaches to discharge mitigation by detention/reduction of urban stormwater runoff. Constructed wetlands for CSO treatment have been considered among suites of GI solutions. However, these wetlands differ fundamentally from other GI technologies in that they are "end of the pipe" treatment systems that discharge from a point source, and are therefore regulated in the U.S. under the National Pollution Discharge Elimination System (NPDES). We use a comparative regulatory analysis to examine the U.S. policy framework for CSO treatment wetlands. We find in all cases that permitting authorities have used best professional judgment to determine effluent limits and compliance monitoring requirements, referencing technology and water quality-based standards originally developed for traditional "grey" treatment systems. A qualitative comparison with Europe shows less stringent regulatory requirements, perhaps due to institutionalized design parameters. We recommend that permitting authorities develop technical guidance documents for evaluation of "green" CSO treatment systems that account for their unique operational concerns and benefits with respect to sustainable development.

Keywords: combined sewer overflow; constructed wetlands; green infrastructure; environmental regulation; policy; National Pollution Discharge Elimination System

1. Introduction

The United States Environmental Protection Agency (USEPA) estimates that the 772 combined sewer systems (CSSs) in the United States (U.S.) discharge approximately 850 billion gallons of untreated storm and sewage effluent into the nation's waters each year [1]. CSSs are sewers that convey stormwater and industrial/municipal wastewater to publicly owned treatment works (POTWs) through the same pipe. During wet weather, combined runoff and sewage flows can exceed the conveyance capacity of the CSS and discharge into local waterways from multiple point sources prior to receiving treatment. This discharge is known as combined sewer overflow (CSO).

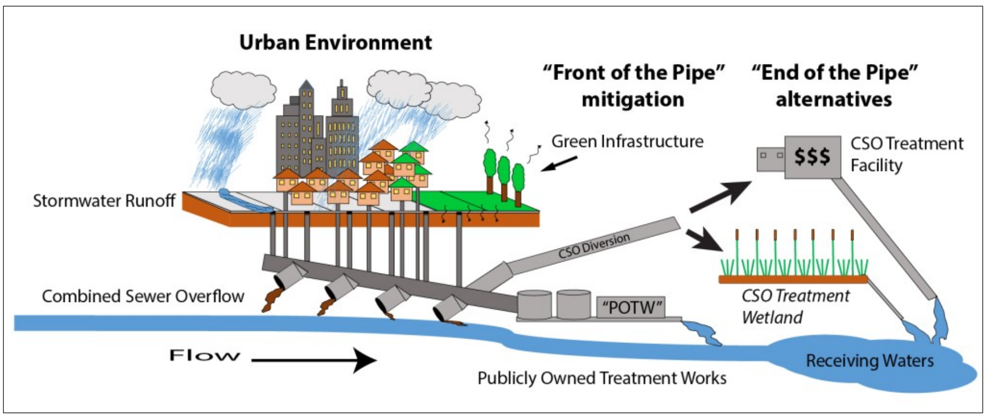
Point discharges of pollutants into waters of the U.S. are regulated under Section 402 of the Clean Water Act, which establishes the National Pollution Discharge Elimination System (NPDES) and its state corollaries. CSO and POTW outfalls are considered point sources and are therefore regulated under NPDES (40 CFR § 122) [2]. POTWs require NPDES permits to discharge treated effluent to waters of the U.S., and include either technology or water quality-based limits for pollutant loading and compliance monitoring. Discharges from diffuse networks of municipal CSO outfalls are harder to characterize and control, necessitating a more complex policy framework. The initial CSO Control Policy released by the USEPA in 1994 granted oversight to NPDES permitting authorities to ensure CSO communities develop long term control plans (LTCPs) including phased implementation of nine minimum technology-based controls [3,4]. Subsequent control strategies focused on maximizing wet weather flows to POTWs and enhancing traditional "grey" infrastructure, such as underground storage tanks and additional satellite CSO treatment facilities [2].

Recently, there has been a sea change in CSO management policy, supporting green infrastructure (GI) technologies as "front of the pipe" approaches to CSO mitigation by detention/reduction of urban stormwater runoff [5,6]. The USEPA defines green infrastructure as "An adaptable term used to describe an array of products, technologies, and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services" [7]. Examples of GI technologies include: rain gardens, bioswales, green roofs, constructed wetlands, and permeable pavement. Integration of GI in stormwater management plans is a sustainable practice in that it reduces the carbon footprint and economic cost associated with traditional "grey" solutions (e.g., sewer separation). Additionally, GI provides various societal benefits including aesthetic improvements to public spaces and mitigation of environmental justice issues associated with some "grey" infrastructure expansion projects [8,9].

Constructed wetlands for wastewater treatment (*i.e.*, treatment wetlands) have become a globally accepted practice for treatment of municipal and industrial wastewater supported by more than fifty years of design and operational experience [10–13]. In the U.S., treatment wetland systems are often used in tandem with traditional treatment facilities as a polishing step, or in lieu of secondary treatment [13]. These types of systems effectively treat total suspended solids (TSS), biochemical oxygen demand (BOD), nitrogen, phosphorus, coliform bacteria, and metals through commonly understood pollutant removal processes of mass transport, volatilization, sedimentation, sorption, and biological uptake; consistent with current engineering understanding [12,14]. Virtually all types of water have been treated including: municipal and industrial wastewaters, feedlot runoff, and landfill leachate; typically at much higher strengths than experienced during CSOs [12]. Wetlands are efficient at lowering TSS concentration and a range of 50%–90% reduction is typical [12,15]. BOD concentration reduction may be expected to be in the 50%–80% percent range [12]. Nitrogen and phosphorus concentration reductions of 30%–90% and coliform bacteria reduction by three orders of magnitude can be achieved in treatment wetlands dependent upon inflow concentration, hydraulic loading rate, and system type [12].

Constructed "stormwater" wetlands have also become a common best management practice (BMP) in the U.S. for detention and treatment of peak runoff flows [16–18]. Conversely, only a handful of CSO *treatment* wetlands have been built in the U.S., although the technology has been applied in Europe [19]. Recently, CSO treatment wetlands have been included in LTCPs along with suites of GI solutions to mitigate the impacts of CSO discharges on receiving waters [20–21]. However, CSO treatment wetlands differ fundamentally from preventative GI approaches (e.g., green roofs, stormwater wetlands) in that they are "end of the pipe" treatment systems that discharge from a point source, and are therefore subject to requirements of the NPDES program (Figure 1). A crucial point remains: NPDES guidance differs significantly with respect to effluent limits and compliance monitoring for different classes of point source. We hypothesize that CSO treatment wetlands occupy a regulatory gap at the nexus of CSO control, wastewater treatment, and GI policies. This article will examine the U.S. regulatory framework and NPDES-based requirements for CSO treatment wetlands. Additionally, we qualitatively compare U.S. with European CSO treatment wetland regulatory policy, discuss applicable criteria for sustainability assessments, and recommend key considerations for development of technical guidance documents to fill the policy gap.

Figure 1. Process diagram illustrating urban runoff and combined sewer overflow management.



