Massachusetts
Inland Wetland Replacement Guidelines

Second Edition, September 2022

Massachusetts Department of Environmental Protection

Bureau of Water Resources

Wetlands Program

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Acknowledgements

This project was funded by the Environmental Protection Agency (EPA) through a 2015/16 Wetland Program Development Grant. We thank them for their continued support of the Massachusetts Wetlands Program.

MassDEP acknowledges the contributions of its staff in the preparation of this handbook, especially:

Christina Wu,
David Cameron,
Rachel Freed,
Daniel F. Gilmore,
Tom Gruszkos,
Andrew Poyant,
Jill Provencal,
Brian Harrington,
Judith Schmitz, and
Maissoun Reda.

MassDEP also acknowledges the contributions of the Massachusetts Association of Conservation Commissions and the Association of Massachusetts Wetland Scientists.

Individual contributors include

Dorothy McGlincy,
Amy Ball,
Stacy Minihane, and
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MassDEP would like to acknowledge contributors from the previous edition of the Handbook including

Dr. Stephen Brown,
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E. Heidi Ricci,
Sally A. Zielinski, Ph.D.,
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Lois Bruinooge,
Gillian Davies,
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Suggested Citation: Jackson, S. D., L. Rhodes, D. Hilgeman, T. Maguire, and M. McHugh. 2022. Massachusetts Inland Wetland Replacement Guidelines, Second Edition, Massachusetts Department of Environmental Protection, Bureau of Water Resources, Wetlands Program, ## pp

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1.0 | Introduction and Background

1.1 | The Need for Guidance

Two studies conducted by the University of Massachusetts, one published in 1998[1] and the other produced in 2018[2], found that the majority of wetland replacement projects undertaken in the Commonwealth of Massachusetts (Commonwealth) do not meet minimum performance standards in the Massachusetts Wetlands Protection Act (WPA) regulations (Regulations). According to the studies, the most common reasons why proposed mitigation failed to meet performance standards were 1) a replacement wetland was never built, 2) the replacement area lacked wetland hydrology, and 3) replacement wetlands were smaller than what was required by the Issuing Authority, either a conservation commission or the Massachusetts Department of Environmental Protection (MassDEP).

The Massachusetts Inland Wetland Replacement Guidelines (Guidelines) responds to the evidence of mitigation failures by confirming the importance of avoiding and minimizing impacts to wetlands and reducing reliance on wetland replacement. Further, these Guidelines seek to improve the effectiveness of wetland mitigation by providing applicants with an outline of recommended steps necessary to design and construct an appropriate wetland replacement project. The Guidelines also provide information to assist conservation commissions and MassDEP staff in determining whether replacement projects are appropriately designed, constructed as designed, and adequately monitored to ensure mitigation is successfully achieved.

In the Regulations, the term "issuing authority" refers to conservation commissions and/or MassDEP because both have a role in reviewing Notices of Intent and issuing Orders of Conditions (in the case of MassDEP, Superseding Orders of Condition in response to appeals). Throughout this document, we use the term "issuing authority" to mean a conservation commission, MassDEP or both.

Although this document represents current knowledge of wetland replacement science, MasDEP contemplates that the science of wetland replacement will continue to advance and our ability to construct replacement wetlands will improve. As such, the application of this guidance document should allow for future advances that improve the long-term success of wetland replacement projects.

1.2 | Regulatory Requirements

This guidance document provides information about freshwater wetland mitigation in Massachusetts. Wetland replacement, provided as compensation for permitted wetland impacts, is the term used to describe the creation of a wetland site where none previously existed. Wetland replacement typically involves excavation of upland soils to a depth where the naturally occurring water table can support wetland vegetation. This document was written to help applicants prepare freshwater wetland mitigation plans to meet the requirements of the WPA Regulations for Bordering Vegetated Wetlands (BVWs; 310 CMR 10.55 (4)) and Section 401 of the Clean Water Act pertaining to Water Quality Certification (314 CMR 9.06(2)). This document was also written to help conservation commissions and MassDEP ensure that the interests of the WPA are protected when BVW impacts are proposed.

The Regulations state in 310 CMR 10.55(4)(a) that proposed work in BVW shall not destroy or otherwise impair any portion of the resource area. However, 310 CMR 10.55(4)(b) allows for the loss of up to 5,000 square feet of BVW if the wetland is replaced according to certain general conditions and any additional, specific conditions the Issuing Authority deems necessary. Larger BVW impacts may be permitted for specified Limited Projects, pursuant to 310 CMR 10.53(3). In addition to specific performance standards, the Regulations give Issuing Authorities broad authority to ensure that a wetland replacement project replicates the lost functions of the impacted BVW. Section 310 CMR 10.55 (4)(b) of the WPA Regulations states, in part, that the **Order of Conditions may include "any additional, specific conditions the issuing authority deems necessary to ensure that the replacement area will function in a manner similar to the area that will be impacted.**" Examples of additional requirements that Issuing Authorities may impose include vegetation goals, specific approaches to planting or soil translocation, compensatory flood storage, and completion of the replacement site before beginning any work that will affect BVW.

[1]Brown, S., and P. Veneman. 1998. Compensatory Wetland Mitigation in Massachusetts. Massachusetts Agricultural Experiment Station, University of Massachusetts, Amherst. Research Bulletin 746.

[2]Jackson, S., L. Rhodes, and M. McHugh. 2018. Wetland Replacement in Massachusetts. Center for Agriculture, Food, and the Environment, University of Massachusetts, Amherst MA. 67 pp. plus appendices.

The general conditions governing the replacement of BVW set forth in 310 CMR 10.55(4)(b) can be summarized as follows:

- Surface area must be equal to the impacted area;
- The replacement area must have similar groundwater and surface elevation as the impacted area;
- The replacement area must have a similar location relative to the bank as the impacted area;
- The replacement area shall have an unrestricted hydraulic connection to the same water body or waterway as the impacted area;
- The location of the replacement area must be in the same general area as the impacted wetland;
- The replacement area must have at least 75% cover of native wetland plants within two growing seasons, and there must be temporary stabilization of exposed soil to avoid erosion; and
- The replacement area must be provided in a manner which is consistent with all other General Performance Standards for each resource area affected

Wetland mitigation can include the restoration of wetlands. When wetland restoration is proposed as part of BVW mitigation, proposed mitigation sites should only include former wetlands that have been so completely altered that they would now represent non-wetland areas. Enhancement of existing but degraded wetlands, while valuable, does not meet the performance standards for replacement. Because storm water management facilities require periodic maintenance, they should not be considered as a form of BVW mitigation. The complete text of the performance standards in the Regulations should be reviewed when assessing the adequacy of a mitigation plan.

1.3 | Sequencing (Avoidance, Minimization, Mitigation)

The two UMASS studies documented a high failure rate for wetland replacement projects in Massachusetts. These Guidelines are intended to reduce that failure rate by outlining standards for design, construction, and oversight of replacement projects. Although more careful design and management of replacement projects can improve replacement success, the UMASS studies and other reports[3] establish that wetland replacement is, at best, an uncertain science. Based on this compelling evidence, **MassDEP is wary of placing too much reliance on replacement, even under improved standards, to achieve the goals of the WPA or the no net loss of wetlands policy of the Water Resources Commission (April 9, 1990)**. These goals can best be achieved by avoiding and minimizing impacts to wetlands, thereby reducing the need for replacement projects of uncertain success.

Wetland mitigation is a three-step process often referred to as “sequencing.”

1. Avoidance of wetland impacts
2. Minimizing unavoidable impacts as much as possible
3. Replacing losses that cannot be avoided

The importance of avoiding and minimizing wetland impacts is expressly recognized in the Regulations at 310 CMR 10.53 governing Limited Projects. Furthermore, the BVW Performance Standards in 310 CMR 10.55(4)(b) state, “In the exercise of [discretion to allow wetland replacement to mitigate impacts to BVW], the issuing authority shall consider the magnitude of the alteration and the significance of the project site to the interests identified in M.G.L. c. 131, Section 40, the extent to which adverse impacts can be avoided, the extent to which adverse impacts can be minimized, and the extent to which mitigation measures, including replication or restoration, are provided to contribute to the protection of the interests identified in M.G.L. c. 131, Section 40.

The Regulations allow the Issuing Authority to consider, on a case-by-case basis, the relevance and propriety of “sequencing” for projects that propose to alter less than 5,000 square feet of BVW under 310 CMR 10.55 (4) (b). While this regulation does not specify the factors to be considered in determining whether to allow replacement, an Issuing Authority shall take into account the particular facts and circumstances of each case and how the proposed activity will affect the eight interests of the WPA. Even if the proposed wetland replacement area would meet all of the general conditions in 310 CMR 10.55(4)(b), an Issuing Authority should exercise its discretion under 310 CMR 10.55(4)(b) to deny the proposed BVW alteration if practicable avoidance and minimization measures are available but have not been taken.

The Issuing Authority should consider alterations in the project design that would avoid and/or minimize wetland impacts before evaluating a wetland mitigation plan. The

[3]See, National Academy of Sciences: Committee on Mitigating Wetland Losses. 2001 Compensating for Wetland Losses Under the Clean Water Act. National Academy Press, Washington, D.C.

first step, **avoidance**, involves consideration of alternative project designs that locate projects away from wetlands in order to avoid impacts. If wetlands cannot be avoided, an applicant should consider measures to **minimize** unavoidable impacts. Approaches that can help avoid or minimize wetland impacts include the following:

- Seek a waiver or variance on zoning requirements, such as setbacks and parking capacity, to allow greater flexibility in siting the project away from wetlands.
- Reduce or reconfigure subdivision lots to avoid wetland impacts.
- To reduce the footprint size of a house or commercial structure, consider building up instead of out; design the garage to be the first story of the house/structure instead of as a separate structure.
- Consider an easement from a neighbor to share a driveway or provide alternative access that avoids or minimizes wetland impacts.
- Design driveways and subdivision roads to be as narrow as possible in BVW or buffer zone; consider seeking a variance from roadway design regulations to allow for narrower roads/driveways in these sensitive areas.
- Carefully plan subdivision roads to avoid or reduce the number of wetland or stream crossings to one per project; where possible, cross wetlands at their narrowest point.
- Use retaining walls to avoid or minimize fill in BVW; this can be particularly helpful for wetland or stream crossings, but should be considered only when such use would not result in adverse impacts to other protected interests such as wildlife habitat.

Replacement of wetlands should only be considered for unavoidable losses that cannot practicably be reduced by redesign of the project. Once unavoidable impacts have been identified and impacts have been minimized to the maximum extent possible, then wetland mitigation locations should be carefully considered to determine the replacement location with the best likelihood of success. **Replacement projects should not simply create wetlands equal in size to those impacted, they should be designed to replicate the wetland functions (eight interests of the Act) previously provided by the impacted wetland.**

To the extent possible, Issuing Authorities should be involved prior to finalizing the mitigation design and submitting the Notice of Intent. Issuing Authorities are encouraged to convene a pre-application meeting with the project proponent whenever BVW impacts are proposed, to discuss options for avoiding and minimizing those impacts.

Figure 1 Example of a wetland replacement area in progress

2.0 | Wetland Mitigation Plan Guidelines

2.1 | Evaluation of Existing Conditions and Functions

The Regulations presume that BVWs serve the following public interests identified in the WPA: public or private water supply, groundwater supply, flood control, storm damage prevention, prevention of pollution, protection of fisheries (land containing shellfish pertains to coastal wetlands only), and wildlife habitat. These public interests describe the range of wetland functions that must be considered when designing mitigation for the loss of impacted wetlands. Applicants should design replacement areas that closely resemble impacted wetlands; however, good replacement projects may be difficult to achieve, and the resulting wetlands may have characteristics quite dissimilar from the impacted site. Therefore, replacement efforts should focus on design characteristics and strive to maximize the functions being lost due to BVW impacts. Where impacted wetlands are not available (e.g., lost as part of a wetland violation) or inappropriate (e.g., degraded), another wetland (reference wetland) may be used instead as a model for wetland replacement. In all cases, replacement plans should describe the wetland characteristics, structural features, and functions that will be replicated. Plans should clearly indicate the goal of replacement in a measurable way (i.e., success standards for hydrology, vegetation, and soils) so that the success or failure can be determined objectively and enforced.

