CHAPTER 26

Selection and Evaluation of Sites for Constructed Wastewater Treatment Wetlands

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INTRODUCTION

Constructed wetlands are practical alternatives to conventional treatment of domestic and municipal sewage, industrial and agricultural wastes, storm water runoff, and acid mine drainage.[1-4] Siting a constructed wetland is often dictated by the location of the wastewater source, e.g., a public sewage treatment works or an acidic seep at a coal mine. The wastewater source can seldom be relocated; therefore, siting a wetland system is usually limited to the immediate area, which is often a mediocre or poor site. Nevertheless, siting can be optimized through a comprehensive site investigation process, including site selection, temporary and permanent engineered works design, environmental effects analyses, construction evaluation, remedial works design and construction, and operational and safety checks.

Site selection is based on geological, geotechnical, hydrological, and other environmental information that could affect construction, performance, and effects of a wetlands treatment system. Site selection is constrained by the availability of a suitable site and geotechnical merits, e.g., well-developed soils, good access, or low flood potential. This chapter describes ideal site selection considerations and investigative techniques and presents a methodology for selecting and evaluating sites for constructed wetlands.

SITING CONSIDERATIONS

Once a constructed wetland is proposed as an alternative for wastewater treatment, numerous siting considerations must be evaluated to ensure optimum design, construction, and operation of the facility. Depending on the project magnitude, e.g., a 900-m^2 swine waste marsh system vs a 30,000-m^2 municipal sewage treatment wetland, the degree of site evaluation will differ. Ideally, site investigation and selection includes the following:

1. preliminary office fact-finding survey
2. aerial photography interpretation
3. initial field/aerial survey
4. limited subsurface exploration, site soils classification, and collection and evaluation of environmental data
5. detailed subsurface exploration and collection of environmental data, as necessary
6. evaluation of data, potential environmental effects, and regulatory requirements

Unfortunately, due to costs and schedule delays for ideal site evaluations, the site screening process is often limited to identifying a wastewater source and designing a treatment system. At a minimum, the site screening process should (1) clearly define the wastewater management objectives and the regulatory considerations, (2) collect sufficient data to develop preliminary design of a wetland system, (3) investigate the environmental and social conditions and sensitivities to predict any adverse effects and provide mitigation, and (4) obtain legal access to the site.

Site Selection

Site selection considerations can be classified into four categories of equal importance: land use/general considerations, hydrology, geology, and environmental/regulatory considerations. These categories can be evaluated by several methodologies discussed in this chapter.

Land Use and General Considerations

Probably the most important considerations in siting a wetland are land use and access. Foremost, the wastewater to be treated must be accessible to the site. In the case of a municipal sewage treatment wetland, accessibility may be only constrained by the economics of transporting sewage to the site. For an urban runoff or mine drainage wetland treatment system, wastewater access to numerous sites may be limited if more natural, self-sustaining gravity-flow systems are desired. The site must be accessible to construction equipment, operational personnel, and chemical delivery vehicles. If public access cannot be controlled, adequate safeguards must be incorporated into the wetland design to prevent personal injury or vandalism. Also, availability of utilities, e.g., water and electricity, should be evaluated for access rights-of-way and costs.

Land availability is nearly always an issue. Immediate and surrounding landowners must be consulted so the wetland can be protected and operated for its intended life span and long-term access can be ensured. Some states may require surface control of the site by an operator prior to wetland construction. Generally, surface rights should be obtained through fee purchases, land trades, or long-term leases and easements. If land control and resulting legal costs are extensive, another site may have to be selected. Required land area is

dictated by the desired wetland size, flow control structures, associated buildings or equipment storage areas, access roads and utility rights-of-way, construction material borrow areas, buffer zones, and potentially a chlorine contact basin, a flow equalization basin, or a final polishing/chemical treatment cell.

Use and values of the site and adjacent land should be evaluated with respect to public opposition to potential odors, mosquitoes, lowered property and business values, water quality degradation, aesthetic impacts, or other environmental impacts. Public involvement techniques employed to improve acceptance include local workshops, public hearings and meetings, newsletters, site visits, mass media, surveys, and personal meetings.[5] Prior to wetlands proposals and site selection, target audiences should be identified, including area residents and elected officials, media representatives, environmental and public interest groups, community and industry leaders and local service organizations, and appropriate local employees.

Site history, interpreted from sequential aerial photography,[6] maps, local interviews, and other sources of information, can often give clues to siting criteria for a wetland. Clues might include drainage modifications; historic flooding and potential for erosion/sedimentation; patterns and trends of land use; cultural resources; buried, abandoned, or reclaimed facilities such as coal mines, landfills, waste disposal sites, or road beds; and property ownership (old fence lines, cultivation, etc.).