2. Methods

There have been a number of comparative water quality regulation studies and papers, which include international, national, regional, and technology-based assessments. Several international regulatory comparisons have been made between the U.S., Europe, Canada, Sweden, and Indonesia; with "command and control" frameworks being historically much stronger in the U.S. [22–26]. Cole and Grossman [27] document the early U.S. regulatory philosophy of command and control. Later this philosophy was augmented by incentives [28] and comparative risk analysis [29]. Newer policy views for environmental regulation include social cost [30], ecological integrity [31], and most recently ecological services [32].

One of the few studies that compare "grey" *vs.* "green" infrastructure is by Jaffe *et al.* [33], which is a review of selected state practices and programs. In a summary article, Jaffe [5] argues that green infrastructure (including treatment wetlands) is the most cost effective solution on a simple cost-benefit analysis and use of ecological service valuation is not needed. However, this assertion may be questionable *in situ*ations where regulators mandate that specific ecological and water quality objectives be met, regardless of cost.

We did a comparative regulatory analysis in order to identify and delineate a regulatory policy gap for CSO treatment wetlands. Our analysis consists of two parts: (1) identification of key federal policies applicable to NPDES permitting of CSO treatment wetlands, and (2) investigation as to how CSO treatment wetlands have been permitted in different states with respect to interpretation of federal guidance. For the latter analysis, we specifically focused on effluent limitations and compliance monitoring requirements included in NPDES permits. We did an Internet and professional network search for CSO treatment wetlands throughout the U.S., and obtained their NPDES permits directly (if they existed) from the appropriate regulatory authorities. We also interviewed the NPDES authorities responsible for CSO treatment wetland regulation in order to clarify rationale for permit requirements when it was not clearly stated in the NPDES permit.

3. Results and Discussion

3.1. Current U.S. Regulatory Framework

3.1.1. "Grey" *vs.* "Green" Wastewater Treatment Policy

Effluent limits and compliance monitoring requirements for municipal POTWs under the NPDES program are developed using either technology or water quality-based limits. Best Practicable Control Technology Available (BPT) or Best Available Technology Economically Achievable (BAT) are *technology-based* rubrics that depend on the ability of the discharger to treat waste loads effectively using economically viable state-of-the art treatment technologies. Section 301 of the Clean Water Act specifies limits for POTW effluent based on traditional ("grey") secondary treatment technology [34]. This includes maximum allowable concentrations for five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and pH (Table 1). Alternately, *water quality-based* effluent limits are derived to be protective of state water quality standards, which are based on the class and attainable use (e.g., fishable, swimmable) of the receiving waterbody. Regulatory authorities codify the more stringent of the two sets of limits (typically the water quality-based standards) into NPDES permits along with compliance monitoring requirements [34].

Requirements for biological ("green") treatment technologies such as trickling filters or waste stabilization ponds may be relaxed by NPDES permitting authorities since these systems do not always consistently achieve secondary treatment standards for BOD_5 and TSS (Table 1). This sometimes occurs due to the fact that these systems may develop new algae and microbes that, while in technical violation of secondary treatment effluent limitations, do not have the same impact as solids typically found in raw sewage [12]. In 1981, Congress included provisions in amendments to the Clean Water Act Construction Grants program (*Public Law 97–117, Section 23*), which resulted in mandated regulations in 1984; establishing alternative standards applying to facilities with "equivalent to secondary treatment" (40 CFR § 133.105) [34]. Additionally, reductions to secondary treatment standards may be made by NPDES permitting authorities on a case-by-case basis for BOD_5 and TSS from waste stabilization ponds and trickling filters [34].

Table 1. Comparison between technology-based secondary treatment standards and biological equivalent to secondary treatment standards (adapted from USEPA [34]).

Parameter	Secondary Treatment Standards ("grey")		Equivalent to Secondary Treatment Standards ("green")	
	30-day average	7-day average	30-day average	7-day average
BOD_5	30 mg/L (or 25 mg/L $CBOD_5$)	45 mg/L (or 40 mg/L $CBOD_5$)	not to exceed 45 mg/L (or not to exceed 25 mg/L $CBOD_5$)	not to exceed 65 mg/L (or not to exceed 60 mg/L $CBOD_5$)
TSS	30 mg/L	45 mg/L	not to exceed 45 mg/L	not to exceed 65 mg/L
BOD_5 and TSS removal (concentration)	not less than 85%	-	not less than 85%	-
pH	within the limits of 6.0–9.0		within the limits of 6.0–9.0	

3.1.2. CSO Control Policy

Following the passage of the Clean Water Act in 1972, a D.C. Circuit Court decision (*NRDC vs. Costle*, 568 F.2d 1369 (D.C. Cir. 1977)) designated CSO outfalls as point sources for pollutants, therefore subject to the requirements of the NPDES program [2]. In response to this ruling, the USEPA developed a general "umbrella" NPDES permit to regulate multiple CSO outfalls belonging to the same community [5]. Since this ruling, discharges from POTWs and CSOs are typically covered by the same general NPDES permit. However, in 1980 the U.S. Court of Appeals for the DC Circuit determined that discharges at CSO outfalls are not the same as discharges from POTWs and *not subject to the secondary treatment standards* typically applied to the latter (*Montgomery Environmental Coalition vs. Costle*, 46 F2d 568 (D.C. Cir. 1980)) [1].

In 1994, the USEPA released the national CSO Control Policy (59 FR 18688) [3]. The policy assigns primary responsibility to NPDES permitting authorities for its implementation and enforcement, based largely on best professional judgment. The policy further requires CSO communities to develop long term control plans (LTCPs) to mitigate the impact of CSO on local waterbodies that include nine minimum technology-based controls [4]:

(1) Proper operation and regular maintenance programs for the sewer system and the CSOs;
(2) Maximum use of the collection system for storage;
(3) Review and modification of pretreatment requirements to assure CSO impacts are minimized;
(4) Maximization of flow to the publicly owned treatment works for treatment;

(5) Prohibition of CSOs during dry weather;
(6) Control of solid and floatable materials in CSOs;
(7) Pollution prevention;
(8) Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts; and
(9) Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

The CSO Control Policy also allows for phased implementation of the LTCP through two stages of NPDES permitting. Monitoring and characterization of CSOs to ensure compliance with NPDES permits remains a challenging undertaking and relies on monitoring of select outfalls and the application of models to estimate discharge quantity and quality on the sewershed-scale [2].

Federal regulation/guidance concerning CSO treatment remains vague. The 1994 CSO Control Policy recommends that technology-based control alternatives involving CSO treatment should include, at a minimum, primary treatment (with floatables and solids control) and disinfection [3].

3.1.3. Green Infrastructure Policy

The USEPA has released four policy memos and six factsheets since 2007 in support of the integration of GI into NPDES permits and CSO remedies [35–44]. A memorandum released in 2007 suggested that NPDES permitting authorities structure permits and guidance for LTCPs and stormwater plans "…to encourage permittees to utilize green infrastructure approaches, where appropriate, in lieu of or in addition to more traditional controls" [37]. Additionally, the same memorandum states that the USEPA "…will also consider the feasibility of the use of green infrastructure as a water pollution control technology, and encourages state authorities to do likewise" [37]. Despite this, there remains no specific policy or guidance related to the uses or benefits of GI for the *treatment* of waters containing municipal/industrial waste products.