Wetlands form as a result of the dynamic interactions of a large number of ecological conditions and understanding these conditions at both the impacted/reference wetland and the replacement site is necessary to develop a plan for replicating ecological functions. For the existing/impacted/reference wetland, general wetland characteristics should be described, including:

- Cowardin[4] classification or MassDEP[5] wetland type
- Percent plant cover for each vegetative stratum present
- Dominant plants in each vegetative stratum
- Soil horizonation, texture, color and other characteristics (e.g. presence and type of organic soils)
- Hydrology, including the Novitski[6] wetland classification system for landscape position and water source
- Microtopography

In addition to a general description of the impacted/reference wetland, applicants should also describe the capacity of the wetland to provide functions protected by the WPA (Interests of the Act). It is not practical to measure wetland function in order to ensure that a replacement wetland functions in a way similar to the impacted wetland. **The most effective way to document wetland function is to identify and describe wetland characteristics that are associated with the various wetland functions. Table 1 describes the protected functions performed by wetlands within the Commonwealth, the characteristics of wetlands that contribute to those functions, and design features to consider in designing replacement.**

Table 1 | **Wetland Characteristics that Contribute to Protected Wetland Functions** (Interests of the WPA)

Public Interests	General Description of Wetland Function	Design Features to Replace Function
Public and private water supply, groundwater supply	Movement of surface water (usually downward and laterally) from the wetland into the groundwater (recharge). Movement of groundwater (laterally or upward) through the wetland into surface water (e.g., springs, ponds, streams etc.). The capacity to remove pollutants from water (see Prevention of Pollution below)	Wetland characteristics that contribute to protection of public and private water supply, including groundwater supply: • Adequate surface water source with sufficient residence time to allow for some infiltration • High bank/edge to volume ratio permitting increased opportunities for "bank storage" (lateral movement into more permeable soils during high water periods)

[4]Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. Washington, DC.

[5]For more information on MassDEP wetland types, consult the MassDEP Online Map Viewer: Wetland and Wetland Change Area Map. http://maps.massgis.state.ma.us/images/dep/omv/wetviewer.htm

[6]Novitski, Richard P. 1982. Hydrology of Wisconsin Wetlands. Wisconsin Geological and Natural History Survey. Informational Circular 40. University of Wisconsin – Madison. https://wgnhs.wisc.edu/pubshare/IC40.pdf

Table 1 | **Wetland Characteristics that Contribute to Protected Wetland Functions** (Interests of the WPA)

Public Interests	General Description of Wetland Function	Design Features to Replace Function
		• Wetland elevation and topography that permits groundwater/surface water exchange • Position over sand and gravel deposits, also known as stratified drift, likely to be associated with significant groundwater supplies
Flood Control and Storm Damage Prevention	Wetlands store floodwater and either retain that water until it infiltrates or evaporates, or gradually release it after flood peaks have passed Wetlands reduce water velocity and stagger flood peaks from tributaries so that they don't all arrive downstream at the same time Wetlands also decrease erosive energy of waves or flowing water and anchor banks and shorelines.	Characteristics that contribute to flood control and storm damage prevention include: • Capacity to received runoff or flood waters • Flood ratio: the ratio of water volume stored during high water periods to the volume of water contained in the wetland at other times • Presence of a constricted outlet; water flow through the entire wetland should not be less constricted than it was prior to the wetland replacement • Degree to which water moves through the wetland as sheet versus channelized flow • Meandering as opposed to straight channels through the wetland • Roughness: dense vegetation (especially woody vegetation), microtopography, leaf litter, woody debris, rocks and boulders that slow water velocity via drag/friction • Dense vegetation adjacent to open water that experiences high velocities and/or waves
Prevention of pollution	Processes by which suspended particles, dissolved constituents and chemical contaminants (such as pesticides and heavy metals that may be attached to organic material or soil particles) are removed from water and retained or chemically transformed within a wetland. Storage of nutrients within the sediment or plants; the transformation of inorganic nutrients to organic forms; and the transformation and subsequent removal of nitrogen as a gas. Sequestration and storage of carbon in the form of peat, muck or organic matter incorporated into wetland soils.	Characteristics of wetlands that contribution to pollution prevention include: • Capacity to receive runoff or flood waters • Capacity to retain water until it infiltrates or evaporates • Flood ratio: the ratio of water volume stored during high water periods to the volume of water contained in the wetland at other times • Presence of a constricted outlet • Degree to which water moves through the wetland as sheet versus channelized flow • Dense vegetation that physically traps sediments, and takes up, stores and transforms nutrients (including carbon) and other contaminants • Soils high in organic matter contribute to contaminant adsorption • Soils of appropriate density (not artificially compacted) • Natural microbial communities in the soil • Duration of shallow water inundation that creates an aerobic/anaerobic soil interface

Table 1 | **Wetland Characteristics that Contribute to Protected Wetland Functions** (Interests of the WPA)

Public Interests	General Description of Wetland Function	Design Features to Replace Function
Fisheries	Providing spawning and nursery habitat for fish Providing support for the aquatic food chain through the provision of particulate organic matter (POM) from the wetland to downstream or adjacent deeper waters Providing shade that maintains thermal conditions appropriate for fish Contributing woody debris that creates habitat structure in adjacent water bodies and waterways Maintaining natural hydrology in water bodies and waterways Maintaining water quality (see Prevention of Pollution above)	Wetland characteristics that support fisheries include: • Accessibility from areas of permanent water • Pools at low water • Presence of springs • Natural as opposed to straightened channels • Natural fluctuations in water levels • Shade • Habitat structure • Primary and secondary productivity and export of particulate organic material (POM)
Wildlife habitat	Providing food, shelter, breeding habitat, overwintering areas, and migratory routes for a variety of wildlife. Maintaining natural hydrology in down-gradient water bodies and waterways Maintaining water quality (see Prevention of Pollution above)	Wetland characteristics associated with abundance and diversity of wildlife include: • Diversity of wetland classes • Favorable interspersion of vegetation and open water • Horizontal and vertical plant diversity • Association with upland habitats and features • Scarcity: uncommon habitat types • Specific habitat features[7]

2.2 | Replacement Site Selection

The success of a wetland replacement area is dependent on the existence of an appropriate site as determined by the evaluation of site characteristics and other pertinent data. Replacement areas can be proposed in upland areas that can be converted to wetland. Alternatively, they can be proposed in previously (legally) filled or drained wetland areas. Good replacement sites may include degraded landscapes, such as mined out gravel pits, where creating a wetland will greatly increase resource value beyond what exists now. Whenever possible, replacement sites should not be located in high-quality upland areas such as mature forests.

Information about potential wetland replacement sites should be collected, including land ownership, land use (current and historical), access (ability to construct a proposed site without impacts to other resource areas), topography, geology, hydrology, soils, proximity to other wetlands, water bodies or waterways, ability to take advantage of existing over-story trees (for shading), and regulatory requirements. Design goals should be based on wetland functions provided by the impacted wetland, as well as opportunities and limitations at the mitigation site. To replace wetland functions and meet the performance standards in 310 CMR 10.55(4)(b), replacement areas should be comparable to that of the wetland to be impacted. For Limited Projects, Issuing Authorities shall consider the extent to which mitigation measures, including replacement, are provided (310 CMR 10.53(3)).

Wetland Replacement in Massachusetts (Jackson et al, 2018)

[7]For more information about habitat features of importance to wetland wildlife, see Massachusetts Wildlife Habitat Protection Guidance for Inland Wetlands (MassDEP, March 2006).

identified common failures in replacement site selection and planning. Many unsuccessful replacement sites can be attributed to inadequate hydrology. The following sections 2.2.1 to 2.2.4 describe feasibility assessment tools and methodologies to adequately assess potential replacement sites, and design and construct successful replacement wetlands.

2.2.1 | Feasibility Assessment

Getting suitable hydrology at the replacement site is critical for establishing an appropriate plant community, developing hydric soils, and supporting ecological functions necessary for successful mitigation. The feasibility of potential replacement sites must be determined relative to hydrologic goals and characteristics of the replacement wetland site. The first step is to define a hydroperiod for the proposed wetland that is comparable to the existing wetland (or in some cases a reference wetland). The proposed hydroperiod should be used for designing the replacement wetland and for post-construction monitoring to determine success.

USDA's Natural Resources Conservation Service (NRCS) defines the minimum hydroperiod for wetlands as 15 or more consecutive days of inundation or saturation during the growing season with at least a 50 percent annual probability of occurrence[8] (i.e., on average, once every other year or more frequently). The NRCS minimum hydroperiod will not be sufficient to meet wetland replacement performance standards for wetlands characterized as having longer hydroperiods. To determine the target hydroperiod, an assessment of the impacted/reference wetland should be performed. This is important for choosing an appropriate location and a conceptual design for the replacement wetland.

Determining hydrologic feasibility of potential sites is an essential element of wetland replacement planning. In Wetland Mitigation: Planning Hydrology, Vegetation and Soils for Constructed Wetlands, Gary Pierce recommends assigning the impacted/reference wetland to one of four Novitski system classifications. The Novitski model is simple, widely applicable, and firmly entrenched in the literature; therefore, it is preferred as the conceptual basis for hydrologic analysis in wetland construction.[9] These four hydrology-specific wetland types (below) are essential for understanding the hydrology based on water source and topographic position.

- Surface water depression
- Groundwater depression
- Surface water slope
- Groundwater slope

The Novitski classification uses landscape position and water source to differentiate wetlands, simplifying wetland types by topographic and geological context. It is important to note that some wetlands overlap Novitski's hydrological wetland types. For example, a wetland could be both a surface water depression and a groundwater depression, depending on the season. For replacement wetland design, the Novitski classification should be used along with other classification systems, such as the Cowardin[10] or the Hydrogeomorphic (HGM)[11] systems, that are better suited for describing overall wetland characteristics and functions.

The ultimate goal of the impacted wetland/reference wetland assessment and hydrologic feasibility study is to determine if the hydroperiod (i.e., duration of saturation and/or inundation) for the proposed wetland will be comparable to the hydrologic characteristics of the impacted/reference wetland. In general, if the proposed site can provide depths and duration of inundation and/or saturation that are comparable to the impact/reference wetland, then that site is likely to be suitable for creation of the replacement wetland.

For hydrologic feasibility assessment, each Novitski classification requires the collection of specific topographical and hydrologic data. Table 2 shows examples of each Novitski class, along with associated hydrologic data that assists with accurate hydroperiod development and feasibility determination. Different hydrologic data are required for the different types of wetlands.

[9]Pierce, Gary J. 2015. Wetland Mitigation: Planning Hydrology, Vegetation and Soils for Constructed Wetlands. With Mallory N. Gilbert and Robert J. Pierce contributing editors. Wetland Training Institute, Inc. Glenwood, New Mexico. 360 p.

[10]Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. Washington, DC.

[11]Brinson, Mark M. 1993. A Hydrogeomorphic Classification for Wetlands. U.S. Army Corps of Engineers Wetlands Research Program Technical Report WRP-DE-4. Washington DC.

Table 2 | **Novitski Classification Examples and Relevant Hydrologic Information**

Novitski Classification	Definition	Water Feature Examples[12]	Assessment Techniques
Groundwater depression	Characterized by contact with the water table with minimal surface drainage away from the site.	Bogs, fens, interdunal wetlands, karst sinkhole wetlands	Section 2.2.2
Groundwater slope	Typically occur at the intersection of the slope and groundwater (i.e., toe of slope). They can be characterized as having a relatively flat slope and water surface elevation, with extremely slow-moving water draining away from the site.	Fens, sedge meadows, wet meadows, some shrub/forested wetlands	Section 2.2.2
Surface water slope	Located above the water table along the margins of lakes, streams, and other water bodies. Water drains readily as the stage of the adjacent water body falls. Can include capillary fringe-driven features.	Fringe wetlands that rely on water from an adjacent lake, pond, river or stream, floodplain forests, and tidal marshes	Section 2.2.3
Surface water depression	Occur where precipitation and overland flow (both sheet and channel) collect in a depression, generally without significant inputs from groundwater.	Vernal pools, river meander scars, beaver ponds, farm ponds	Section 2.2.4

Inadequate hydrology often results from an inadequate evaluation of the replacement site before construction. Section 2.2.2, Section 2.2.3, and Section 2.2.4 describe the pre-project monitoring and assessment techniques required prior to design, to establish a target hydroperiod, characterize hydrology at various elevations, identify a suitable location for the replacement wetland, and grade the design for success. The longer the hydrology is monitored prior to design and construction, the greater the likelihood of success. In general, projects should not be required to submit multiple years of data to justify a wetland design. The pre-design level of effort should be commensurate with the size /character of wetland impact and proposed replacement areas. For example, a single-family home might provide design justification based on several months of hydrologic data, while an airport development with many acres of wetland impacts should provide a thorough design justification with several years' worth of hydrologic data.