Hydrology

Hydrologic considerations include characterizing surface and groundwater flow patterns, use, quantity, and chemistry. Hydrology, if neglected or insufficiently characterized during the siting process, can significantly impair the operation and effects of a treatment wetland.

Drainage basin characteristics for candidate sites should be evaluated. Unless the wetland is to receive only a regulated quantity of wastewater and direct precipitation, such as a lined municipal sewage treatment wetland, surface runoff can profoundly affect the constructed wetland. Flooding and scouring potential and the need for levees can be evaluated from flood hazard maps, USGS topographic maps, aerial photography interpretation, and site surveys. Minimum, maximum, and average seasonal water levels influencing the wetland hydroperiod should be determined from site data or various methodologies.[7] Wetlands should be sited away from major streams or springs because of potential flooding, scouring, sedimentation, erosion, high groundwater tables, saturated ground, and variable water quantity and quality.

The wastewater and receiving surface water bodies should be chemically characterized and evaluated for existing and potential downstream use. Downstream users should be identified, and sites that would adversely affect downstream users should be avoided unless adequate mitigation can be arranged.

Following is a list of recommended minimum water quality analyses that should be performed for baseline and wastewater characterization.

- *Acid mine or ash disposal drainage*—pH, TSS, DO, Fe, Mn, SO_4
- *Municipal and domestic sewage*—pH, TSS, DO, BOD_5, NH_3-N, NO_2 + NO_3-N, TKN, orthophosphate, alkalinity, fecal coliform
- *Urban storm water*—pH, TSS, DO, BOD_5, NH_3-N, NO_2 + NO_3-N, fecal coliforms, oil and grease, TDS, TOC, total phosphate, Pb, Fe, chlorides
- *Landfill leachate*—pH, TSS, DO, BOD_5, TKN, TDS, total phosphate, Fe, Mn, Zn, VSS, COD, heavy metals, PCBs
- *Pulp and paper mill waste*—pH, TSS, DO, TDS, Fe, Mn, TOC, chlorides, alkalinity, hardness, color, turbidity, SiO_2, free CO_2, Cl, Hg, heavy metals
- *Agricultural wastes*—pH, TSS, DO, TDS, NH_3-N, COD, BOD_5, VSS, alkalinity, fecal coliform, NO_2 + NO_3-N

In addition to these parameters, a survey of aquatic invertebrates can document stream recovery, stability, or degradation.[8] For National Pollutant Discharge Elimination System permitting, flow and relevant priority pollutants may also be required.

Any additional minor seepage or drainage that might enter the main waste stream should also be characterized. Construction operations and water ponding may alter the site hydrology and induce additional seepage downstream of the constructed wetland. Some wetland construction, e.g., acid mine drainage system substrates and dikes, if constructed of inferior material, may allow infiltration or flow-through seepage. Therefore, siting should include evaluating the sensitivity of the hydrologic environment to alterations. Sufficient area should be included to locate the permitted monitoring point downstream of the final wetland cell.

Groundwater hydrology characterization should include general flow patterns, depth, quality, high or perched water tables, existing and potential use, and nearby wells. Depending on the wastewater type, wetlands might successfully be located in either groundwater recharge or discharge areas. Sites overlying karst geology, perched water tables, arid streambeds, fissured igneous or metamorphic rock, or known groundwater recharge areas should be avoided if the wastewater has potential for recharging groundwater with deleterious contaminants. Hydrologic siting constraints for wetlands may be eased or overcome using low-permeability or impermeable liners or adequate compaction techniques in certain soils. Some wetlands systems or regulatory requirements mandate lined cells to preclude groundwater contamination. Ideally, a constructed wetland should be sited in a groundwater discharge area to minimize groundwater pollution potential. Additional advantages include base level recharge of the wetland during periods of low or no wastewater flow and dilution water to minimize ecologic stress on wetland biota or to enhance chemical, biological, and biochemical treatment mechanisms (Figure 1).