3.2. CSO Treatment Wetlands in the United States

3.2.1. History and Specifications

We found evidence of only four CSO treatment wetlands built in the U.S. to date. These systems are located in the states of Indiana (IN) and New York (NY) exclusively, have a diverse assortment of design parameters, and range from 0.5 to 27 acres in size (Table 2).

The first extant CSO treatment wetland built in the U.S. is located in Elkhart, IN. The wetland was designed and constructed in 1999 through a grant from the Indiana Department of Environmental Management (IDEM), the state environmental regulatory agency. The "Arch and Bar" wetland originally consisted of an ecological treatment system, monitoring station, and an interactive public education component, including an educational kiosk and viewing platform [45]. Regular monitoring of the system ended in 2004 [46]. The treatment system is composed of a bar screen chamber and sedimentation basin to remove grit and floatables; an open wetland channel (*i.e.*, free-water surface wetland) with an active littoral habitat and micropool graded below the groundwater table; and a vertical down-flow wetland system (see Kadlec and Wallace [12] for further discussion of ecological treatment design types). The Arch and Bar CSO treatment wetland is the smallest-scale system in the U.S. (Table 2).

Table 2. United States combined sewer overflow (CSO) treatment wetland specifications (NA = data not available).

CSO Community	Construction Completed	Treatment System Area (Acres)	Maximum Capacity (MG)	Peak Design Flow (MGD)	Grit and Floatables Removal	Treatment Wetland Components	Receiving Water
Elkhart, IN	1999	0.5	NA	NA	Bar screen and sedimentation basin	Free-water surface (shallow and deep zones) wetland, vertical down-flow wetland	Elkhart River
Akron, IN	2001	6	0.5	NA	Swirl concentrator	Two free-water surface wetlands ("serpentine earthen channels")	Town Lake
Washington, IN	2012	27	25	307.7	Nutrient baffle and forebay pond	Free-water surface wetland, UV disinfection system	Hawkins Creek
Syracuse, NY	2013	2	0.7	28.4	Swirl concentrator	Floating wetland islands, vertical down-flow wetland, free-water surface wetland	Harbor Brook

The Akron, IN treatment wetlands were constructed in 2001 adjacent to the municipal waste water treatment facility by the Town of Akron to treat wet weather CSO discharges. The project was constructed using funds from a federal 104 (b) (3) Innovative Low Operation and Maintenance Demonstration Grant [47]. The system receives discharges from two separate outfalls which both undergo grit and floatable control in swirl separators before flow through two "serpentine earthen channels" (*i.e.*, free-water surface wetlands) and recombine to discharge into Akron's Town Lake [48].

The Washington, IN system is the largest CSO treatment wetland that has been built in the U.S. to date. The treatment wetland itself is 27 acres in size and has a capacity of 25 million gallons. The City of Washington commissioned the wetland to battle an extremely sensitive CSS, which discharged CSO in response to as little as 0.1 inches of rainfall. A 2002 study by the city found that traditional "grey" infrastructure solutions to the problem could cost up to $40 million. The current CSO treatment wetland system was constructed for $26.4 million and consists of a 5 million gallon storage tank, nutrient baffle, and a 27-acre free-water surface treatment wetland (including a forebay pond for grit/floatables control), and a UV disinfection system at the outfall [49].

The Harbor Brook treatment wetland in Syracuse, NY is a unique, full-scale pilot demonstration project that showcases three different wetland designs in discrete cells that can be operated in multiple flow configurations (e.g., series, parallel). Following grit and floatables control by a swirl separator, CSO is channeled into the wetland system, which includes a floating wetland island basin, vertical down-flow wetland, and a free-water surface wetland. The Harbor Brook treatment wetland was included as a major component of Onondaga County's Green Infrastructure Plan with the overall goal of detention and treatment of 13.6 million gallons of CSO per year for events up to and including the One Year, Two Hour Storm [20,50]. The Harbor Brook wetland will be able to provide valuable information on CSO treatment wetland design parameters once sufficient monitoring data has been collected.

3.2.2. Regulatory Standards and Practices

Since CSOs are not formally considered to be discharges from POTWs they are not subject to federally mandated technology-based secondary treatment requirements (*Montgomery Environmental Coalition vs. Costle*, 46 F2d 568 (DC Cir. 1980)) [1]. Therefore effluent limits and compliance monitoring requirements for CSOs and CSO treatment systems are left up to the best professional judgment of NPDES-permitting authorities.

State environmental regulatory agencies in New York and Indiana (NYSDEC and IDEM, respectively) have adopted the non-rule policy guidance set forth in the 1994 CSO Control Policy for CSO treatment. This states that minimum CSO treatment should include primary clarification to remove floatables and settleable solids, solids and floatables disposal, and disinfection, if necessary, to meet water quality standards [3]. These basic standards are codified in New York State Environmental Conservation Law (6NYCRR Part 703) and IDEM Non-rule Policy (Water-016) [51,52].

The IDEM's CSO treatment policy, originally effective in 2008, was modeled after Michigan's [52]. It states that CSO treatment facilities should treat flows greater than the One Year, One Hour Storm up to and including the Ten Year, One Hour Storm with at least 30 min of detention for TSS control, skimming detained flows for solids and floatables, disinfection, and dechlorination (if applicable). Treatment of flows in excess of the Ten Year, One Hour Storm is relaxed to "whatever treatment is feasible given capacity limitations at the CSO Treatment Facility and [Wastewater Treatment Plant]" [52]. It also sets forth effluent limits for *E. Coli* (daily maximum no more than 235 colonies/100 mL) and recommends additional monitoring should be required for flow, BOD_5, TSS, Ammonia-nitrogen (as N), Total Phosphorous (as P), pH, dissolved oxygen (DO), and total residual chlorine (if applicable).

Our analysis of some basic NPDES permits requirements for the extant CSO treatment wetlands in the U.S. shows wide variability within a small sample set (Table 3). The City of Elkhart's general NPDES permit makes no mention of the Arch and Bar treatment system [53]. This is due to the fact that outfall relocation never took place (*i.e.*, the treatment system discharges through the original CSO outfall). Since the City of Elkhart never chose to take regulatory credit in their NPDES permit for the treatment benefits of the system, effluent limits and compliance monitoring were never required by the state [46].

The Akron CSO treatment wetland has the most stringent effluent limitations of all the systems examined in this paper (Table 3). This is due to the fact that they discharge into a lake and are thereby subject to *water quality-based* effluent limitations as set forth in Indiana Administrative Code

(327 IAC 2-1-6) [48]. Alternatively, the Washington wetland has technology-based limits for *E. coli* and is also monitored for effluent flow, $CBOD_5$, TSS, Ammonia-Nitrogen, pH, and DO [54], pursuant to IDEM's Non-Rule CSO Treatment Policy as discussed above (Table 3). A major difference between the Akron and Washington projects is that the former was constructed before IDEM's CSO Treatment Policy was developed. The Washington wetland follows this policy closely and has been fairly successful in satisfying effluent limits and design requirements [49]. The Town of Akron has been in violation of limits for DO and coliform bacteria from the wetland outfall and is pursuing a sewer separation strategy [47,55].