2.2.2 | Groundwater Slope and Groundwater Depression Assessment Techniques

The following list includes techniques used to document wetland hydrology for proposed groundwater-driven slope and depression wetlands. Note that the listed methods are important during the feasibility phase, but should also be used during design and in determining post-construction success. Note that not all of these techniques are required for every project. As long as a sufficient hydrologic profile can be established, any one, or a combination of the below techniques can be used.

Soil observation holes: A soil observation hole is an open hole dug to allow examination of the soils, including any free water and/or redoximorphic features that may be present. Typically, the soil observation hole is hand dug using a tile or sharpshooter spade, approximately 12-inches in diameter and 20-inches deep. Deeper observation holes may be required to determine depth to groundwater in proposed mitigation areas. Soils should be examined from the bottom, as well as from a slice removed using the spade from the side wall of the observation hole. Soil observation holes are also used to determine appropriate areas for observation pits or piezometers/groundwater monitoring wells, as well as to determine whether a replacement wetland meets regulatory performance standards after it is built.

[12] Specific topographical and geological context can extend to other types of water features so overlap between the types is common.

Observation pits: Observation pits are used for observing the depth and thickness of soil layers and horizons, the depth at which redoximorphic features occur, and the elevation of any free water that may be present. An observation pit may be hand dug or machine excavated using a backhoe or similar equipment. The depth, breadth, and shape of the observation pit will vary depending on the soil material,l but generally the observation pit should allow for full viewing and documentation of all soil horizons. Unlike soil observation holes where the soil layers need to be carefully removed from the hole to be examined, observation pits allow the soil layers to be observed directly by examining the walls of the observation pit. It is important to record the depth below ground surface at which redoximorphic features occur (an indicator of seasonal high groundwater) and the presence and depth of free water in the observation pit. Observation pits are also useful in determining whether there may be perched groundwater conditions or if bedrock is present. Observation pits are appropriate for determining site hydrology before constructing a wetland replacement area but are not appropriate for documenting hydrology after a wetland replacement area has been built.

Piezometers and shallow groundwater observation wells: Piezometers and/or shallow groundwater observation wells are used to document and record groundwater levels during the growing season[13] and throughout the year. Long periods (several months to multiple years) of groundwater monitoring are better than short term monitoring in order to avoid misleading results due to unusually wet or dry conditions. Piezometers measure water pressure in the soil by recording the height to which water will rise against gravity. Groundwater observation wells measure the water surface elevation of the free water surface. The pressure head and/or water surface elevations may be measured and recorded manually or by using automated instruments. Piezometers may be more useful in determining whether perched groundwater conditions exist. When using piezometers, several of them should be installed together at varying depths. It is important that piezometers and groundwater observation wells be screened with sand filter pack and sealed with bentonite clay to prevent seepage of surface water runoff. Use multiple piezometers or observations wells to determine the variability of groundwater elevations and direction of groundwater flow.

Figure 2 Soil observation hole with redoximorphic features at the bottom of the pit

Figure 3 Observation monitoring well located in a wetland replacement area

[13]U.S. Army Corps of Engineers, 2005, Technical Standard for Water-Table Monitoring of Potential Wetland Sites, ERDC TN-WRAP-05-2, WEB: https://www.nrc.gov/docs/ML1327/ML13276A040.pdf

U.S. Army Corps of Engineers, 1993, Installing Monitoring Wells / Piezometers in Wetlands, WRP Technical Note HY-IA-3.1, WEB: https://apps.dtic.mil/dtic/tr/fulltext/u2/a434496.pdf

Recorded groundwater elevation data: Groundwater elevation data from USGS groundwater monitoring wells can be transposed to an onsite groundwater observation well using the Frimpter Method.[14] Selection of the USGS index well requires specialized expertise and certain limitations exist. USGS is currently updating the Frimpter Method so users should confirm they are using the most up-to-date version available.

Observations of capillary fringe: Capillary fringe depths and ranges should be understood and well-documented when designing saturation-based wetlands (i.e. wetlands with no standing water during the growing season). Capillary fringe is the zone of soil where groundwater (or surface water) seeps vertically above the water table and fills vacant space between the soil particles due to tension saturation. In saturation-based wetlands where groundwater comes within 12 inches of the surface, capillary fringe can often reach the surface depending on the soil type, and hydric soils can develop above the water table. Capillary fringe zones will be higher in finer substrates such as clays, compared to courser substrates such as sands.[15] In addition to assessing the hydrologic feasibility of potential replacement sites, understanding the depth of the capillary fringe zone is integral for assessing groundwater slope and groundwater depression wetlands, where standing water or inundation does not constitute a significant component of hydrology.

2.2.3 | Surface Water Slope Assessment Techniques

The following list includes techniques used to document wetland hydrology for proposed surface water slope wetlands. Surface water slope wetlands occur adjacent to lakes, ponds, rivers and streams, and their hydrology should be characterized based on the water levels in these adjacent water bodies and waterways. Data sources for estimating water levels in adjacent water bodies and waterways includes data from USGS stream gauging stations as well as direct observation/records of inundation, ponding and saturation, mean annual high water or bank full indicators for streams/rivers, or their equivalent in BVWs. Typical direct measurement practices include the following.

Staff gauges: Staff gauges indicate surface water depths and are marked with measurement units (e.g. inches, centimeters) which can be recorded manually or by automated instruments. Staff gauges can be affixed to piezometer or observation well casings in order to collect both surface and groundwater from a location. This allows the recording of water surfaces when groundwater rises above the ground surface, as well as during surface pulses from ponds, lakes, streams, and rivers that may be adjacent to the site.

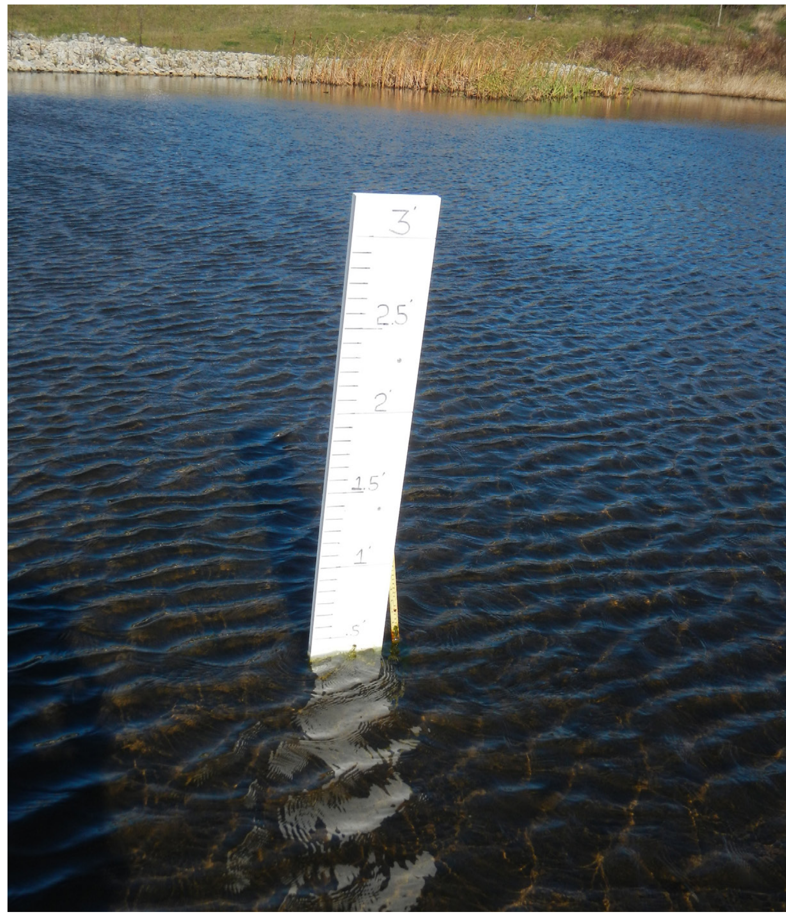


Figure 4 Staff gauge used to measure surface water depths

Bankfull indicators/Mean annual high water: Bankfull elevation is the elevation at which water in a stream or river leaves its channel and enters the floodplain. Determination of the of bankfull elevation allows one to determine the elevation of the seasonal pulse of water that strongly effects the hydrology of BVWs located adjacent to streams and rivers. Keep in mind that the water surface elevation of bankfull is a slope from upstream to downstream and likely will not be a single elevation.

[14]Frimpter, Michael. Probable High Ground-Water Levels in Massachusetts, Water Resources Investigations 80-1205, U.S. Geological Survey, 1981, pp. 1–22.

[15]Mausbach, M. J. 1992. Soil Survey Interpretations for Wet Soils. Pages 172–178 in J. M. Kimble, editor. Characterization, Classification, and Utilization of Wet Soils, Louisiana and Texas. Proceedings of the Eighth International Soil Correlation Meeting (VIII ISCOM). U.S. Department of Agriculture, Washington, DC, USA.

USGS stream gauges: Stream gauges record water surface elevation and sometimes stream flow (Q) of streams and rivers. A qualitative assessment of these data can be used to determine the hydroperiod of the river or stream. For example, if a stream flows at elevation 315 feet NAVD88 (North American Vertical Datum of 1988) for 15 or more consecutive days of inundation during the growing season with at least a 50 percent annual probability of occurrence (i.e., 1 out of every 2 years) then it would qualify as meeting minimum wetland hydrology at that elevation. Note that this type of analysis is specific to surface water slope wetlands and the wetland must be directly abutting the adjacent water body or waterway, in the vicinity of the gauge. The location of USGS gauges can be found here: https://dashboard.waterdata.usgs.gov/app/nwd/?region=lower48&aoi=default.

Observations of capillary fringe: Capillary fringe depths and ranges should be observed and documented when designing saturation-based wetlands (i.e., wetlands with no standing water during the growing season) (see section 2.2.2). Capillary fringe height above the water levels in rivers or other waterbodies will be higher in finer substrates such as clays compared to coarser substrates such as sands. This is also an important process for groundwater slope or groundwater depression wetlands, but the source of water is different: capillary fringe occurring due to an adjacent waterbody rather than groundwater.

2.2.4 Surface Water Depression Assessment (Water Budget)

The purpose of a hydrologic feasibility assessment is to predict the hydrology (i.e. the depth and duration of inundation and/or saturation) for potential replacement sites, and define the target hydroperiod and site design parameters for the replacement wetland. For some wetlands, the hydroperiod cannot be adequately determined from observational or qualitative data. In these scenarios, a water budget must be developed from a thorough analysis of hydrologic inputs and outputs for both the impacted/reference and proposed replacement wetland.

Calculating and deriving data for water budget calculations is time and resource intensive, and results can be sensitive to minor changes in model parameters. For this reason, limitations exist on their application and designers must understand when to develop water budgets and how to utilize their results. Not all water budgets are created for the same purpose, as researchers and/or academics might include specific nutrients and/or chemicals in their calculations that may not be relevant for characterizing hydrology for wetland replacement.

Water budgets are an essential tool in understanding and developing hydroperiods for both proposed and existing wetlands. However, water budgets are not always required for a feasibility determination or design of a replacement wetland. If a reasonably accurate hydroperiod can be estimated from qualitative or observational data, then a water budget is generally not required for groundwater or surface water slope wetlands.[16] If an in-depth understanding of wetland function is warranted, a water budget should be considered for replacement wetland design and construction.