Existing and potential use of groundwater at candidate sites should be evalu-

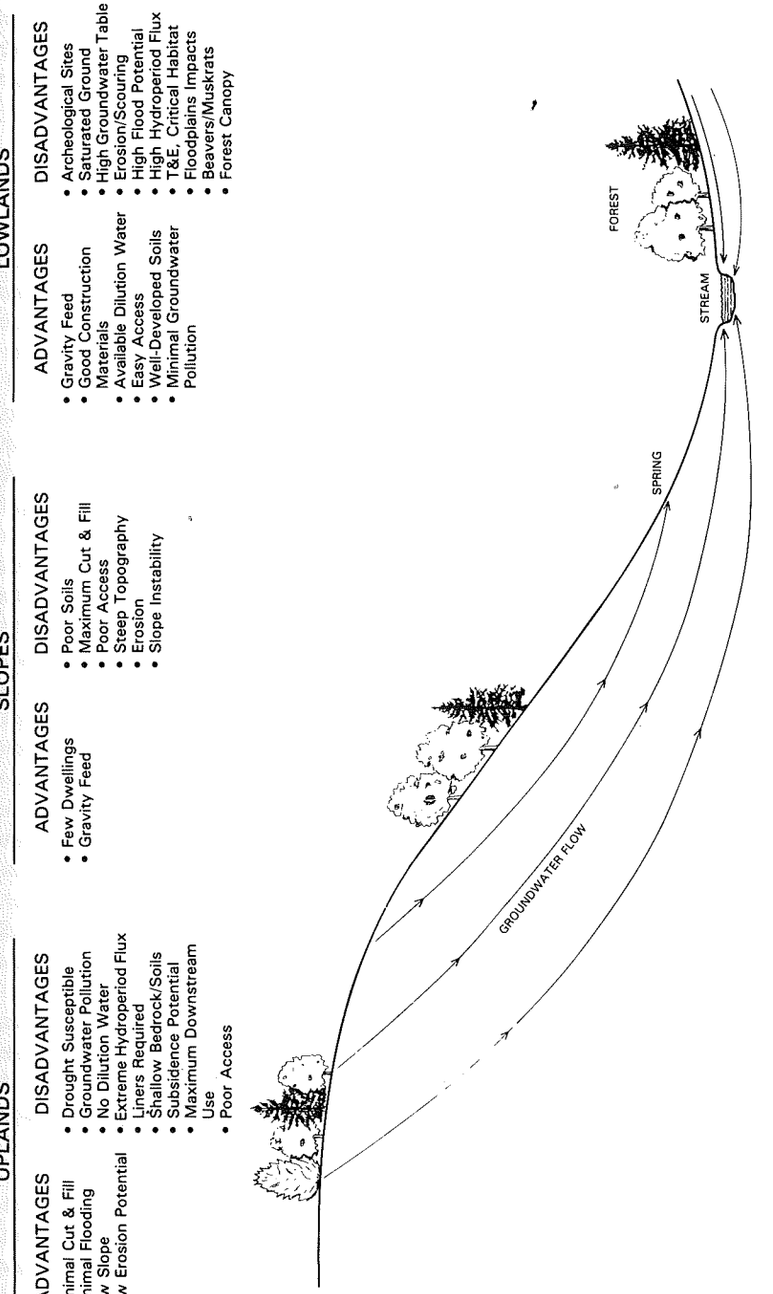

Figure 1. Advantages and disadvantages of siting constructed wastewater treatment wetlands on uplands, slopes, and lowlands.

ated. Nearby potentially affected springs and water wells should be sampled and analyzed to completely characterize baseline water quality (see p. 310). Sites that could adversely affect users should be avoided unless adequate mitigation can be ensured.

Geology

Geologic considerations include characterizing surface materials and soils, bedrock depth, topography, available construction materials, and other geological and geotechnical aspects that could affect wetlands construction and performance. Neglecting geologic considerations in the siting phase could result in increased construction and maintenance costs and/or poor performance of the wetland.

Soils and surface materials should be characterized at candidate sites for thickness and depth, classification and composition, use as construction materials, drainage characteristics, erosion potential, and variability. Investigations should include available information, e.g., soil surveys, geologic and topographic maps, aerial photography, and site investigations such as augering, test pits, percolation tests, and soils and geologic mapping.[9] Thin, poorly developed soils make poor wetland substrates, and importing of adequate substrate materials could be required. Soil composition could have important effects on wetlands performance. For example, soils with greater extractable aluminum have greater potential for phosphorus removal than do organic soils, making them better suited for a sewage treatment wetland; highly organic soils might be better suited for an acid drainage treatment wetland to enhance sulfate reduction and ionic adsorption; and soils with higher microbial activity have greater potential for nitrogen transformation.[10] Site soils and rock should be evaluated for their use as construction materials for earthdams and cores (low plasticity clay-silt loam), spillways (nonerodible soils and rock), riprap and aggregate, embankments, filters (well-graded aggregate), and pond liners (clay, silt). Such evaluations might include volume estimates, soil and rock sample analyses, permeability and compaction tests, gradation analysis, and erodibility.