Syracuse's Harbor Brook CSO wetland is a unique pilot demonstration project that showcases multiple green treatment technologies. Currently, a draft SPDES (New York's NPDES equivalent) general permit for the Syracuse POTW and CSO network requires monitoring of a wide range of environmental parameters for both system influent and effluent; with effluent limits only imposed for Fecal Coliform and Total Residual Chlorine (Table 3). This is similar to monitoring requirements set for the other grey CSO treatment facilities included under the general SPDES permit [56]. However, these permit requirements will be subject to change at the end of a two-year pilot monitoring period [57]. At this point, the NYSDEC reserves the right to impose stricter effluent limitations and compliance monitoring requirements, as well as require the installation of additional disinfection facilities if Fecal Coliform standards are not maintained [58].

Table 3. Summary of United States CSO Treatment Wetland NPDES Compliance Monitoring and Effluent Limit Requirements.

CSO Community	NPDES/ SPDES Permit	Compliance Monitoring (effluent, unless otherwise specified)	Effluent Limits	Basis for Effluent Limitations
Elkhart, IN	None	None	None	None
Akron, IN	General NPDES	Flow [i] (MGD)	Report (Daily Maximum and Monthly Average)	Water Quality-Based, Indiana Administrative Code limits for lake dischargers (327 IAC 2-1-6) [48]
		$CBOD_5$ (mg/L)	Monthly Average: 10, Weekly Average: 15	
		TSS (mg/L)	Monthly Average: 12, Weekly Average: 18	
		Ammonia-nitrogen (mg/L)—Summer	Monthly Average: 1.1, Weekly Average: 1.6	
		Ammonia-nitrogen (mg/L)—Winter	Monthly Average: 1.6, Weekly Average: 2.4	
		Phosphorous (mg/L)	Monthly Average: 1.0	
		pH (standard units)	Daily Minimum: 6, Daily Maximum: 9	
		Dissolved Oxygen (mg/L)	Daily Minimum 6	
		Escherichia coli (E. coli) (colonies/100 mL)	Monthly Average: 125, Daily Maximum: 235	
Washington, IN	General NPDES	Effluent Flow (MGD), $CBOD_5$ (mg/L), TSS (mg/L), Ammonia-nitrogen (mg/L), pH (s.u.), Dissolved Oxygen (mg/L)	Report	Technology-Based, primary treatment and disinfection [52,54]

Table 3. *Cont.*

CSO Community	NPDES/ SPDES Permit	Compliance Monitoring (effluent, unless otherwise specified)	Effluent Limits	Basis for Effluent Limitations
Washington, IN	General NPDES	*Escherichia coli (E. coli)* (colonies/100 mL)	Monthly Average: 125, Daily Maximum: 235	Technology-Based, primary treatment and disinfection [52,54]
Syracuse, NY	Draft General SPDES	Event Flow [i] (MG), BOD_5 [i] (mg/L), TSS [i] (mg/L), Settleable Solids [i] (mL/L), Oil & Grease (mg/L), Floatable Material (visual obs.), Screenings (Monthly Total—influent only), Ammonia [i] (mg/L), TKN (mg/L), Total Phosphorous [i] (mg/L), Dissolved Oxygen (mg/L)	Report	Draft for pilot purposes; Technology-Based, primary treatment and disinfection [51,56]
		Fecal Coliform [i] (colonies/100 mL)	Overflow Event: 200	
		Total Residual Chlorine (mg/L)	Overflow Event: 0.2	

[i] monitoring of both influent and effluent required.

3.3. European CSO Treatment Wetland Policy

In Europe, where to our knowledge the only existing CSO wetland projects (besides the U.S.) are under operation, treatment of CSOs using constructed wetlands has been implemented under conditions of high population density. Examples can be found mostly in Germany (several hundred [19]), the Netherlands (more than 5 [59]), Denmark (more than 5 [60]), and Belgium (more than 2 [61]). Single experimental full-scale applications currently under scientific monitoring are located in France [19], Italy [19], and Scotland [62].

European CSO wetland design is based broadly on the vertical down-flow type (originated from Germany in the 1990s), though different variations on this theme have been implemented (see Meyer *et al.* [19] for an in-depth discussion on CSO wetland design parameters). Comparatively old approaches in the Netherlands and Belgium have horizontal free-water surface flow designs, and are either planted, unplanted, or equipped with floating plantation mats. In general, only a few CSO wetlands have been monitored, even less data nationally published, and almost no study internationally published.

Both common and country-specific policies need to be respected by the members of the European Community. Fundamental requirements for wastewater discharge can be found in the EC Water Framework Directive [63], demanding a "good quality status" for all water bodies (including surface and ground water). Thus, CSO treatment has become essential in many places to decrease the environmental impacts of untreated CSO discharge, mainly due to suspended solid accumulation, biochemical oxygen demand, and nutrient loading.

In Germany, CSOs are stored in tanks and subsequently treated in POTWs. Hard or long rainfall events can result in flows exceeding tank capacity and thereby to CSO discharges. It is expected that the CSO storage functions as a sedimentation tank. In this way, physical treatment is the only general national discharge requirement. In addition, each CSO discharge point needs to be approved by local water authorities. Due to the quality and sensitivity of the receiving water bodies, increased water quality-based requirements may be stated. In these cases, CSO treatment wetlands have been used to help meet water quality standards. The national guideline DWA-M 178 ([64], currently under revision), summarized in Uhl and Dittmer [65], must be followed for the wetland design. According to DWA-M 178, local water authorities may require specific treatment performances, but there are no standing technology-based effluent limits on the national level. Monitoring of CSO quantity or quality is not generally required, but might be requested for approval.

In France, a new national guideline for CSO discharge is currently under discussion. The existing concept requires a global monitoring of all sewer system discharges. Annually averaged loads would be divided by flows in order to calculate theoretical discharge concentrations, which will need to be under certain maximum values. In this way, high performing sewage plants can balance untreated CSOs. The new concept is based on maximum numbers of untreated annual CSO events. Discharges from CSO wetlands are considered to be treated and therefore are incorporated into the "good effluent" part of the discharge budget. The new guidelines have not been implemented yet because current pollutant load estimates would force intractable investment demands on hundreds of small communities. This policy and various alternatives are currently under consideration.

In Italy, the main idea of CSO treatment is based on a "first flush concept". It is required by law to treat the overflow of the first 5 mm of rain, though no standards exist with respect to flow, if a recurrence interval of two years is considered in the treatment system design. Therefore a volume of 50 m^3/ha has to be considered for water quality purposes (regional law of Lombardy on CSO, R.R. 3/2006) [19]. Additional water storage before discharge to natural water bodies may be required for flood prevention. These requirements can result in differing treatment concepts, because the retention function is disconnected from pollution control. Monitoring is not required.

