Sustainable Design for Water Pollution Engineering
Part III of a 3-Part Series: Integrating Sustainable Design

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This is Part III of a series on sustainable water pollution engineering that provides a description of specific ways to integrate sustainable stormwater management, wastewater treatment, buildings, and development planning. Part I offered an introduction to sustainable design, and Part II discussed the broader implications of sustainable design policies and practices. Readers can access the complete series at: http://www.sustainabledesign360.net/EWRI_article_series.html

Introduction

Hallmarks of sustainable water pollution engineering include water pollution control systems that minimize material and energy use; water recycling systems that transform "waste" water into a marketable commodity; water management plans that balance water supply needs with aquatic habitat requirements; the use of natural treatment systems that mimic sustainable natural processes; and ultimately being mindful of the impacts of engineered systems upon the global water cycle.

Impacts of engineered systems, particularly the cumulative effects of small localized systems, is now measurable on a global scale. For example, in river systems, engineered channelization, industrial and agricultural activities, hydropower facilities, and land use changes have resulted in tremendous impacts on aquatic and terrestrial ecosystems. Stormwater management systems often pipe water out to sea, where the hydrologic cycle is short-circuited when it bypasses groundwater recharge. On-site wastewater treatment, while providing beneficial local water recharge, can often result in local contaminant loading; and wastewater treatment plants in urban environments frequently discharge significant portions of flow to receiving waters with low baseflow (the amount of flow in a stream during dry conditions).

Cumulative impacts of water pollution engineering strategies are crucial factors in the maintenance of healthy and resilient ecosystems. Without such resilience, natural disasters such as floods and fires will likely become more frequent and damaging. A good example of this is Hurricane Katrina. According to Gregory Stone and Robert Twilley of Louisiana State University, some research indicates that a storm surge in adjacent inland areas is reduced by one foot for every square mile (640 acres) of wetland that is restored. Since more than one million acres of wetlands and barrier islands along the Louisiana coast have been lost since 1930, the storm surge that occurred during Hurricane Katrina theoretically could have been smaller and less devastating if more of these wetlands still existed. Hurricane Katrina and other similar events provide substantial cases for sustainable designs, since such designs can create more resilient ecosystems that can conceivably reduce the impacts of these events. Future water pollution engineering strategies will need to include an assessment of the cumulative effects of a design and balance industrial, commercial, residential, and agricultural operations with ecosystem survival.

Incorporating Sustainable Development into Conventional Designs

Proper design of engineered features can yield more sustainable facilities; the key is to limit the impact to the environment and maintain existing natural features as much as possible. Some areas where incorporating sustainable design can reduce water pollution include:

- Stormwater Management and Flood Control
- Wastewater Treatment
- Water Supply
- Buildings
- Development Planning

The following sections present some of the hallmarks of sustainable engineering practices in each of these areas, and the reader is encouraged to seek more detailed information in some of the resources cited at the end of this article.

Stormwater Management and Flood Control

One of the most wide-spread best management practices (BMPs) for collecting and improving stormwater quality is the wet detention pond. Almost any new development includes a wet detention pond of some size, shape, or form. A wet detention pond is essentially a big hole in the ground where water collects and then either evaporates or "leaks" into the ground. The pond accomplishes stormwater detention, but once the ground is removed and the bottom and the side slopes of the pond are smoothed, very few natural features remain. Most of the original vegetation and microorganisms disappear, and the remaining biota are stressed as they are forced to compete with the development that necessitated the detention pond. New methods are needed for controlling stormwater quantity and improving its quality so that contemporary solutions do not inadvertently reduce ecosystem capacity for future generations.

Some ways to make stormwater management features more sustainable are to:

- Maintain natural wetland features wherever possible
- Construct wetlands to provide a closer substitute to natural treatment processes
- Encourage infiltration, which allows runoff to seep back into the ground and recharge the groundwater (provided this does not contribute to groundwater pollution)
- Incorporate bioretention, which helps to reduce the travel times of stormwater runoff by incorporating natural intercepting features, such as plants and trees
- Use BMPs and natural features to prevent the sedimentation of creeks and waterways

Wastewater Treatment

Most engineered systems are based on natural biochemical processes, and yet the systems being built today are not particularly sustainable. Their footprint, materials, and energy use bear little resemblance to the natural systems that inspired them. Although it would not be feasible or prudent to use a natural wetland for municipal wastewater treatment, there is a move towards more decentralized engineered systems like the "marsh pond meadow" designs that can provide high levels of treatment but better mimic natural systems that require less intensive operation and maintenance.

Water Supply

Because water is a limited resource, our society needs to manage its quantity and quality, preserving existing water sources wherever possible to moderate supply and reduce demand stresses. Some sustainable options for managing the water supply include:

- Use recycled water (with additional treatment) from the wastewater treatment plants for recharging aquifers or substituting reclaimed water for potable water for irrigation.
- Use non-potable water wherever possible, such as for irrigation or for toilets
- Monitor and manage fresh water stream baseflow needs to provide aquatic habitat continuity
- Identify groundwater recharge areas and limit development on or near these areas

Buildings and Site Development

Many building features can incorporate sustainable, low-impact water pollution engineering features. The Green Building Council's Leadership in Energy and Environmental Design (LEED), as well as other certification programs are helping to increase the inclusion of low impact site development practices such as:

- Rain gardens to remove some contaminants, reduce overall impervious surface area, and thereby reduce stormwater runoff volumes
- Porous pavers and related options to reduce impermeable surface area in walkways and parking areas
- Use of materials available locally to reduce energy consumption and pollution from material transport to the site
- Geothermal and solar energy for water heating when they can reduce pollution and consumption of non-renewable energy sources

Development Planning

Sustainable engineering practices include the use of early planning phases and a high level of collaboration with project "stakeholders," or the owners, users, community representatives, and others whom the project will impact. Inclusion of simple steps such as avoiding an existing wetland or natural forest would greatly contribute to the sustainability of a development. Some engineers are hesitant to suggest these practices to an owner or developer for fear of being tagged a "tree-hugger," but it becomes the responsibility of engineers to educate the design team and stakeholders about the links between development and the loss of ecosystem services. Some elements of sustainable development planning include:

- Convene stakeholders at the conceptual stage of a development to ensure that the use of the space is optimized and that energy use and material use are minimized
- Minimize the disturbance of existing natural spaces and preserve open spaces and wetlands (e.g. Smart Growth)
- Cluster residential and shopping areas and provide bike paths and sidewalks between them to reduce car trips and large paved parking expanses

Critical Success Factors for Sustainable Designs

A sustainable design can be outstanding in concept but a failure in its execution if it does not successfully succeed in all of the following critical areas:

- Cost
- Environmental impacts and ecosystem perturbations
- Community acceptance
- Long-term maintenance
- Regulatory approval

Costs

Every business and community is concerned with project costs, so a sustainable design must be comparable to a conventional design in costs and effectiveness to be successful. Engineers must be ready to make the case for long-term cost savings in situations where initial short-term costs of a sustainable project may be higher. Consumers need to be educated to look at the total value of a design, including the value of the parcel, the long-term costs of operation, the public perception and reputation of the owner, and the benefits to the community to minimize pollution mitigation costs, maintain ecosystem services, and maintain public health.

Environmental Implications

Nothing is gained from a sustainable design if it substitutes one environmental problem for another. Therefore, the designer must carefully consider the possible long-term implications of the design. This requires a different vision or ethic around development in general.

Community Acceptance

Sustainable design will not be successful unless the public understands and accepts it. Members of the community must be willing to maintain their property sustainably and must be supportive of the community's or local businesses' attempts to develop sustainably. One of the best ways to stimulate community acceptance is to engage the community in the sustainable development effort. Teaching sustainable development concepts to school children and practicing sustainable design in schools will help facilitate this acceptance, as the next generation will grow up accustomed to sustainable building environments and will be able to bring their knowledge home to practice the concepts with their families.

Long-Term Maintenance

Engineers must consider the long-term maintenance of a facility in their designs. An ideal sustainable design will require little or no maintenance. Although achieving a completely maintenance-free facility is not realistic, engineers should consider the costs, difficulty, and level of effort to maintain facilities to maximize the sustainability of the facility.

Regulatory Approval

As with community acceptance, the regulatory agencies must approve a sustainable design for it to be successful. Regulatory outreach is an essential first step: it is important to make certain the regulatory agencies will support your effort and be a partner for progress rather than an obstacle to approval. In addition, it is helpful if the agency provides incentives for sustainable design.

Summary and Conclusions

Sustainable design is the art of designing with nature rather than against it. It is truly an art because sustainable designs require a delicate balance between designing naturally and designing effectively (the feature still has to work). In addition to being functional and naturally beneficial, sustainable designs must also meet the critical success criteria of cost and client/community acceptance. Only with all of these elements in harmony can sustainable designs provide viable and effective alternatives to conventional design.

Additional resources on sustainable design include:

The Cloud Institute for Sustainability Education
http://www.sustainabilityed.org/

EPA's Guidelines for Water Reuse
http://www.epa.gov/ORD/NRMRL/pubs/625r04108/625r04108.htm

EPA Water Conservation Guidelines
http://www.epa.gov/owm/water-efficiency/wecongid.htm

Green Building Council LEED Certification Program
http://www.usgbc.org/DisplayPage.aspx?CategoryID=19

Green Roofs for Healthy Cities
http://www.greenroofs.org/

HUD Low Impact Development Center
http://www.lowimpactdevelopment.org/sitemap.htm

Miller, C. Vegetated Roof Covers: A New Method for Controlling Runoff in Urbanized Areas. Pennsylvania Stormwater Management Symposium at Villanova University, Villanova, Pennsylvania: October 21-22, 1998. http://www.epa.gov/owow/nps/roofcover.pdf

Prince Georges County, Maryland Programs and Planning Division. Low-Impact Development: An Integrated Design Approach: June 1999.

Southface Energy Institute. Sustainable Design, Construction, and Land Development: Guidelines for the Southeast (Oak Ridge National Laboratory Document ORNL/TM-2000/192). Atlanta, Georgia: August 2000.
http://www.southface.org/web/resources&services/publications/large_pubs/Sustainable_community_development.pdf

United States Environmental Protection Agency's Office of Water. Low Impact Development (LID): A Literature Review (4203) EPA-841-B-00-005. Washington, DC 20460: October 2000.
http://www.epa.gov/owow/nps/lid/lid.pdf

Water Reuse Foundation
http://www.watereuse.org/Foundation/index.html

"Wetland Restoration Seen As Crucial - Delta's marshes, islands form buffers against storm surges, scientists say" San Francisco Chronicle; September 5, 2005. http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2005/09/05/MNG69EIHUK1.DTL

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