Bedrock depth often eliminates a site from consideration for constructed wetlands. Shallow bedrock sites require either blasting or ripping and disposal of large quantities of rock or importing large amounts of soil. Bedrock depth should be investigated at the wetland site and at potential construction material borrow areas using existing maps and aerial photography, field surveys, or hand augers and test pits.

Topography affects cut and fill requirements, drainage and erosion potential, access, and slope stability. Ideally, sites should be flat to gently sloping, but such sites are rare. Steep slopes require maximum earth-moving activities but are amenable to terraced wetlands if a level site is not available.

In mined areas or in areas of karst geology, land subsidence or sinkholes may influence wetland siting. Soil surveys, geologic and geologic hazards

maps, and aerial photography should be evaluated for potential land subsidence, mine shafts, sinkholes, faults, or other features that could affect engineered works or cause groundwater contamination from a constructed wetland.

Aerial photography interpretation[6] can often identify site lineations (e.g., buried pipelines, trenches, roads, archeological features, abandoned roadways, joint patterns, or channels) that might affect the design and construction of a treatment wetland.

Environmental and Regulatory Considerations

Environmental and regulatory considerations vary from state to state for various wastewaters to be treated and for the entity proposing to construct a wetland treatment system (e.g., private or federal). Nevertheless, general concerns should be evaluated prior to siting a wetland to minimize delays or cessations due to unanticipated environmental issues. Federal laws that should be considered in the siting phase are:

Clean Air Act
Clean Water Act
Endangered Species Act
Executive Order 11988—Floodplain Management
Executive Order 11990—Protection of Wetlands
Fish and Wildlife Coordination Act
National Environmental Policy Act
National Historic Preservation Act
Surface Mining Control and Reclamation Act

Local, regional, and state laws and requirements should be reviewed for application to siting or constructing a wetland.

Archeological and cultural resources of potential wetland sites should be generally evaluated.[11,12] Existing state and federal laws and regulations are becoming stronger, and some states require detailed surveys prior to any construction even if federal funding is not involved. For example, in Tennessee and other states, a human burial must not be disturbed until a professional archeologist has reviewed the site. Drainages are often suitable or necessary for wetlands construction sites but are also areas of potential past human habitation and burial. The prudent engineer should contact the state historic preservation officer to identify the potential for cultural sites in the area and local attitudes toward significant sites.

Critical habitat and the potential or existence of threatened or endangered species or other important wildlife should be investigated with respect to impacts on wildlife from the wetland and vice-versa. Drainages or existing wetlands at potential construction sites often harbor important species, and reviews should include contacting the appropriate U.S. Fish and Wildlife Service office or performing limited surveys. The presence of certain species, such

as beavers, muskrats, and geese, may inhibit constructed wetland performance, and possible control of these species should be considered.

Low, poorly drained areas may have desirable site attributes but could entail Section 404 (dredge and fill) permitting. Early coordination with the U.S. Corp of Engineers is recommended.

Site Investigation

Generally, site selection for constructed wetlands does not entail detailed environmental resources data collection. To improve the quality of site selection and evaluation, the following should be considered:

1. Use available information from USGS topographic and geologic quadrangle maps; aerial photography; county and regional maps; aeronautical charts; previous or current permitting data; soil surveys; water, oil, or gas well drilling records; stream water surveys; hydrologic surveys; and interviews with knowledgeable people.
2. Use aerial photography at the earliest stage of the siting process. High- and low-altitude color and black-and-white, infrared, and oblique photos are perhaps the most valuable data available for initial site screening.
3. Site evaluations and field work should be directed by experienced engineers conversant with project goals and technology.
4. Site selection, investigation, and project design and construction should all incorporate flexibility, e.g., alternative sites or additional available area, to compensate for site conditions as necessary.

Site selection and evaluation should be tailored to the degree of complexity and magnitude of the project. Limited site evaluation followed by a design based on an excessive safety factor is generally wasteful and imprudent. Conversely, conducting a detailed site investigation can be very costly and is unnecessary for siting a small wetland.

A modification to Peck's observational method[13] for geotechnical investigations is appropriate to site selection and evaluation for constructed wetlands in many cases:

1. Conduct sufficient investigation and site exploration to establish the general nature, pattern, and properties of site conditions.
2. Assess the most probable conditions and most unfavorable conceivable deviations from observations based on geological, hydrological, and environmental knowledge and experience.
3. Select the site and design the wetland based on the most probable conditions expected.
4. Modify the design before, during, and after construction to suit actual site conditions.