Generally, monitoring requirements and effluent limits for CSO treatment wetland discharges appear to be minimal in Europe, and are only implemented under special circumstances. In many cases, adequate treatment by constructed wetlands is assumed based on prior experience. This could be due to a longer history of treatment wetlands that have institutionalized design parameters and proven treatment efficiencies. Modeling efforts are currently underway to better quantify European CSO wetland treatment efficiencies [66].

3.4. Sustainability Criteria for CSO Treatment Wetlands

Sustainability criteria have become increasingly important to stakeholders involved in GI projects, who often seek to optimize the "triple bottom line" of environmental, economic, and social impacts [67–68]. The sustainability of constructed wetlands in general has been analyzed in-depth [69]. However, there have been no studies highlighting or integrating metrics of sustainability for CSO treatment wetlands. Here, we propose three focal areas for sustainability analysis of CSO treatment wetland systems, followed by a brief discussion of each: (1) construction and avoided infrastructure costs, (2) long-term operations and maintenance, (3) ecosystem services.

3.4.1. Construction and Avoided Infrastructure Costs

Initial construction costs for constructed wetlands are generally much lower than for traditional, grey wastewater treatment systems [70]. Conceptually, Geiger [71] estimated that, total CSO treatment costs could be reduced by 20%–30% using de-centralized strategies such as settling tanks, soil filters, and constructed wetlands. The Washington, IN wetland project was able to reduce CSO treatment costs from an estimated $40 million to $26.4 million using a constructed wetland [49]. In addition to a comparison of initial construction costs, avoided "grey" infrastructure costs can be estimated as the marginal cost of providing an equivalent service using "green" alternatives [67]. This tends to be much lower in the case of constructed wetlands, as flow is typically gravity-powered and facilities have lower staffing requirements [69].

3.4.2. Long-Term Operations and Maintenance

Analysis of a CSO treatment system operations and maintenance (O&M) needs is critical in understanding the long-term sustainability of these technologies, and can be incorporated into life-cycle assessment frameworks [68]. These concerns will obviously vary depending on treatment system design. In Germany, where CSO wetlands have been widely used since the 1990s (see Section 3.3 above), vertical down-flow systems are designed for a lifespan of more than 30 years. The biggest problem with their operation has been clogging over time, but this has been ameliorated by replacing older designs using fine filter media to ones specifying technical sands [19,65]. In general, key considerations for CSO wetland O&M include grit and floatables removal, invasive species removal/plant harvesting, and odor/vector control [50]. Depending on the system, maintenance requirements for grit and floatable removal can range from one visit per event to one visit per year. Vegetation control (once the initial planting is established) is typically done on an annual basis and does not represent a major expenditure of time, energy, or money.

An emerging concern is the sustainability of treatment systems in changing climates that could induce extreme flow events and flooding. Typically, CSO flows in excess of system design capacities are routed back along conventional routes through the trunk sewer or to a relocated CSO outfall. Wetland systems maintain maximum design water levels using berms with emergency spillways [50]. For the most part, since these systems are labile and naturally regenerating, we may expect storm damage cost to be less than "grey" treatment facilities, which are also dependent on utilities that can be impaired by storm events (e.g., electric power lines). Vertical down-flow wetlands may require increased invasive removal in drought-affected areas, where natural regulation of species by intermittent flooding could be adversely impacted [19,65].

3.4.3. Ecosystem Services

Ecosystem services applicable to CSO treatment wetlands can be grouped as: regulating (water quality improvement, storm flow abatement, carbon sequestration), supporting (habitat, nutrient cycling, pollination), or cultural (education, recreation, aesthetics); as defined by the Millennium Ecosystem Study [72]. The USEPA is also working on a system to quantify ecosystem services delivered to users by wetlands in general [32].

Water quality improvements are obviously one of the most important metrics of treatment system performance. However, these can also be examined outside of the range of regulatory thresholds to account for the important biogeochemical transformations (e.g., denitrification) treatment wetlands support that may not directly translate into regulatory credit. Seasonal habitat value for waterfowl, songbirds, amphibians and mammals will need to be balanced against excessive grazing of wetland plants. Treatment wetlands also provide educational and interpretation value precisely due to linkages between their design and the aforementioned functions [73].

Constructed wetlands are sinks for atmospheric CO_2, and sources for other greenhouse gases such as CH_4 and N_2O. Over the long-term, it can be expected that greenhouse gas emissions are unimportant compared to total carbon sequestration if proper management actions are taken, such as pulsing water regimes and enhancing aquatic macrophyte growth [74–75]. The net carbon footprint of these systems is usually lower when compared with "grey" alternatives that require greater ongoing external energy inputs.

3.5. Critical Analysis and Recommendations

We contend that U.S. regulation of CSO treatment wetlands occupies a nexus at the confluence of wastewater treatment, CSO control, and green infrastructure policies—and represents a policy gap (Figure 2). While it is true that non-rule guidelines for CSO treatment requiring primary treatment and disinfection do exist—federal guidance remains vague at best and was not designed to account for unique operating requirements of green treatment systems.

Some important points can be gleaned from the preceding analysis of the current U.S. regulatory policy framework:

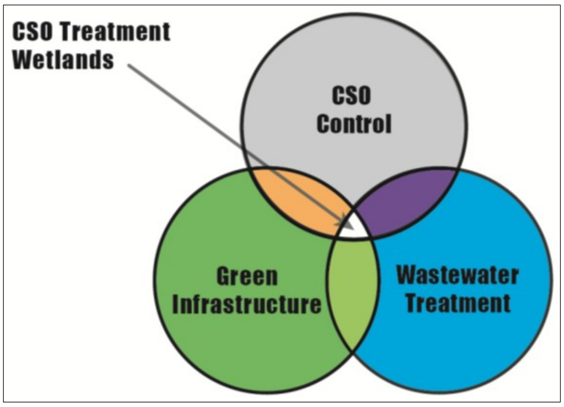
- There is a precedent for different technology/performance-based standards between "grey" and "green" wastewater treatment systems;
- Federal CSO control policy favors technology-based treatment alternatives; and
- Federal guidelines support the integration of sustainable GI alternatives into LTCP's and NPDES permits.

Based on these observations, we suggest that the current framework does in fact support the emerging "green" CSO treatment wetland technology. However, these disparate policies need to be codified into a formal guidance to be most effective for regulatory agencies on the state level.

The case studies in IN and NY discussed above show that regulation of CSO treatment wetlands based on best professional judgment has varied on a case-by-case basis. Older, smaller projects in Elkhart and Akron run the gamut from no regulatory oversight to strict water quality-based effluent limits. Adoption of a CSO treatment policy by IDEM [52] helped to form a well-developed rubric, which was considered in the development of the Washington CSO wetland [76]. However, the IDEM CSO Control Policy was originally developed by Michigan for grey CSO treatment, and does not overtly take into account different operational requirements and variability inherent in "green" ecological engineering designs. Similarly, the Syracuse Harbor Brook treatment wetland's effluent limits (e.g., fecal coliform in Table 3) reflect those of grey CSO treatment facilities in the sewershed [56].