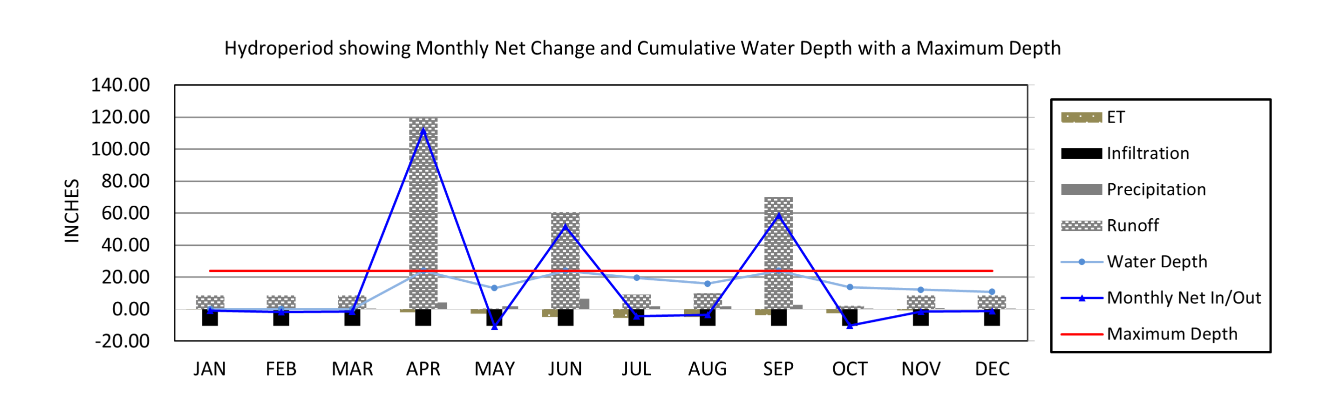
Only surface water depression wetlands require a water budget to understand, or predict, the hydroperiod. For other wetlands, qualitative or observational data are sufficient in determining feasibility and defining the hydroperiod for replacement wetlands. Sections 2.2.2 lists groundwater measurement techniques that should be used for groundwater depressions and groundwater slope wetlands, while Section 2.2.3 lists surface water measurement techniques to determine surface water slope hydrology.

Developing a water budget for surface water depression wetlands requires compiling, measuring, and/or calculating all hydrologic inputs and outputs. This includes site-specific precipitation amounts, runoff quantities, stream or other waterbody overflow volumes, infiltration rates, and evapotranspiration rates. After all inputs and outputs are determined, water volume is calculated and compared to the overall volume of the topographic depression. The results can then be presented as water depth over time.

Figure 5 shows the results of a surface water depression wetland budget. The maximum depth (red line) for this depression is 24 inches so the excess runoff in April, June, and September would be discharged as spillover or outflow. Methodologies for water budget development can differ, but most simplified methods do not consider side slopes within the submerged (or potentially submerged) part of the depression. This means that the volume of the topographic depression should be determined first and then divided by the footprint (or surface area) of the inundation to provide model depth. In situations where the designer wants to model or calculate different depths for different types of wetlands (deep marsh vs. shallow marsh) within the same depression, multiple water budgets should be developed with varied depression volumes and footprints.

[16]Guidelines for the Development of Wetland Replacement Areas. Washington, D.C.: Transportation Research Board, National Research Council: National Academy Press, 1996.

Figure 5 | **Water Budget Example**



Note - For this example, the depression depth is relative to the bottom of the depression, not specific elevations, although the results can easily be converted to elevations if needed.

Precipitation varies from year to year, so multiple hydroperiods should be developed that simulate conditions in a dry, average, and wet year of precipitation. Water budget preparation is different from most hydraulic or hydrologic calculations because the end goal is to determine seasonal patterns rather than a single storm event (e.g., 10-year, 25-year, etc.). The water budget shown in Figure 1 is a monthly budget based on daily precipitation events. Precipitation must be assessed at the daily time interval, or at least event-based, so initial losses can be applied before accumulating the monthly total.

When developing a water budget, the designer should consider multiple years of precipitation data, as well as the impact of snowmelt runoff, frozen ground, depression depth changes over time, and potential land use changes. Snow accumulation will decrease runoff in the wintertime but release the stored excess during spring thaw. Another winter consideration is that frozen ground can reduce or halt infiltration. For smaller replacement wetlands, the designer should be aware that depression wetlands are prone to incidental filling via sediment accumulation. In these situations, a soil loss analysis should be performed during the feasibility phase.

The designer should also be aware of infiltration rate (otherwise known as saturated hydraulic conductivity) sensitivity. Determination of the saturated hydraulic conductivity is often the most important component in developing a water budget. Rates should be determined by field measurement using commonly accepted methods. Published or laboratory derived rates are not precise enough. In addition to field derived data, a reference wetland or pond[17]near the proposed site should be used to calibrate field-derived rates. Good information regarding natural drawdown can sometimes be collected from nearby farmers or landowners familiar with hydrologic seasonal patterns in the area. Soil complexes for large sites are routinely nonhomogeneous so developing multiple budgets may be necessary to determine sensitivity of applied rates.

Precipitation data can be accessed from a variety of sources. Site-specific or locally-collected data often works best, especially for the calibration component of a reference wetland. Monthly and annual precipitation averages should be checked to determine what precipitation data should be used for dry, average, and wet years. Some sources of precipitation data include:

The Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) has a large network of volunteer-based precipitation data: https://www.cocorahs.org/ViewData/ListDailyPrecipReports.aspx

Regional Precipitation Gauges: NOAA, through the National Weather Service (NWS) and the National Centers for Environmental Information (NCEI, formerly the NCDC), measures precipitation at ground stations located throughout the Commonwealth. Weather data collected at Airports through the Federal Aviation Administration are available through the NWS and NCEI. Multiple gauges should be used to transpose precipitation records to a site using the Thiessen Polygon or isohyetal method.

The National Weather Service provides historical weather data located here: https://w2.weather.gov/climate/local_data.php?wfo=box

[17]Ponds and other depressional waterbodies often serve as excellent references since calibrations can isolate the saturated hydraulic conductivity.

After daily precipitation data are collected, runoff should be calculated using the USDA NRCS WinTR-20 or WinTR55 methods. Multiple references exist for runoff calculations.[18]

Evapotranspiration can be estimated using the Penman-Monteith[19] or Thornthwaite methods. Daily evapotranspiration data are available for a limited number of sites in Massachusetts through CoCoRaHS including Berlin 1.3 WSW; Attleboro 0.9 ENE; Watertown 1.1 W; Buckland 1.8 ESE; and Chatham 0.2 SSE. Note that this could change as the Network is operated by volunteers. A charting function is available through CoCoRaHS to visually display the water balance.

Designers should understand the limitations and difficulty in developing a water budget. For determining replacement wetland feasibility, the goal is to determine reasonable estimates of the seasonal hydroperiod. In other words, the tool should be used to establish overall site patterns and should not be used to predict water depths at any specific point in the future. Due to technical difficulties involved in water budget preparation, wetland budgets should be prepared by a Registered Professional Engineer licensed in Massachusetts, or other professional competent in such matters, including but not limited to a hydrologist, geo-hydrologist, or hydrogeologist. The methodology used should closely follow a widely accepted protocol like the one outlined in *Wetland Mitigation: Planning Hydrology, Vegetation and Soils for Constructed Wetlands* by Gary Pierce (2015). When reviewing water budgets, Issuing Authorities should confirm the expertise of the designer, along with the calculations for the hydrologic inputs and outputs. Precipitation data should be located near the site, and the hydraulic saturated conductivity should be field calculated and/or calibrated with a nearby water feature.

MassDEP recommends that conservation commissioners request assistance from peer reviewers when evaluating hydrological feasibility assessments, especially when they involve water budgets. Conservation commissions that have adopted rules under M.G.L. Ch. 44, §53G can impose reasonable fees to cover consulting services for application review.

2.3 | Considerations for the Design of Replacement Wetlands

The sections below provide a general discussion about hydrology, soils, and vegetation, as they relate to the design of replacement wetlands.

2.3.1 | Hydrology

General

The hydrology at the replacement site is critical for shaping the plant community that develops, and for many of the of the replacement wetland's ecological functions. I nappropriate hydrology often results from an inadequate evaluation of the replacement site before construction. This is particularly the case when constructed wetlands that are intended to be groundwater dependent are not excavated deep enough to produce saturated conditions in the upper part of the soil long enough and at appropriate times of the year. When side slopes are included in the footprint of the replacement area, but adequate hydrology is not established for those elevations, replacement wetlands will often be smaller than required to fully mitigate any wetland losses. Section 2.2 describes replacement site selection and pre-project monitoring that should be conducted to determine whether groundwater is present at appropriate elevations, whether a replacement area is suitably located, and how much grading will be required to achieve appropriate depths. The longer pre-project hydrology is monitored, the greater the likelihood of success.

Conversely, problems can also result when the replacement site is over-excavated to a depth well below the water table. This can result in a wetland type that is dissimilar to the impacted or reference wetland. The replacement area design plans should include information that demonstrates that the applicant understands the current and proposed hydrology of the replacement site and will be able to predict the surface and groundwater elevations in the replacement wetland. All proposed hydrologic sources must be naturally occurring and self-sustaining over time. Artificial sources of water such as hoses or pumps that contribute to the hydrology are not acceptable.

Desirable Information

For the existing/reference wetland, plans should characterize the depth and duration of surface water, the duration of saturation in the upper part of the soil, and the flow regime, with the goal of replicating the hydrology and wetland functions of the impacted/reference wetland. **The expected annual seasonal depth, duration, and timing of both**

[18]U.S.D.A., NRCS 1986, Urban Hydrology for Small Watersheds, Technical Release 55 (TR55), WEB: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

U.S.D.A., NRCS 2015, WinTR-20 User Guide Version 3.10, WEB: https://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/WinTR20/WinTR20UserGuideVer310Mar2015.pdf

[19]Lincoln Zotarelli, Michael D. Dukes, Consuelo C. Romero, Kati W. Migliaccio, and Kelly T. Morgan; Step by Step Calculation of the Penman-Monteith Evapotranspiration (FAO-56 Method), University of Florida Extension, WEB: http://edis.ifas.ufl.edu/pdffiles/ae/ae45900.pdf

inundation and saturation must be estimated for the existing wetland, and for each of the proposed vegetation classes (forested, shrub, emergent, etc.) in the replacement wetland.

As part of the design process, surface water inputs should be estimated (Section 2.2.3) and groundwater elevations determined (Section 2.2.2) as needed to develop an effective design. **Ideally, replacement areas should not depend on precipitation and surface water runoff alone but should also have a seasonal source of groundwater or connectivity to a stream or other waterbody.** As discussed above in Section 2.2.4, surface water depressional wetlands may be established without groundwater inputs, but site-specific data should be presented to demonstrate that runoff and precipitation inputs exceed infiltration and evapotranspiration rates in the water budget.

Applicants should begin data collection in advance of filing a Notice of Intent (NOI) for the project. The method and length of time during which hydrology data should be collected will vary based on the characteristics of the impacted/reference wetland and proposed replacement wetland, as well as the extent of BVW impacts.

Land Subject to Flooding

When replacement takes place in Land Subject to Flooding (310 CMR 10.57), only the amount of flood storage that was provided by the impacted BVW should be designed for in the replacement areas. Additional, compensatory flood storage should not be allowed in replacement areas, unless it can be demonstrated that periodic floods will not adversely affect the wetland functions of the replacement area. Impacts from flooding can include inundation for extended periods, scour, and sediment deposition.

2.3.2 | Soils

General

An important factor in the success of a replacement area is the proper use of soils, either translocated from the impacted wetland (i.e., the relocation and reuse of hydric soils from the impacted BVW to the proposed replacement area) or soil amendments brought in from off-site. The development of hydric soils provides substrate for wetland plants and contributes to wetland functions. Hydric soil filters groundwater, binds pollutants, transforms or sequesters nutrients, and supports vegetation that anchors soils, slows floodwaters, and contributes to wildlife habitat. Issuing Authorities should ensure that the factors described below are considered in the design of the replacement area. Appropriate hydrology, as indicated in Section 2.2, must be provided to maintain the soils in a hydric condition.

Figure 6 Example of soil in a wetland replacement area beginning to develop hydric soil characteristics

Soil Translocation

Soil translocation is the preferred methodology for obtaining soil for replacement areas. If additional soils are needed, or if on-site soils are not appropriate for translocation (e.g., due to invasive species, contamination, etc.) then off-site soil and amendments, such as compost or biochar[20], may be used. The mitigation plan should include soil profile information from test pits at the impacted/reference wetland. Information should include horizons, and characteristics such as texture, organic matter, color (Munsell hue, value, and chroma), and evidence of hydrologic influence, such as redoximorphic features and gleyed soils. A detailed schedule for the collection, stockpiling, and placement of the soils should be included in the wetland replacement plans. Replacement sites containing subsoil that developed in upland conditions will have difficulty in supporting hydric soils. Excavation of the replacement area to appropriate sub grade elevations should be completed prior to placement of wetland soils in the replacement area. Soil from areas where the invasive species listed in Section 2.3.3 are present should not be used in replacement areas.

Soil Amendments

If soils are brought in from off-site, the specifications should include detailed descriptions of the material composition and the techniques to be used in its preparation and placement. Specifications should require that the contractor obtain a suitable source of this material in the event that additional

[20]Biochar is a fine-grained, highly porous form of charcoal.

soil is needed during construction. Proposals to use translocation as the primary method for establishing appropriate soil conditions should include a contingency for obtaining soil amendments in the event that the wetland soils from the impacted site are insufficient to provide the soil depths specified in the replacement plan.