Regardless of methodology employed in site selection, a "walkover" survey is necessary for assessment of candidate sites. This survey should include site inspection and local inquiries. The site visit should investigate any observa-

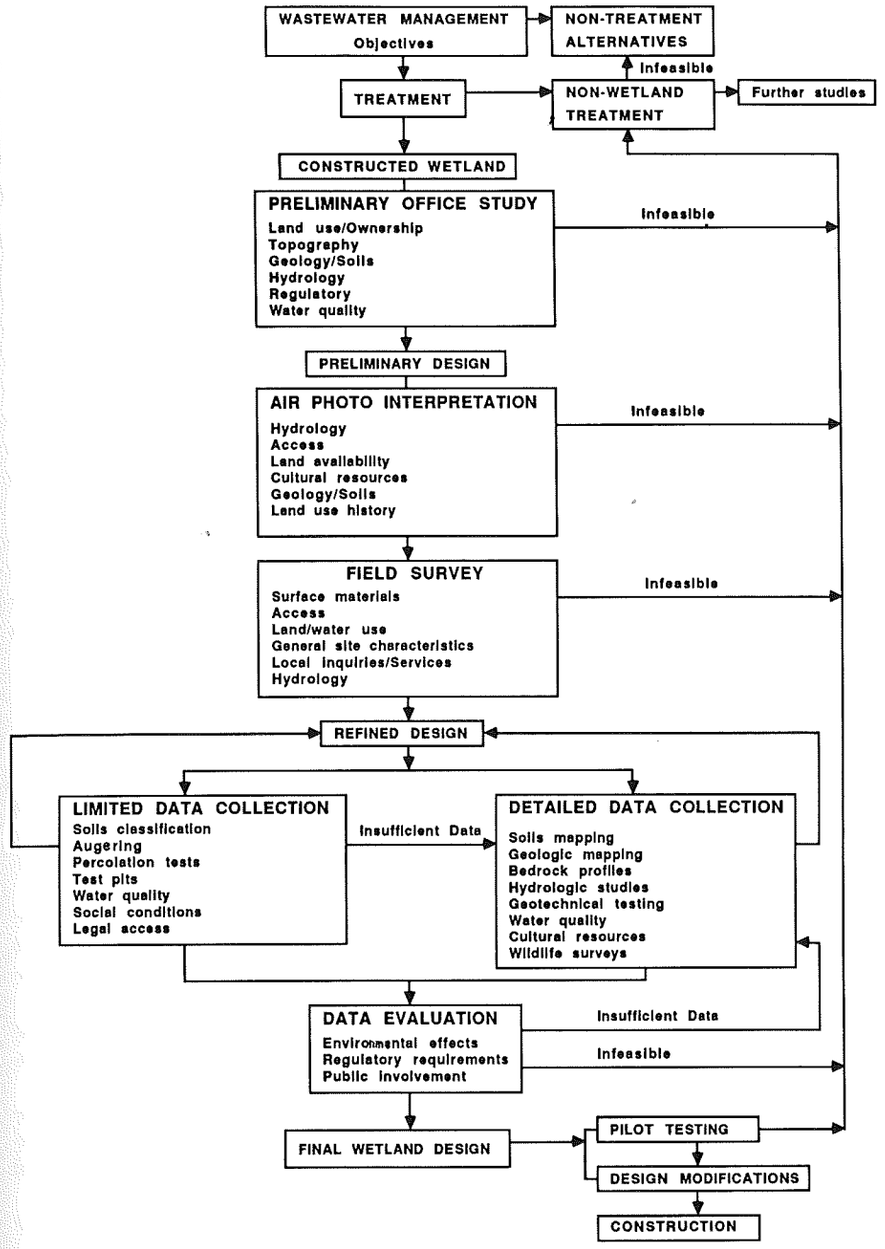

Figure 2. A generalized methodology for screening sites for constructed wetlands.

tions made from initial surveys, e.g., maps and aerial photography interpretation, presence of cultural resources, etc. Topography, surface materials, rock exposures, groundwater conditions, erosion, and access should all be confirmed. Local inquiries might include local builders and contractors, surveyors, utilities, archives and libraries, local inhabitants, clubs, societies, schools, colleges, universities, and government authorities.

SUMMARY

Proper selection and evaluation of sites for constructed wetlands for wastewater treatment are essential to optimal design, construction, and long-term operation. Site selection must include evaluation of land use, hydrology, geology, and environmental, regulatory, geotechnical, and general characteristics of candidate sites. The degree of data collection and evaluation necessary for site selection will vary with size of wetland, type of wastewater, location, and other factors.

Figure 2 illustrates a generalized methodology for site selection and evaluation to accompany detailed site-specific studies and investigations using techniques and considerations discussed herein. The methodologies and discussions are neither complete nor applicable to all cases but summarize a systematic process for screening sites for wetland construction.

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