Additional extensive monitoring requirements are due to the pilot nature of the project and will be revised after two years of monitoring [57–58].

Figure 2. Venn diagram illustrating how CSO treatment wetlands occupy a regulatory gap at the nexus of CSO control, green infrastructure, and wastewater treatment policies.



Transfer of regulatory guidance documents from "grey" to "green" CSO treatment facilities can be problematic due to fundamentally different technical and operational guidelines. For example, many gravity-powered constructed wetland systems have markedly different hydraulic residence times than "grey" systems, some ranging up to 78 h (e.g., Harbor Brook [57]). Increased CSO storage and treatment has the benefit of reducing impacts of flooding and pollutant load on receiving waters that may not have the assimilative capacity to handle the full effluent discharge during peak flows. However, benefits stemming from the unique operations of these systems necessitate special consideration when developing compliance monitoring protocols (e.g., sampling frequency) or effluent limitations. In addition, in many cases, what makes the system "green" are reduced staffing and energy costs, but these would be increased by elaborate monitoring programs and automated flow control/disinfection. Construction of "green" treatment wetland systems according to "grey" treatment standards may result in the conceptual equivalent of a rain barrel inside an underground storage tank.

One of the biggest barriers to widespread implementation of CSO treatment wetland technology in the U.S. is the disinfection standard that has been carried over from "grey" CSO treatment guidance. Disinfection is typically accomplished in traditional wastewater treatment by UV light systems (which require an external power source) or addition of chlorine to the water. The treatment wetland environment is naturally hostile to most septic pathogens, which are attenuated due to the changes in temperature, natural UV radiation from the sun, predation, sedimentation, and unfavorable water chemistry [12]. However, natural wildlife populations such as muskrats or waterfowl can substantially increase fecal coliform levels, making it difficult to consistently meet the often mandated 200–235 colonies/100 mL limit [12]. This is an important consideration to be made when setting effluent limits for CSO treatment wetlands, and should be considered by permitting authorities. Similar allowances could be made for coliform bacteria that have been made for BOD_5 and TSS in biological wastewater treatment systems, but this will likely require in depth consideration and subsequent guidance on the federal level.

Finally, the de-centralized and modular application of CSO treatment wetland systems, which include a wide variety of design types (e.g., vertical down flow, free-water surface), can be used strategically to target specific pollutants of concern in order to meet LTCP goals. No one treatment design should be considered a silver bullet. An interesting example of this is the Banklick Creek Regional Wetland Pilot Project in northern Kentucky, which targets coliform bacteria in a CSO impacted watershed by pumping receiving waters out of the creek and into two parallel free-water surface treatment wetland cells before recombining downstream. Since the system does not receive effluent from a recognized point source (e.g., CSO outfall) only water withdrawal and floodplain construction permits were required, as opposed to an NPDES permit with associated effluent limits [77]. Versatility in application of treatment wetland designs is essential to meeting watershed-specific water quality goals. However, regulatory trade-offs may be necessary to maximize cost-effective, technology-based CSO treatment.

In consideration of the preceding policy analysis and discussion, we recommend that federal and/or state technical and operational guidance documents specific to *green* CSO treatment be developed with the following principles in mind:

(1) Benefits of "grey" and "green" CSO treatment systems are assessed using sustainability analyses that include construction and avoided infrastructure costs, long-term operations and maintenance, ecosystem services;
(2) Effluent limits and compliance monitoring requirements take into account fundamental technical differences between "grey" and "green" CSO treatment systems; and
(3) Design recommendations facilitate meeting LTCP goals by versatile application of different treatment wetland technologies (e.g., vertical down-flow, free-water surface).

4. Conclusions

Constructed CSO treatment wetlands are a form of GI that have enormous potential to mitigate pollution in urban watersheds of the United States, and may be more sustainable in the long-term when construction and avoidance costs, operations and maintenance, and ecosystem services are considered. However, these unique systems fall into a regulatory policy gap at the nexus of wastewater treatment, CSO control, and GI policies. Currently, non-rule federal policy for CSO treatment recommending primary treatment and disinfection has influenced NPDES permitting approaches on the state level. Examples in the U.S. are limited, but show that CSO treatment policy developed for "grey" facilities has been transferred during permitting of "green" treatment systems with fundamentally different operational concerns. European countries have much less stringent regulatory requirements for CSO treatment wetlands, perhaps due to institutionalized design parameters. As we attempt to develop more sustainable solutions to problems like CSO that are less costly and more ecologically efficient; regulators will be challenged to bridge the gap between protecting public health and safety—and more sustainable treatment technologies. We recommend that permitting authorities develop technical guidance documents for evaluation of "green" CSO treatment systems that account for their unique operational concerns and benefits with respect to sustainable development.

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Zeno Levy researched and wrote the paper. Richard Smardon contributed to the Methods and Sustainability Criteria sections. James Bays contributed to the Introduction and Critical Analysis and Recommendations. Daniel Meyer drafted the European CSO Treatment Wetland Policy section. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References and Notes

1. USEPA (U.S. Environmental Protection Agency). *Report to Congress: Implementation and Enforcement of the Combined Sewer Overflow Policy*; Office of Water: Washington, DC, USA, 2004.
2. NRC (National Research Council). *Urban Stormwater Management in the United States*; National Academies Press: Washington, DC, USA, 2009.
3. USEPA (U.S. Environmental Protection Agency). *Combined Sewer Overflow (CSO) Control Policy*; Office of Water: Washington, DC, USA, 1994.
4. USEPA (U.S. Environmental Protection Agency). *Combined Sewer Overflow: Guidance for Nine Minimum Controls*; Office of Water: Washington, DC, USA, 1995.
5. Jaffe, M. Reflections on green infrastructure economics. *Environ. Pract.* **2011**, *12*, 357–365.
6. Barnhill, K.; Smardon, R.C. Gaining ground: Green infrastructure attitudes and perceptions from Stakeholders. *Environ. Pract.* **2012**, *14*, 6–16.
7. USEPA (U.S. Environmental Protection Agency). Greening EPA Glossary. Available online: http://www.epa.gov/oaintrnt/glossary.htm (accessed on 27 January 2014).
8. Perreault, T.; Wraight, S.; Perreault, M. Environmental injustice in the Onondaga Lake waterscape, New York State, USA. *Water Altern.* **2012**, *5*, 485–506.
9. Sun, N.; Hall, M. Coupling human preferences with biophysical processes: Modeling the effect of citizen attitudes on potential urban stormwater runoff. *Urban Ecosyst.* **2013**, doi:10.1007/s11252-013-0304-5.
10. Moshiri, G.A. *Construction Wetlands for Water Quality Improvement*; Lewis Publishers: Boca Raton, FL, USA, 1993.
11. Vymazal, J. Constructed wetlands for wastewater treatment. *Water* **2010**, *2*, 530–549.
12. Kadlec, R.H.; Wallace, C. *Treatment Wetlands*, 2nd ed.; Lewis Publishers: Boca Raton, FL, USA, 2009.
13. Vymazal, J. Constructed Wetlands for Wastewater Treatment: Five Decades of Experience. *Environ. Sci. Technol.* **2011**, *45*, 61–69.