Specifications

The proposed method (such as rototilling) for ensuring appropriate compaction levels (e.g., not too loose, not too dense) should be described. Once prepared, the soil should be tested for proper consistency (e.g., loose to friable), and if the proper consistency has not been achieved, further efforts should be undertaken to achieve the desired soil conditions. **Sub grades and finished elevations should be checked frequently during construction, and at least once prior to soil placement and once prior to planting.** Plans should show the proposed microtopography using cross-sections, including the approximate spacing of mounds and pools.

One reason for the failure of some wetland replacement sites is that when upland soils are excavated, all of the B-horizon (subsoil) is removed, and a few inches of A- or O-horizon material are placed over the C-horizon. Although some C-horizons are sandy and may perform well as subsoil, C-horizons generally have not undergone soil-forming processes (pedogenesis) and may not provide a suitable rooting medium for plants to thrive. Mitigation sites that are constructed on dense compacted C-horizons with a thin layer of A or O placed on top are at risk of failing. Therefore, Issuing Authorities should request evidence that the design will include an A-horizon of sufficient depth to provide a suitable rooting medium *in lieu* of a B-horizon.

The goal for soils at the wetland replacement site should be to create soil profiles that approximate as closely as possible the soil profiles at the impacted/reference wetland or the nearest undisturbed existing wetland. This means that surface horizons in the replacement wetland should approximate the A- and/or O-horizons at the wetland site to be impacted or reference wetland, and that contain 6-12 inches or more of A or O material. Beneath the A or O there should be a B-horizon (subsoil), or a C-horizon of suitable composition, that approximates the depth and texture of the B-horizon at the wetland to be impacted or reference wetland. The consistency of the replacement B-horizon should be loose to friable, and the texture should be loamy sand to silt loam. It is recommended that course woody debris (e.g., branches and logs) be scattered sparingly on the surface of the replacement area in between plantings, to add structure and a long-term source of decaying organic material.

The rate at which a soil is able to oxidize substances contributes to the development of hydric features/indicators, such as the accumulation of organic matter, and the ability of a wetland to bind certain pollutants. The soil pH also plays a role in redox (reduction-oxidation) reactions. The use of redox and pH meters in the replacement area and adjacent wetlands will allowing the applicant to predict the long-term hydric soil development and resulting wetland functions. It is recommended that applicants seek guidance from a professional experienced in this testing since the range of results may vary depending on site conditions.[21]

Soils to be used at the mitigation site should be used immediately or stockpiled for as little time as necessary. While stockpiled, the soils should be watered so that they don't dry out. The method for maintaining the appropriate moisture level should be documented in the plans. Contamination of these soils, by petrochemicals or invasive plant species, should be prevented. Soil materials should be transported in vehicles that have been washed so that exotic/invasive seeds from other sites are not mixed in with them.

If soil amendments are used for the replacement area A- or O-horizons, they should consist of a mixture of equal volumes of organic and mineral materials. These materials should be free from chemical contaminants and seeds or fragments of invasive plants, as well as foreign material such as woodchips. The organic material used should be well or partially decomposed. Clean leaf compost is an excellent soil amendment for achieving these standards. Mineral materials should be predominantly in the loam, loamy sand to silt loam texture range, with minimal quantities of gravel or rock.

2.3.3 | Vegetation

General

According to the Regulations at 310 CMR 10.55, at least 75% of the surface of the replacement area must be reestablished with indigenous wetland plant species within two growing

[21]Wetland soils generally have negative redox potential but can range from –300 to +300 millivolts (mV). The pH of wetland soils nationwide appears to be circumneutral (7) but it is not clear whether this is true in the northeastern U.S. where many wetland soils are poorly buffered. See Creating Freshwater Wetlands, Donald A. Hammer, 1997 by CRC Press Inc., 2nd edition, page 53; and Mitigating Freshwater Wetland Alterations in the Glaciated Northeastern United States: An Assessment of the Science Base, Joseph S. Larson and Christopher Neill, Editors, Publication 87-1, The Environmental Institute, UMass at Amherst, 9/86 pages 31 and 32.

seasons. In order to accomplish this, the hydrology and soil conditions must be appropriate for each type of wetland vegetative community (e.g., emergent, shrub, forested etc.) that is proposed for the replacement area. Indigenous plant seeds/seedlings should be native varieties; cultivars of native species often do not perform as well, and may not provide the same functions, as their native counterpart.

Issuing Authorities should ensure that the plan clearly describes the dominant plants in each vegetative strata (layer) of the impacted/reference wetland and proposed replacement wetland. Existing vegetation that will remain in the replacement areas along with proposed vegetation should be shown in plan view and described in the narrative. The plan and narrative should include relative cover and wetland indicator status for dominant species in each vegetative layer proposed (herbaceous, shrub/sapling, woody vine, and forested canopy). Side slopes should be vegetated to minimize erosion. Side slopes may not have adequate hydrology to qualify for wetland replacement and therefore, vegetation for these areas may need to be different from that used in the bottom of the replacement area. Wetland and upland areas adjacent to the replacement area should be evaluated for their role in providing shade to the replacement wetland.

Planting Details

Wetland replacement plans should provide detailed descriptions of the techniques proposed to establish wetland vegetation, including transplantation of appropriate plant materials from the impacted wetland (if possible). A qualified professional with training in wetland science should oversee planting procedures. Plantings of trees/shrubs should be at least 24 inches in height or have stems that are at least the diameter of a pencil. Shrubs should be planted no further apart than 8–10 feet on center, and trees should be planted no further apart than 10 –15 feet on center unless the nursery or a qualified wetland professional recommends otherwise. Existing shrub and tree densities in the impacted/reference wetland should be used to determine the total number of specimens to be planted within a given area and a wetland professional (or landscape architect) should be responsible for establishing the plantings in a naturalistic manner (e.g., clumping, mini-communities, leaving mud flats, etc.).

If the replacement wetland will be planted using vegetation transplanted from the impacted wetland, the applicant should include a detailed plan for this procedure including species to be transplanted, and techniques for maintaining the viability of seeds, rootstocks, and plants during the transplantation process. Plants for transplanting should be removed in plugs or culms and protected against desiccation. Trees and shrubs should be root pruned prior to transplanting. Plants should be properly protected (e.g., burlap), watered, and handled and planted within one day, or as soon as possible, after removal.

The plan should provide details regarding any additional planting proposed to take place from other sources. If plant stock from off-site will be used, the plan should include a list of species to be included, the sources of plant material, and a detailed description of the planting methods to be used.

Figure 7 A tree planted in a wetland replication area

Invasive Species

Notices of Intent for wetland replacement should address potential for the introduction of invasive species into the replacement wetland and proposed methods to prevent the establishment of undesirable species. If invasive species are found growing in replacement areas, measures should be taken to eliminate them as soon as possible. Once well-established, invasive plants will be much more difficult to control. Soils from existing wetlands containing invasive species should never be used in replacement areas. Trucks that have previously been on other sites should be washed prior to entering the replacement site so that soils containing exotic/invasive seeds are not inadvertently introduced into the replacement wetland.

Timing of Plantings

All planting should occur at the beginning or end of the growing season. Fall herbaceous plantings should be done before the first frost. Shrubs and trees, however, may be planted up to November 15, weather permitting. It should be noted, however, that some plant species (including red maple) are ill-suited to fall planting and therefore, careful investigation regarding individual plant tolerances should be conducted during design and checked again once the construction schedule is known. Specific growing season dates can be found in **Appendix A**.

Intended Vegetation Community and Contingency

The plan should contain a general discussion about the wetland vegetation anticipated after two growing seasons and the intended vegetation community that will develop following natural succession. A contingency plan should be included in case of vegetation mortality, invasive species, failure of desired plants to thrive, or inappropriate hydrology necessary to sustain the intended plant community.

Experience has shown that it can be particularly challenging to replace forested wetlands. Conditions need to be wet, but not too wet and there can be little room for error in establishing the appropriate hydrology. In addition to ensuring proper hydrology and soil structure in a forested wetland replacement area, designers should specify number, density, type, and size of plant species to be planted, including shrub and understory layers in the replacement area, and describe the intended process of succession to a forested wetland community. Tree plantings should be as mature as possible to reduce temporal functional loss. It is less important to replicate the vegetative community composition immediately after creation than to correctly achieve soil and hydrological conditions that will eventually become functional forested wetlands. The use of purchased wetland seed mix should be limited in forested replacement areas as such seed mixes can make it difficult for woody plants to become established. For replacement forested wetlands consider using alternatives to wetland seed mixes, such as herbaceous plugs. Use of leaf litter as an alternative source of mulch is often desirable for stabilizing soils, providing cover, and inhibiting invasive species in forested wetland replacement areas.

2.3.4 | Wildlife Habitat

When BVW alteration and replacement are proposed, the most recent Estimated Habitat Map of State-Listed Rare Wetlands Wildlife published by the Natural Heritage and Endangered Species Program of the Department of Fish and Game must be reviewed to determine whether the site serves as habitat for state-listed wetlands wildlife. If so, special review procedures (310 CMR 10.59) must be followed.

Figure 8 Evidence of beaver activity found adjacent to waterbody

Figure 9 Red eft, the terrestrial phase of the Red-spotted newt. This species utilizes aquatic/wetland and upland forest habitat for different stages in its life cycle.

Wetland resource areas provide important food, shelter, migratory and over-wintering areas, and breeding areas for many birds, mammals, amphibians, and reptiles. General wetland characteristics that provide important wildlife habitat are listed in Section 2.1, Table 1. Bordering Vegetated Wetlands are presumed to be significant for wildlife habitat, and so wildlife habitat evaluations might need to be conducted for projects that propose to alter and replace BVW. A separate MassDEP guidance document, "Massachusetts Wildlife Habitat Protection Guidance for Inland Wetland" (MassDEP 2006) provides information about how to conduct and interpret wildlife habitat evaluations under 310 CRR 10.60. This document provides data forms and procedures for two levels of evaluation: a simplified habitat evaluation and a detailed wildlife habitat evaluation. Most projects that alter BVW can use the simple evaluation procedures. However, some projects will need to complete detailed evaluations, such as when the project:

- Is located in mapped "Habitat of Potential Regional of Statewide Importance,"
- Affects certified or documented vernal pool habitat, including habitat within 100 feet of a certified or documented vernal pool,
- Involves installation of structures that prevent animal movement, or
- Affects the sole connector between habitat > 50 acres in size.

In addition, it is recommended that detailed habitat evaluations be conducted for Limited Projects and Variance projects that affect > 5000 square feet of BVW.

The purpose of wildlife habitat evaluations is to identify and document wetland characteristics that support important habitat functions for wildlife, and determine whether BVW impacts will result in adverse impacts to wildlife habitat. For projects that will affect the wildlife habitat function of BVWs, Issuing Authorities may require replication of that function regardless of the size of the impact. Mitigation plans and narratives should describe the wildlife habitat characteristics of the replaced wetland and demonstrate that it will be sufficient to mitigate any loss of wildlife habitat value from alterations to the impacted wetland. According to the Regulations, wildlife habitat evaluations "shall be performed by an individual with at least a master's degree in wildlife biology or ecological science from an accredited college or university, or other competent professional with at least two years experience in wildlife habitat evaluation."

The designer should propose a vegetative community and the inclusion of structural characteristics sufficient to successfully replicate the desired wildlife habitat. In forested wetlands, woody vegetation of varying heights adds structural diversity that is important for wildlife. While it is not immediately feasible to replace a mature forested swamp complete with large trees and standing snags, replacement projects should incorporate shrubs and saplings so that woody components will develop over time, as well as areas of surface water interspersed with hummocks. It is also beneficial to provide water at varying depths and duration. Wetlands with diverse conditions are preferred, instead of simple wetlands such as ponds rimmed by emergent aquatic plants.

Changes to wildlife habitat value can result if replacement wetlands are not appropriately sized or constructed, but can also result from secondary impacts such as fragmentation of habitat caused by roads, construction of barriers that impede wildlife movement, and the loss of surrounding upland areas. In particular, small, slow-moving species (e.g., salamanders and turtles), which depend on both wetlands and adjoining uplands, are threatened by roadway crossings and buffer zone clearing. **One-to-one replacement of BVW characteristics may be insufficient to replicate wildlife habitat functions if the replacement area lacks an adequate buffer or access to important upland habitats. To address this problem, Issuing Authorities should require applicants to address not just the size of the impacted wetland, but also its specific landscape context.**

2.4 | Replacement Area Design & Application Requirements

The replacement area must be designed to ensure that the interests of the WPA will be protected. This requires different amounts of detail depending on the size and complexity of both the impacted/reference and proposed replacement wetlands. Note that site design should be based on the target hydroperiod, as well as other considerations discussed in previous sections. Site plan details such as excavation depths, planting plans, and soil translocation specifics should be informed by what the hydroperiod feasibility analysis revealed. Applicants should provide the following information as part of their Notice of Intent describing both the impacted/reference wetland and the replacement site.