14. ITRC (Interstate Technology & Regulatory Council). Technical and Regulatory Guidance Document for Constructed Treatment Wetlands. Available online: http://www.itrcweb.org/Documents/WTLND-1.pdf (accessed on 6 April 2014).
15. Wong, T.H.F.; Fletcher, T.D.; Duncan, H.P.; Jenkins, G.A. Modeling urban stormwater treatment—A unified approach. *Ecol. Eng.* **2006**, *27*, 58–70.
16. USEPA (U.S. Environmental Protection Agency). *Constructed Wetlands Treatment of Municipal Wastewaters Manual*; Office of Research and Development: Cincinnati, OH, USA, 2000.
17. Scholz, M. *Wetlands Systems to Control Urban Runnoff*; Elsevier: London, UK, 2006.
18. USEPA (U.S. Environmental Protection Agency). Menu of BMPs: Stormwater Wetland. Available online: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=74 (accessed on 27 January 2014).
19. Meyer, D.; Molle, P.; Esser, D.; Troesch, S.; Masi F.; Dittmer, U. Constructed wetlands for combined sewer overflow treatment—Comparison of German, French and Italian approaches. *Water* **2013**, *5*, 1–12.
20. Save the Rain. Onondaga County, New York Save the Rain Program 2010–2018 Green Infrastructure Plan. Available online: http://savetherain.us/wp-content/uploads/2011/10/2010-2018-Green-Infrastructure-Plan.pdf (accessed on 27 January 2014).
21. Renew Evansville. Volume 1 Final Integrated Overflow Control Plan. Available online: http://www.evansvillegov.org/modules/showdocument.aspx?documentid=13319 (accessed on 27 January 2014).
22. Harrison, K. Ideas and environmental standard setting: A comparative study of regulation of the pulp and paper industry. *Governance* **2000**, *15*, 65–96.
23. Keleman, R.D. Regulatory Federalism: EU environmental regulation in comparative perspective. *J. Public Policy* **2000**, *20*, 133–167.
24. Knill, C.; Lehmkuhl, D. The national impact of European Union regulatory policy: Three European mechanisms. *Eur. J. Polit. Res.* **2002**, *41*, 255–280.
25. Navrud, S.; Pruckner, G.J. Environmental valuation—To use of not to use? *Environ. Resour. Econ.* **1997**, *10*, 1–26.
26. Pargal, S.; Hettige, H.; Singh, M.; Wheeler, D. Formal and informal; regulation of industrial pollution: Comparative evidence from Indonesia and the Unites States. *World Bank Econ. Rev.* **1997**, *11*, 433–50.
27. Cole, D.K.; Grossman, P.Z. When is command and control efficient? Institutions, technology, and the comparative efficiency of alternative regulatory regimes for environmental protection. Available online: http://www.repository.law.indiana.edu/facpub/590 (accessed on 8 February 2014).
28. Hahn, R.W.; Stavins, R.N. Incentive-based environmental regulation: A new era for an Old idea? *Ecol. Law Q.* **1991**, *18*, 1–42.
29. Hornstein, D.T. Reclaiming environmental Law: A normative critique of comparative risk analysis. *Columbia Law Rev.* **1992**, *92*, 562–633.
30. Hazilla, M.; Kopp, R.J. Social cost of environmental quality regulations: A general equilibrium analysis. *J. Polit. Econ.* **1990**, *98*, 853–873.
31. Karr, J.R. Defining and assessing ecological integrity: Beyond water quality. *Environ. Toxicol. Chem.* **1993**, *12*, 1521–1531.

32. Ringold, P.L.; Boyd, J.; Landers, D.; Weber, M. What data should we collect? A Framework for identifying indicators of ecosystem contributions to human well-being. *Front. Ecol. Environ.* **2013**, doi:10.1890/110156.
33. Jaffe, M.; Zellner, M.; Minor, E.; Gonzalez-Meler, M.; Cather, L.; Minor, D.; Ahmed, H.; Elberts, M.; Sprague, H.; Wise, S.; *et al*. *Using Green Infrastructure to Manage Urban Stormwater Quality: A Review of Selected Practices and State Programs*; Illinois Environmental Protection Agency: Springfield, IL, USA, 2010.
34. USEPA (U.S. Environmental Protection Agency). *NPDES Permit Writers' Manual*; Office of Water: Washington, DC, USA, 2010.
35. USEPA (U.S. Environmental Protection Agency). Memorandum, Achieving Water Quality through Integrated Municipal Stormwater and Wastewater Plans. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/memointegratedmunicipalplans.pdf (accessed on 27 January 2014).
36. USEPA (U.S. Environmental Protection Agency). Memorandum, Protecting Water Quality with Green Infrastructure in EPA Water Permitting and Enforcement Programs. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_memo_protectingwaterquality.pdf (accessed on 27 January 2014).
37. USEPA (U.S. Environmental Protection Agency). Memorandum, Use of Green Infrastructure in NPDES Permits and Enforcement. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_memo_enforce.pdf (accessed on 27 January 2014).
38. USEPA (U.S. Environmental Protection Agency). Memorandum, Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and Other Water Programs. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/greeninfrastructure_h2oprograms_07.pdf (accessed on 27 January 2014).
39. USEPA (U.S. Environmental Protection Agency). Factsheet 1: General Accountability Considerations for Green Infrastructure. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/gi_regulatory.cfm (accessed on 27 January 2014).
40. USEPA (U.S. Environmental Protection Agency). Factsheet 2: Combined Sewer Overflows. Available Online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/EPA-Green-Infrastructure-Factsheet-2-061212-PJ.pdf (accessed on 27 January 2014).
41. USEPA (U.S. Environmental Protection Agency). Factsheet 3: Sanitary Sewer Overflows. Available Online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/EPA-Green-Infrastructure-Factsheet-3-080612.pdf (accessed on 27 January 2014).
42. USEPA (U.S. Environmental Protection Agency). Factsheet 4: Stormwater. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/EPA-Green-Infrastructure-Factsheet-4-061212-PJ.pdf (accessed on 27 January 2014).
43. USEPA (U.S. Environmental Protection Agency). Factsheet 5: Total Maximum Daily Loads. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/EPA-Green-Infrastructure-Factsheet-5-061212-PJ.pdf (accessed on 27 January 2014).
44. USEPA (U.S. Environmental Protection Agency). Factsheet 6: Water Quality Standards. Available online: http://water.epa.gov/infrastructure/greeninfrastructure/upload/EPA-Green-Infrastructure-Factsheet-6-110112-508.pdf (accessed on 27 January 2014).

45. Umble, A.K.; Machlan, M.; Horvath, E.C.; Newvine, L.A. Constructed wetlands for treating combined sewer overflows: An alternative solution for implementing the CSO strategy. In *Proceedings of the Water Environment Federation Watershed 2000 Management Conference, Vancouver, Columbia, July 2000*; Water Environment Federation: Alexandria, VA, USA, 2000; Volume 2000, No. 6, pp. 2571–2588.
46. Machlan, M. City of Elkhart Wastewater Utility, Elkhart, IN, USA. Personal communication, 7 January 2014.
47. Cluxton, P. Indiana Department of Environmental Management, Indianapolis, IN, USA. Personal communication, 9 January 2014.
48. IDEM (Indiana Department of Environmental Management). Final NPDES Permit No. IN0025232, Town of Akron Wastewater Treatment Plant, Fulton County. Available online: http://vfc.idem.in.gov/Pages/Member/View.aspx?DocId=59116233 (accessed on 27 January 2014).
49. Water & Wastes Digest. 2011 Top Water and Wastewater Projects. Available online: http://www.wwdmag.com/sites/default/files/23_RG_TopProjects.pdf (accessed on 27 January 2014).
50. Mosley, E.; Legnetto, P.J.; Pries, J.; Fordiani, R. Constructed Wetlands for CSO Treatment: A Full-scale Pilot in Onondaga County, NY. In Proceedings of the Water Environment Federation Technical Exhibition and Conference, New Orleans, LA, USA, 27 September–1 October 2012.
51. NYSDEC (New York State Department of Environmental Conservation). Long Term Control Plan (LTCP) Requirements. Available online: http://www.dec.ny.gov/chemical/48985.html (accessed on 27 January 2014).
52. IDEM (Indiana Department of Environmental Management). Agency Nonrule Policy Document: CSO Treatment Facilities (Water-016). Available online: http://www.in.gov/idem/files/wpcb_2008_mar_npd-016.pdf (accessed on 27 January 2014).
53. IDEM (Indiana Department of Environmental Management). Final NPDES Permit No. IN0025674, City of Elkhart Wastewater Treatment Plant, Elkhart County. Available online: http://vfc.idem.in.gov/Pages/Member/View.aspx?DocId=65956939 (accessed on 27 January 2014).
54. IDEM (Indiana Department of Environmental Management). Final NPDES Permit No. IN0025658, City of Washington Wastewater Treatment Plant, Daviess County. Available online: http://vfc.idem.in.gov/Pages/Member/View.aspx?DocId=69041904 (accessed on 27 January 2014).
55. IDEM (Indiana Department of Environmental Management). *Inspection Summary/Violation Letter, Akron Municipal Waste Water Treatment Plant, NPDES Permit No. IN0025232*; IDEM: Akron, IN, USA, 31 December 2013.
56. NYSDEC (New York State Department of Environmental Conservation). State Pollution Discharge Elimination System (SPDES) Discharge Permit Number NY 002 7081 (Draft). Received from NYSDEC on 17 January 2014.
57. Save the Rain. Quality Assurance Project Plan: Harbor Brook CSO 018 Constructed Wetlands Pilot Treatment System. Available online: http://savetherain.us/wp-content/uploads/2011/06/Monitoring-Plan.pdf (accessed on 27 January 2014).
58. Stephenson, V. New York State Department of Environmental Conservation (NYSDEC), Syracuse, NY, USA. Personal communication, 6 January 2014.
59. Van Dien, F. ECOFYT, Oirschot, The Netherlands. Personal communication, 1 April 2014.

60. Arias, C. Aarhus University Department of Bioscience, Aarhus, Denmark. Personal communication, 26 March 2014.
61. Rousseau, D. Gent University, Department of Industrial Biological Sciences, Gent, Belgium. Personal communication, 1 April 2014.
62. Hawes, P. ARM Ltd., Staffordshire, UK. Personal communication, 26 March 2014.
63. EC (European Commission). Water Framework Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Off. J. Eur. Community* **2000**, 1–73. Available online: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060 (Accessed on 18 April 2014).
64. DWA Deutsche Vereinigung für. DWA Empfehlungen für Planung, Konstruktion und Betrieb von Retentionsbodenfilteranlagen zur weitergehenden Regenwasserbehandlung im Misch- und Trennverfahren (Design, construction and operation guideline for retention soil filters for enhanced combined sewer overflow treatment); DWA-Regelwerk, Merkblatt M 178: Hennef, Germany, 2005. Available online: http://www.dwa.de/dwa/shop/produkte.nsf/663C11FEBE91CE72C125753C00345630/$file/vorschau_DWA_M_178.PDF (accessed on 18 April 2014). (In Germany)
65. Uhl, M.; Dittmer, U. Constructed wetlands for CSO treatment—An overview of practice and research in Germany. *Water Sci. Technol.* **2005**, *51*, 23–30.
66. Meyer, D.; Dittmer, U. Design supportive modelling of constructed wetlands for combined sewer overflow treatment in Germany. *Ecol. Eng*. **2014**, in press.
67. Wise, S.; Braden, J.; Ghalayini, D.; Grant, J.; Kloss, C.; MacMullan, E.; Morse, S.; Montalto, F.; Nees, D.; Nowak, D.; *et al*. *Integrating Valuation Methods to recognize Green Infrastructure Multiple Benefits*; Center for Neighborhoods and Technology: Chicago, IL, USA, 2010.
68. Spatari, S.; Yu, Z.; Montalto, F. Life cycle implications of urban green infrastructure. *Environ. Pollut.* **2011**, *159*, 2174–2179.
69. Campbell, C.S.; Ogden, M. *Constructed Wetlands in the Sustainable Landscape*; John Wiley & Sons Inc.: New York, NY, USA, 1999.
70. Droguett, R.B. Sustainability Assessment of Green Infrastructure Practices for Infrastructure Practices for Stormwater Management: A Comparative Energy Analysis. Master Thesis, SUNY College of Environmental Science and Forestry, Syracuse, NY, USA, 2011.
71. Geiger, W.F. Combined sewer overflow treatment—Knowledge or speculation. *Water Sci. Technol.* **1998**, *38*, 1–8.
72. Millennium Ecosystem Assessment. *Ecosystems and Human Well-Being: Wetlands & Water Synthesis*; World Resources Institute: Washington, DC, USA, 2005.
73. Smardon, R.C. Human perception of utilization of wetlands for waste assimilation, or how to make a silk purse out of a sow's ear. In *Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural*; Hammer, D.A., Ed.; Lewis Publishers: Chelsea, MI, USA, 1989; pp. 287–295.
74. Mander, Ü.; Tournebize, J.; Kasak, K.; Mitsch, W.J. Climate regulation by free water surface constructed wetlands for wastewater treatment and created riverine wetlands. *Ecol. Eng.* **2013**, doi:http://dx.doi.org/10.1016.

75. Mitsch, W.J.; Bernal, B.; Nahlik, A.M.; Mander, Ü.; Zhang, L.; Anderson, L.; Jørgensen, S.E.; Brix, H. Wetlands, carbon, and climate change. *Landsc. Ecol.* **2013**, *28*, 583–597.
76. Harrison, M. Bernardin, Lochmueller & Associates, Indianapolis, IN, USA. Personal communication, 6 December 2013.
77. Gibson, J.P., Jr.; Bell, S. The Banklick Constructed Wetland. *Water Environ. Technol.* **2013**, *25*, 34–39.