Figure 10 Example of a successful wetland replacement area

2.4.1 | Project Narrative

A narrative description of the impact/reference wetland (in general terms) and proposed replacement wetland (more detailed) should specify the type of wetland the applicant proposes to create (e.g., wet meadow, marsh, shrub-scrub, or forested). It should include descriptions of water flow in and out (surface water and groundwater hydrology), wetland vegetation (species and their relative cover and interspersion and diversity of various cover types), soils, proximity to other wetlands, and underlying geological conditions. The narrative should document how the mitigation plan meets the performance standards (especially for hydrology) and that the functions of the existing wetland will be replicated.

The information should include but not be limited to the following:

- A discussion of how the replacement site(s) will meet the criteria defined in 310 CMR 10.55 (4) (listed in Section 1.2 of this document)
- An assessment of the functions and values of the existing and proposed replacement wetland(s) with respect to the eight interests of the WPA;
- Compatibility of neighboring land uses. For example, replaced wetlands adjacent to hazardous waste sites or downstream of parking lots, snow disposal areas or road ways may receive large inputs of pollutants (including salt) that may affect their ecological functions. Replacement sites adjacent to areas of high intensity land use are less likely to provide the full range of wildlife habitat and other ecological functions of the impacted wetland. Applicants should address whether replacement areas near undesirable land uses will meet the performance standards.
- Topographic and geologic considerations that may affect construction feasibility in the event large amounts of fill or bedrock require removal to achieve appropriate grades.
- Soil composition, distribution, depth, and soil chemistry (e.g., redox potential and pH) should be addressed in the narrative.
- Hydrological considerations (especially hydroperiod) based on the Novitzki wetland type, including 1) area of contributing watershed; 2) water budget inputs and outputs; 3) depth of seasonal high and average ground-water tables; 4) boundaries of wetlands; and 5) seasonal variability in hydrology.

As noted in Section 2.2, applicants should try to avoid disturbing valuable upland wildlife habitats such as mature forests. Avoid locating replacement areas in isolated wetlands, including vernal pools. If there are no potential replacement areas on-site that will avoid disturbance of high-quality upland habitat, applicants may consider alternative areas off-site (see Section 5.0). Replacement is required, however, even if the only feasible site is forested. It is important to note that Issuing Authorities have no jurisdiction over upland areas adjacent to inland wetlands under the Wetland Protection Act unless they are buffer zones, riverfront area, or bordering land subject to flooding. Any measures taken to avoid valuable upland habitats that are non-jurisdictional are strictly voluntary by the applicant.

2.4.2 | **Plan**

A site location map such as a 1" = 2000' USGS locus map depicting the geographic relationship between the impacted and proposed wetlands should be included in the NOI packet. The NOI should also include a map at a scale in the range of 1"=10' to 1" = 40', showing the size and location of the existing and replaced wetland(s). The map should include easily identifiable landmarks such as surveyed flag locations, benchmarks, or structures. Detailed plans should be developed with contour lines at 1-foot intervals depicting elevation differences required for different vegetation classes (forested, shrub, emergent, open water/aquatic bed). Locations of hydrology monitoring sites, soil test pits, and vegetation plots should be depicted on the plans. The plans should show construction access sufficient to demonstrate that construction access will not create additional impacts. Plans should also include other relevant regulatory setbacks such as those related to Title V (septic systems) and/or storm water management structures. Issuing Authorities should require that a Professional Land Surveyor (PLS) and/or a Registered Professional Engineer (PE) stamp the plans.

Design plans for the replacement wetland should include details on the soil profile to be created and any proposed planting or seeding. For complicated sites, a plan depicting the location and size of general wetland cover types, with information on the intended plant composition within each cover type, is recommended.

For groundwater driven replacement wetlands, the proposed grading should be based on site-specific knowledge of groundwater elevations. Once the seasonal high and average groundwater elevations are identified, plans for the wetland replacement area, including proposed excavation depths and the upper elevation of placed soils, can then be designed to create the desired wetland community (e.g., emergent marsh, shrub swamp, forested wetland). The key is to ensure that the land is graded so that the uppermost portion of the soil profile intercepts the groundwater table for the duration needed to achieve the target hydroperiod, and to produce saturation and anaerobic conditions sufficient to support the intended wetland plant community. See Section 2.2.2 for details on how to monitor groundwater.

The grading design for surface water driven replacement areas should be based on surface water elevations in adjacent water bodies and waterways or a water budget that accounts for expected surface inputs and outputs, and any contributions from groundwater. See Section 2.2.3 for details on how to assess or estimate surface water inputs, and Section 2.2.4 for details on water budgets. It is recommended that all details about the design and construction (including equipment access and storage areas) of the replacement wetland be in the packet of material included as part of the Notice of Intent and referenced in the Order of Conditions. Plans and procedures submitted to, and approved by, the Issuing Authority become required elements under the Order of Conditions.

2.4.3 | Surface Area Calculations

The Regulations require that replacement areas be designed to achieve at least a 1:1 replacement to impact ratio after avoidance and minimization efforts are implemented. **Research suggests that created wetlands are less efficient at removing nutrients and suspended sediment than natural wetlands. Therefore, applicants and the Issuing Authority may wish to consider a replacement area greater than 1:1 in order "to ensure that the replacement area will function in a manner similar to the area that will be lost."**[22] A higher replacement to impact ratio also may decrease the chances that a replacement site will fail because it provides a contingency in the event of unforeseen circumstances such as mortality of vegetation, layout errors during construction, accidental encroachment by construction activities, and erosion and sedimentation. It is important to make sure that the side slopes of the replacement area not be counted as part of the replacement wetland, or the final wetland will be smaller than required.

2.4.4 | Cross Sections

Replacement plans should include cross-sections of the proposed wetland, including surface and subsurface features. Surface features include surface water elevation at different times of year, location of different vegetative cover type relative to elevation, and micro-topographic features such as pits, mounds, and hummocks. Where appropriate the 100-year flood elevation should be depicted. The cross-sections should show subsurface features such as soil horizons with depths and soil characteristics, predicted low and high groundwater elevations, and perched groundwater conditions. Cross-section locations should be indicated on the plan view drawings.

2.4.5 | Stormwater Management

Best Management Practices (BMPs) or Stormwater Control Measures (SCMs) are required to mitigate development by reducing the peak runoff rate, inducing recharge, and treating the stormwater prior to discharge to natural wetlands. Some of these BMP or SCMs are "constructed wetlands." **In the event that a "constructed wetland" is used for required stormwater compliance purposes, that area should not be included as replacement credit for the loss of BVW.** Wetland replacement areas should be located at least 50 feet away from existing or proposed infiltrating stormwater structures.

Fully treated stormwater can be useful in supporting the hydrology of replacement wetlands. If any stormwater is to be directed to a replacement wetland, that stormwater must be treated prior to discharge in accordance with the Massachusetts Stormwater Management Standards (MSWMS). This means that stormwater must meet all 10 Stormwater Management Standards before it can be discharged to a replacement wetland (e.g., replacement wetlands cannot be used for removal of total suspended solids, nor can they be used for on-site detention of stormwater volume for peak rate attenuation). If stormwater is to be infiltrated in support of replacement wetland hydrology, care must be taken to ensure the groundwater flow path will supply the replacement area.

Replacement areas for freshwater wetlands should be located away from snow disposal areas. The 2019 MassDEP Snow Disposal Guidance does not allow natural or replacement wetlands or their inner 50-foot buffer zone to be used for snow dumps. If a replacement wetland could potentially be affected by road salting operations, care should be taken in the siting and design to avoid or minimize such effects.

Figure 11 Stormwater detention basin planted with New England wetland seed mix

[22] 310 CMR 10.55(4)(b)

2.4.6 | Construction Period Erosion Control Plan

Erosion and sediment control during construction is required by 310 CMR 10.05(6)(b) and 10.05(6)(k)8. A construction period erosion and sediment control and pollution prevention plan showing how the applicant will stabilize all ground surfaces during construction to prevent erosion and sedimentation must be included as part of the Notice of Intent. During construction and until all disturbed surfaces are stabilized, consideration must be given to preventing the mobilization of sediments from disturbed surfaces and installation of a construction period barrier (such as siltation fencing) to be located between the replacement wetland and the adjacent upland to prevent any sediments that have mobilized from entering the replacement wetland.

Figure 12 Siltation fencing and straw wattles installed to prevent mobilized sediments from entering a wetland

To prevent impacts from erosion, soil disturbance must be minimized, and any disturbed soils must be temporarily stabilized by mulching and seeding with a wetland seed mixture until re-establishment of wetland vegetation occurs.

Hydro seeding is a valuable erosion control measure and may discourage colonization by invasive species. Hay bales should be avoided and straw bales used instead, as hay bales are more likely to be a source of invasive species. Silt fence, mulch socks, and/or straw waddles are other sedimentation control measures that can be used. A commitment to remove erosion and sediment control measures following site stabilization and approval by the Issuing Authority should be included.

All embankment slopes adjacent to wetland replacement areas should have slopes no greater than 2H: 1V unless stabilized by structural means. Bioengineering stabilization methods are recommended for slope stabilization. Erosion controls should be planned for the top of depressions following final grading to prevent sedimentation into the replacement wetland.

Figure 13 Bare soil on steep slope utilizing bio-degradable coconut fiber mat stabilization measures prior to vegetation growing in

3.0 | Considerations During Construction

3.1 | Schedule and Sequencing

The wetland mitigation plan should include a schedule showing the sequence of major construction steps and compliance monitoring. The schedule should include proposed dates for the start of construction, and for each procedure included in the mitigation plan. **Elevations should be surveyed throughout the construction period in order to make appropriate adjustments due to settling or compaction.** Contact information for the contractors and wetland consultant should be provided.

Flagging (or other markers) should be used to clearly identify the limits of work in the wetland to be impacted, and to guide construction of the replacement wetland. Just prior to construction, flags and other construction markers should be inspected, and replaced as necessary, to ensure that they are all clearly visible to construction crews. Orange construction fencing may be appropriate to visibly demarcate the limits of work.

When possible, the replacement area should be excavated and graded to the specifications in the plan before work begins in the wetland to be impacted. Adequate notice should be given to the Issuing Authority prior to commencing excavation for the wetland replacement area, so that the excavation procedure can be monitored. Depending on the conditions encountered, the Issuing Authority may request modifications to the replacement area design or location. Organic soils and wetland vegetation should not be placed in the replacement area until the supervising wetland specialist has verified that the excavated grade will allow the finished grade of the replacement site to meet the design specifications. It is preferred that a replacement project be substantially complete before existing wetlands are impacted unless the reuse of soils or vegetation from the impacted wetland is proposed. In any case, the proposed replacement wetland should be excavated prior to working in the BVW to be impacted.

Compaction that may occur due to use of heavy machinery during construction activities is likely to be an important factor affecting wetland functions and the success of wetland replacement areas. When soils are compacted, pores that allow water and air to move vertically and horizontally through the soil become clogged, affecting hydrological conditions and the ability of soils to support communities of essential microorganisms, thereby degrading conditions needed for successful replacement. The construction plan should minimize use of heavy machinery in the proposed replacement area.

Following excavation work, final grading and landscaping should be completed as soon as possible to minimize erosion. The overall construction schedule should be planned so that soils and vegetation are not stockpiled for an extended period of time. The watering provisions for planted vegetation should also be noted in the construction schedule. In the event that seasonal conditions result in a delay in planting, all exposed soil should be stabilized using seed-free mulch or other appropriate erosion control measures. If the site is excavated to the sub grade in the fall and a delay is inevitable, the site should be stabilized for winter and final grading conducting in the spring. Use of hydro seeding has been found to stabilize a site quickly and may hinder growth of invasive species. Erosion control measures such as hay bales and silt fences should be removed as soon as the site is stable to allow wildlife (e.g., amphibians and reptiles) to access the site and to promote proper hydrologic conditions.

4.0 | Monitoring

4.1 | Environmental Monitors

Monitoring is critical in wetland replacement efforts due to the complex issues that can arise when trying to replicate the specific ecological conditions of wetlands. A detailed monitoring plan for the construction and post-construction periods, with schedules for reporting, should be submitted as part of the Notice of Intent for the project. **Requiring an environmental monitor for the project will help to ensure that the project is built according to the design specifications and avoid the most common causes of failure.** The environmental monitor should be a wetland scientist with a minimum five years of relevant experience in the construction of wetlands and should be on-site to monitor the excavation, grading, and planting of the replacement area.

At a minimum, the environmental monitor should be present during the most important tasks in replacement wetland construction including:

1. Before excavation or erosion control installation work begins to inspect site flagging

2. During excavation of the impacted area if vegetation is to be translocated to the replacement area to ensure survival of the plantings

3. Before soil translocation or addition into the replacement area to inspect excavated elevations and verify post-construction groundwater elevations

4. After each stage of grading work is completed to inspect finished elevations (note that interim as-built surveys may be necessary to confirm elevations depending on site complexity)

5. During planting and seeding and after the first month of the growing season to ensure propagation techniques are appropriately used

6. After one growing season to observe vegetation development and regulatory compliance

7. After two growing seasons to determine vegetation development and regulatory compliance

8. After subsequent growing seasons, if more than 2 years of monitoring is required.

Monitoring reports should be submitted to the Issuing Authority in the late spring and at the end of each of the first two growing seasons, or more often as necessary. Monitoring should be required until regulatory compliance has been achieved.

4.2 | Demonstrating Wetlands Hydrology

A recent study by UMass Amherst and MassDEP (Jackson et al., 2018), concluded that the primary reason for unsuccessful wetland replacement projects was failure to establish appropriate wetland hydrology. Even though those failed replacement areas lacked wetland hydrology, many of them were well vegetated with wetland plants. This is probably due to the robustness of wetland nursery stock and seed mixes. Plantings and seed mixes are essential elements for wetland creation and hearty plants are desired to ensure a well-vegetated site. However, due to the robustness of the resulting plant communities, it may take several years before they give way to more upland plant communities at sites that fail to achieve wetland hydrology. As a result, **it is essential that post-project, compliance monitoring demonstrate that replacement sites have the appropriate hydrology to be considered wetlands and not rely solely on the establishment of wetland plants.**

To be considered wetlands, replacement areas need to be saturated or inundated with water long enough during the growing season to develop anaerobic conditions in the upper part of the soil. Indicators of these conditions include: a) groundwater, including the capillary fringe, within a major portion of the root zone; b) observation of prolonged or frequent flowing or standing water; and/or c) characteristics of hydric soils. A pre-design hydrologic feasibility analysis is essential to determine the target hydroperiod and ensure adequate hydrology. Monitoring hydrology after the replacement wetland construction, over at least two growing seasons, is essential for demonstrating that the replacement wetland meets the hydroperiod and other success criteria. Ultimately, if the project does not meet design goals and success criteria, the project may require corrective action or else it would be ineligible for a Certificate of Compliance.

The groundwater and surface water assessment methods listed in Sections 2.2.2 to 2.2.4 should be used during hydrologic monitoring as appropriate. Ultimately, the results of the monitoring should be compared to the design hydroperiod to determine success. More specifically, monitoring should include:

- At least one groundwater observation well in a representative location within the replacement wetland, with a staff gauge attached to the well casing. For surface water dependent wetlands, a staff gauge alone will suffice.
- The ground surface elevation at the representative location for hydrological monitoring should reflect the average grade elevation for the replacement wetland. The representative location should not be located in a pit within the replacement wetland.
- The well(s) in the replacement wetland should be constructed with sand pack and screened the full length. Bentonite or grout seal should be placed around the well casing to prevent intrusion of surface water. A cap must be installed and locked if it is loosely fitted to prevent vandalism.
- Water levels within the well(s) and at staff gauges should be recorded as frequently as needed to document success of the hydroperiod goal. In extreme cases (dry years and/or complicated sites), monitoring might be done as frequently as once per week during the growing season.
- Water levels may be recorded manually or by automated equipment.
- An onsite precipitation gauge may be used to record precipitation inputs.

The hydrology section of the monitoring report should include:

- Well water levels and/or staff gauge levels, as applicable
- Precipitation data if a precipitation gauge is used
- Characterization of the hydrologic conditions as above normal, normal, or below normal using the Frimpter Method to place the weekly well readings in context
- Duration of inundation/saturation (e.g., length of time inundation/saturation occurs during the growing season, frequency of inundation/saturation, etc.)
- Specific locations of inundation/saturation if the site has a variety of conditions

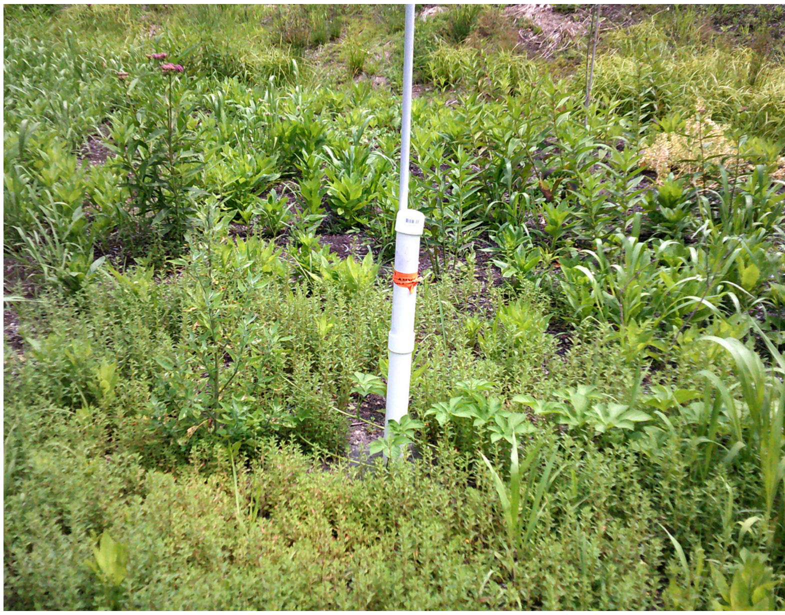


Figure 14 Monitoring piezometer located in wetland replacement area

4.3 | Demonstrating Hydric Soils

Hydric soil characteristics develop slowly after the construction of a replacement wetland. Monitoring and documenting hydrology with assessment methodologies listed in Section 2.2.2 and 2.2.3 is integral to understanding hydric soil development. In addition, the methods below can help document reducing conditions in the soil when adequate hydrology is present:

- Use of IRIS (Indicator of Reduction In Soils) tubes, which are polyvinyl chloride (PVC) tubes coated with iron (Fe) oxide paint.[23] When IRIS tubes are placed in a soil with anaerobic properties, iron oxide is reduced and removed over time. Upon retrieval, zones where the iron oxide paint is removed can be documented and quantified to determine the degree of saturation that occurred.
- Measure organic carbon (or organic matter) in the surface horizons of the replacement wetland after construction, and then again at distinct times in the future (e.g., minimum 2 years, potentially 5 years – 10 years as the Regulations allow for limited projects, variance projects, local bylaw projects, etc.) A measurable increase in organic carbon over time would indicate that the soil is substantially anaerobic in the surface horizon and "naturally" accreting soil organic matter.

The soil section of the monitoring report should include:

- Evidence of hydric soils or documentation that the hydrology supports the development of hydric soils
- Results of IRIS tube testing if performed
- Results of organic carbon measurement if performed.

4.4 | Demonstrating Establishment of Wetland Vegetation

The availability of robust wetlands nursery stock and seed mixes has made it easier to establish wetland vegetation in replacement areas. Revegetation may include native wetland plants that naturally colonize the replacement area, as well as those established via planting and seeding. Poor soil conditions and inappropriate hydrology can result in vegetation coverage that is sparser than desired or required. The regulatory requirement for vegetation is "…at least 75% of the surface of the replacement area shall be reestablished with indigenous wetland plant species within two growing seasons…" (CMR 310 10.55(4)(b)6.). The recommended approach for determining whether a replacement area has achieved 75% coverage with indigenous wetland plants is the **line-intercept method**, as detailed below.

1. Establish a random starting point on the perimeter of the replacement area and establish an initial transect across the replacement wetland perpendicular to the replacement wetland edge. Establish additional transects parallel to the first transect, evenly spaced, and sufficient to cover the entire replacement area. Enough transects should be established to generate 100 sampling points (see step 2).

2. Starting at the edge of the replacement area and moving along each transect, establish a sampling point every two feet along the transect line (for small replacement areas one foot can be used instead).

3. At each sampling point, record whether any native wetland plant species intersects the transect line. On a tally sheet, mark a "yes" if one or more native wetland plants are encountered at a sampling point; otherwise mark "no." Continue until 100 sampling points have been recorded (or fewer for small replacement wetlands).

4. If 75 percent or more of the sampling points are marked "yes" for native wetland plants, then the 75% standard has been met. Issuing Authority

Note: This method is appropriate for replacement areas 0.5 to 1 acre in size. For larger or smaller sites, simply adjust the number of transects and sampling points proportionally. For example, use 50 sampling points for a 0.25-acre replacement area and 200 sampling points for a 1.5 to 2-acre replacement area.

The vegetation section of the monitoring report should include:

- Vegetation planting success
- Natural plant regeneration results as applicable
- Recommendations for additional plantings if it appears that the replacement area will fail to meet the standard of 75% coverage by indigenous wetland plants
- Invasive species presence / absence. Note that any invasive plants should be removed (preferably by hand) before they become widespread and fully established
- Projection of potential successional patterns based on observed establishment of vegetation

In general, monitoring reports should document progress toward achieving specific success standards set by the Issuing Authority. For vegetation specifically, replacement plans

[23] Jacob F. Berkowitz, Jacob F., 2009, Using IRIS Tubes to Monitor Reduced Conditions in Soils-Project Design, U.S. Army Corps of Engineers, ERDC TN-WRAP-09-1. Rabenhorst, M.C., 2008, Protocol for Using and Interpreting IRIS Tubes, Soil Survey Horizons, Volume 49, No. 3, pp. 74-77.

should include a narrative specifying target rates of plant survival, and alternative plans for establishing vegetative communities if initial approaches fail.

4.5 | Final Monitoring Report

The final monitoring report should be accompanied by an as-built plan that demonstrates that the replacement area was constructed according to plans submitted with the Notice of Intent and required by the Order of Conditions, and is in compliance with regulatory performance standards. The final monitoring report should indicate the conditions at the replacement site (including stabilization of embankments) and describe in detail how the functions of the impacted wetland have been replicated by the replacement wetland. **If the replacement area fails to demonstrate wetlands hydrology or achieve the standard of 75% wetlands vegetation within two growing seasons, the Issuing Authority should require additional contingency measures. A Certificate of Compliance should not be issued until regulatory compliance has been achieved.**

Applicants should be prepared to mobilize after replacement wetland construction in the event that the replacement wetland is determined by the Issuing Authority to be unsuccessful. A description of who will be responsible for post-construction remedial actions should be included in the Notice of Intent.

5.0 | Alternatives to Wetland Replacement as Mitigation for BVW Alteration

There are two types of projects subject to the WPA for which there is flexibility to use alternatives to wetland replacement for meeting BVW performance standards.

- "Limited Projects" per 310 CMR 10.24 and 10.53 (note that proposing these alternatives to wetland replacement may trigger the filing of an individual 401 application – see 314 CMR 9.03(1))
- Variance projects per 310 CMR 10.05(10); variance projects are permitted by the Commissioner of MassDEP, not by conservation commissions

In general, wetland replacement should be provided for any direct loss of BVW. However, in some cases, it may not be feasible to replace wetlands, for instance, where a wetland replacement is expected to be of marginal quality, or wetland replacement would come at the expense of high-quality upland habitat (e.g., forest). In these cases, compensatory mitigation may be used as an alternative to traditional BVW replacement as long as it provides an equivalent level of environmental protection. Examples of compensatory mitigation projects that may be acceptable as substitutes for direct loss of BVW include the following.

1. Reconnection of rivers or streams with their floodplains. Restoring more natural hydrology to rivers and streams, and the wetlands that border them is an important climate adaptation strategy that can also provide immediate benefits for flood control, prevention of storm damage, fisheries, and wildlife habitat. This can be done by removing berms, levees, or other structures that hydrologically separate rivers/streams from their floodplains. Square footage of the amount of floodplain reconnected to a river or stream is one way to quantify benefits relative to the amount of BVW impacted.

2. River or stream restoration. This may include stream daylighting (opening up piped or buried streams), restoration of riprapped banks or armored channels, use of bioengineering techniques to stabilize eroding banks, restoration of meanders, riffles and pools, and the enhancement of instream habitat structure (woody debris or rock veins and deflectors).

3. Dam removal. Dam removal provides benefits for aquatic organism passage and restores ecological functions such as downstream movement of sediment and woody debris. Dam removal can also help maintain cold-water habitat in downstream reaches of rivers and streams. Dam removal projects often improve fisheries and wildlife habitat. By reducing the risk of a breach during severe storms, these restoration projects may also contribute to the prevention of flooding, storm damage and pollution. The MA Division of Ecological Restoration has an online tool that can be used to evaluate the relative ecological benefit of removing any known dam in the Commonwealth (https://www.mass.gov/service-details/ders-restoration-potential-model-tool).

Figure 15 Dam removal and stream restoration in progress utilizing several bioengineering techniques including boulders, slope stabilization, and root wads.

4. Replacement of road-stream crossings (culverts and bridges) with structures that provide substantially better passage for sediment, woody debris and aquatic organisms. Replacement of problematic crossings provide many of the same benefits of dam removal (except for restoration of water temperature), although to a lesser extent. The Critical Linkages project, an extension of the CAPS project implemented by UMass Amherst, provides a basis for evaluating ecological benefits of crossing replacement projects. Critical Linkages data for Massachusetts can be downloaded from: http://umasscaps.org/applications/critical-linkages.html.

Figure 16 A partially-blocked culvert filled with sediment and debris.

5. Combination of dam removal and culvert replacement. A web-based tool (http://ecosheds.org/aq-connectivity-tool/#/) based on the UMass Critical Linkages assessment allows users to evaluate various combinations of dam removals and /or crossing replacements to determine which scenarios would provide the greatest ecological benefits. These benefits are expressed in units of "connectivity gain" or "restoration potential" that are only useful for comparative purposes (the units have no intuitive meaning). Calculating the acreage of BVW reconnected above and below a dam (i.e., between the next upstream and downstream barriers) is another way to quantify benefits relative to the amount of BVW impacted.

6. Reforestation (with preservation) of disturbed riparian corridors (including Buffer Zone, Riverfront Area, and Bordering Land Subject to Flooding)

7. Restoration of previously altered wetlands, such as through the removal of historic and lawfully located (i.e., previously permitted or "legacy" fill or solid waste)

Some projects may offer opportunities to restore BVW in place after a temporary disturbance. If the amount of BVW restored is equal to or exceeds the amount impacted, then wetland replacement is not necessarily required. However, these projects often do not fully replicate the functions of the undisturbed BVW, or the functions will not be fully replicated for many years (e.g., clearing of trees from a forested wetland). Compensatory mitigation, such as described above, can be used to address these functional or temporal impacts, as a supplement to traditional wetland replacement or when no replacement is required.

Land preservation and control of invasive plants can also play a role in alternative compensatory mitigation. While neither approach alone would be generally sufficient for mitigating the direct loss of BVW, preservation used in concert with the alternatives described above is a reliable and often proper way to augment a replacement area alternative in order to demonstrate that such mitigation would not be "undone" at some future date. Adding an invasive species management component to the projects above should also be considered to supplement ecological benefits.

Whether compensatory mitigation is used to compensate for direct loss of BVW or functional/temporal losses, where square footage is not a relevant measure it will be necessary to use best professional judgment by both the designer and the Issuing Authority to determine if the proposed restoration would provide an equivalent level of environmental protection.

6.0 | Issuing a Certificate of Compliance

The issuance of a Certificate of Compliance is an important step in ensuring the successful mitigation of BVW impacts. Upon completion of the project, the applicant is required to request in writing the issuance of a Certificate of Compliance from the Issuing Authority that issued the Order of Conditions permitting the project. Such a request should be accompanied by as-built plans and other documentation sufficient to demonstrate that the project has been completed in compliance with applicable performance standards and the Order of Conditions.

Issuing Authorities should review the following list prior to issuing a Certificate of Compliance. Issuing Authorities can deny a request for Certification if replacement areas are not large enough, fail to demonstrate wetlands hydrology, do not meet the 75% wetland plant criteria or are not constructed as designed or conditioned.

1. An as-built plan stamped by a RLS or PE should be submitted that documents the construction of the replacement area. The size of the replacement area as documented should be consistent with the size proposed or required in the

Order of Conditions.

2. A site visit should be conducted prior to issuing a Certificate of Compliance. The replacement area should be compared with the design plans and the Order of Conditions to ensure that it has been constructed as proposed and WPA interests have been replicated.

3. Applicants should provide evidence of appropriate hydrology in the wetland replacement area as part of the request for Certificate of Compliance. Indicators of these conditions would include: a) groundwater, including the capillary fringe, within a major portion of the root zone; b) observation of prolonged or frequent flowing or standing water; and/or c) characteristics of hydric soils. This is a critical requirement for a Certificate of Compliance as failure to establish appropriate hydrology reduces the likelihood of success. The replacement area is not successful if it does not have sufficient water and/or meet the hydroperiod design criteria.

4. At least 75% of the surface area of the replacement site should be reestablished with indigenous wetland species. A qualified wetland scientist should certify that the vegetative community is in compliance with this performance standard. The wetland scientist should also certify that the vegetative communities that were established are comparable to the ones proposed or are on a trajectory to attain vegetation goals. The Order of Conditions may be extended if it is about to expire but the replacement area has not fully established itself through two growing seasons. Each different layer of wetland vegetation (forested, shrub, herbaceous etc.) should be checked to ensure that it is thriving as designed.

5. Vegetation should be checked to ensure that no invasive species have colonized the replacement area. If they have, measures should be taken to eliminate the invasive species prior to issuance of a Certificate of Compliance.

6. All buffer zone areas surrounding the replacement wetland should be stabilized. Inspections should be conducted of erosion control measures such as straw bales and silt fences and those devices should be removed once the site is stabilized. A Certificate of Compliance should not be issued until all erosion controls are removed and any soils disturbed by their removal stabilized.

7. Any drainage feature that supplies water to the replacement area should be checked to ensure water is freely flowing without clogging from sediments, trash, or other impediments.

Issuing Authorities should deny requests for Certificates of Compliance if replacement areas are not adequate and/or not substantially in compliance with performance standards in CMR 310 10.55(4)(b), the approved plans, and the Order of Conditions. Procedurally, Issuing Authorities can allow additional time for plantings or remedial work to reach compliance by a) extending an Order of Conditions, b) requiring submission of a new Notice of Intent if the Order has expired, or c) issuing an enforcement order if compliance cannot be voluntarily attained.

If the project has been completed in compliance with performance standards and the Order of Conditions, the Issuing Authority should then issue a Certificate of Compliance. If the Final Order contains conditions that continue past the completion of the work, such as maintenance or monitoring, they should be included in the Certificate of Compliance. When a Certificate of Compliance is issued, the applicant is required to record it at the Registry of Deeds.

Each conservation commission should maintain records of replacement projects in their town. Such records are a valuable resource for the commission to learn from experience what approaches work well in the area and to document reasons for project failure.

7.0 | Conclusions

Protection of the wetland resources in the Commonwealth cannot be successful unless permitted wetland losses are adequately mitigated by successful replacement projects. Improvement in the success of replacement projects can be accomplished if all of the critical steps outlined above are followed when planning, reviewing and permitting projects with wetland loss and replacement. Mitigation plans should be carefully analyzed to ensure that appropriate requirements and design features are included. The project should be monitored at appropriate points before, during and after construction, so that mid-course corrections can be made if necessary. **Appendix B** describes common problems with replacement wetlands and should be reviewed during project design and implementation. Finally, Certificates of Compliance should only be issued when the project has met all of the appropriate requirements. Following these critical steps in accordance with the guidance provided here will ensure that the public interests in wetlands of the Commonwealth will be protected.

APPENDIX A | USDA Growing Seasons

Soil Survey Area	Growing Season Dates	Weather Station
Barnstable County	April 23 – October 25	Hyannis
Bristol County (Northern)	May 4 – October 8	Taunton
Bristol County (Southern)	April 29 – October 17	New Bedford
Dukes County	April 15 – November 4	Edgartown
Essex County (Northern)	April 30 – October 17	Haverhill
Essex County (Southern)	April 28 – October 17	Middleton
Franklin County	May 6 – October 10	Greenfield
Hampden County	May 6 – October 11	Westfield
Hampshire County (Central)	May 7 – October 11	Amherst
Hampshire County (Western)	May 12 – October 5	Worthington
Middlesex County	May 3 – October 8	Bedford
Nantucket County	April 16 – November 7	Nantucket
Norfolk County	April 30 – October 16	Walpole
Plymouth County	April 21 – October 27	Rochester
Worcester (Central)	April 21 – October 23	Worcester
Worcester (Northern)	May 9 – October 1	Birch Hill/ Royalston
Worcester (Southern)	May 3 – October 18	Buffumville/ Charlton

Growing season ranges can be determined from first and last dates of frost averaged for an available time period. The National Weather Service provides that information here: **https://www.weather.gov/wrh/Climate?wfo=box**.

APPENDIX B | Common Problems and Mistakes

Common Problems with Replacement Wetlands

1. Stormwater detention basins are not wetland replacement areas. Such basins are drainage structures and need to be maintained (e.g., cut, dredged, etc.).

RECOMMENDATION: Include maintenance provisions in Order of Conditions and Certificates of Compliance for detention basins and require that replacement wetlands not be used as stormwater structures.

Figure 17 Stormwater detention basin that requires regular maintenance

2. Side slopes of the proposed replacement area are not accounted for, and the final replacement wetland is smaller than required.

RECOMMENDATION: During the permitting process review plans to be sure that side slopes do not extend into replacement wetland. The Issuing Authority should require an inspection immediately after excavation of replacement wetland.

3. An environmental monitoring is not used, the vegetation dies and is not replaced.

RECOMMENDATION: It is critical to check plant viability and require replanting, if necessary, before issuing a Certificate of Compliance. Include a condition in the Order requiring written monitoring reports at regular intervals and make sure the plan includes replacement of dead or dying vegetation if it is anticipated that the site will not meet 75% after the first year.

Figure 18 Example of wetland replication area where vegetation has not reached 75% cover

4. Wetland replacement is site too dry.

RECOMMENDATION: Prior to approval of the final design, ensure that seasonal groundwater elevations for the replacement area are monitored and the hydroperiod understood. Bottom elevations should be surveyed and if necessary, additional grading should be used to achieve the proper hydrology. The environmental monitor should determine the groundwater elevations before allowing organic soils to be added to ensure that elevations are appropriate to ensure adequate hydrology

5. Wetland replacement site too wet.

RECOMMENDATION: Wetland soils should be added to the site to ensure proper grades. Grades in the replacement area should be surveyed to determine exactly how much fill is needed to achieve design elevations. Groundwater data collected during design should be reevaluated and the design adjusted to establish proper elevations for the proposed vegetation.

6. The applicant constructs the project first and fails to complete the replacement area as required.

RECOMMENDATION: Require wetland replacement to be an initial phase of the project. Commissions should follow up with the landowner, applicant and the wetland specialist identified in the application immediately during construction to obtain voluntary compliance and a milestone schedule for compliance. If the replacement wetland is not completed, a Certificate of Compliance should not be issued. Enforcement action should be taken as needed.

7. The wetland replacement area is deeper than the adjacent wetland, resulting in a change in hydrology and drying out of adjacent wetland.

RECOMMENDATION: Review the cross-sectional information for groundwater depths and depth of replacement area and make appropriate changes.

8. The plants proposed for the replacement area are not common in nearby wetlands.

RECOMMENDATION: Plants should reflect the species density and composition in the altered area. Require native species that are common in the project's town and that were observed in the impacted/reference wetland.

9. The topography is at insufficient detail to accurately assess groundwater elevations, compensatory storage requirements, and resulting hydrology.

RECOMMENDATION: Require surface elevation data be shown at 1-foot contours on the design and as-built plans.

10. Invasive species are beginning to colonize the replacement area.

RECOMMENDATION: Avoid using soils or plants from areas containing invasive species. Require monitoring and if invasive plants are found in the replacement wetland, require removal during the first growing season and in subsequent years after (if necessary).

11. Wildlife habitat functions not replaced.

RECOMMENDATION: Require plans to reproduce previously existing wildlife habitat features, including plant community composition and structure.