The Hydrogeomorphic Approach and Its Use in Vernal Pool Functional Assessment

MARY BUTTERWICK

U.S. Environmental Protection Agency, Region IX, 75 Hawthorne Street, San Francisco, CA 94105 (butterwick.mary@epamail.epa.gov)

ABSTRACT. The hydrogeomorphic (HGM) approach is a method being developed to measure the condition of wetlands through the use of ecosystem functions. The HGM approach involves the classification of wetlands based upon common hydrological and geomorphic characteristics, the identification of functions that each class of wetlands perform, and the use of reference wetlands as the basis for scaling functional attributes of wetlands. The HGM assessment models developed for the regional subclasses of wetlands provide a framework for determining differences and net changes in functional performance resulting from both degradation and restoration. Several regional pilot projects to develop HGM models for specific subclasses of wetlands are currently underway nationwide. In California, the U.S. Army Corps of Engineers, Sacramento District, is leading an interagency effort to develop a regional HGM guidebook for vernal pools, a subclass of the depressional hydrogeomorphic class of wetlands. The interagency team has drafted descriptions of ten functions representing the suite of hydrologic, biogeochemical, and habitat support processes that are necessary to maintain vernal pool ecosystems. The products of the interagency team will be a draft regional guidebook that includes the vernal pool models of functions, methods for applying the models, documentation of the reference sites, and the logic used to develop and calibrate the models. The guidebook may be used in a regulatory context to evaluate impacts to vernal pools, mitigation requirements, and in a nonregulatory context to support planning and restoration efforts that focus on vernal pool resources.

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INTRODUCTION

The U.S. Army Corps of Engineers (Corps) is leading an interagency effort to develop the hydrogeomorphic (HGM) approach to measure the condition of wetlands through the use of ecosystem functions. The method is being developed in recognition of the need to more accurately measure differences and changes in wetland function from both degradation and restoration. The HGM models are also intended to provide a tool for rapidly assessing wetland functions. In 1995, the Corps initiated several regional pilot efforts in California, Florida, Kentucky, and North Dakota. The Sacramento District Office of the Corps is leading a regional pilot project to develop an HGM regional guidebook for vernal pools. The Environmental Protection Agency (EPA) is represented on an interagency assessment team that is working with the Corps District on this pilot project. Other agencies represented on the assessment team include the U.S.D.A. Natural Resources Conservation Service, U.S.D.I. Fish and Wildlife Service, and California Department of Transportation.

The HGM approach provides a procedural framework for measuring the capacity of a wetland to perform functions. The HGM approach involves the classification of wetlands based upon common hydrological and geomorphic characteristics; the identification of functions that each class of wetlands perform; and the use of reference wetlands as the basis for scaling or measuring the functional attributes of wetlands. This paper includes brief descriptions of the components of the HGM approach, provides an update on the vernal pool pilot project, and outlines future steps in preparing HGM models for vernal pools. This overview is based in large part on a series of recent publications on the HGM approach (Brinson, 1993a; 1993b; 1995; 1996; Brinson et al., 1994; Smith et al., 1995; Brinson and Rheinhardt, 1996).

COMPONENTS OF THE HGM APPROACH

Classification of Vernal Pools

Because wetlands occur under a wide range of conditions, the HGM approach involves classifying wetlands first into broad classes and then into geographically similar subclasses that function similarly. Classifying reduces the range of variation that must be dealt with for any given assessment and allows for the consideration of only those functions most likely to be performed by a particular type or subclass of wetland. According to the HGM approach, a guidebook is developed for each recognized subclass of wetland which includes the vernal pool models of functions, methods for applying the models, documentation of the reference sites, and the logic used to develop and calibrate the models.

Seven broad classes of wetlands are currently recognized and are based on hydrogeomorphic characteristics of: (a) geomorphic setting, referring to the wetland's topographic position in the landscape; (b) dominant water source, or the location of water just prior to entry to the wetland; and (c) dominant hydrodynamics, the direction of movement of water through the wetland (Table 1). Depressional wetlands, the class of wetlands most pertinent to this conference, is the focus of this paper. Vernal pools are an example of a regional subclass of depressional wetlands.

Depressional wetlands, including vernal pools, occur in topographical depressions with closed elevation contours that allow for the accumulation of surface water. However, these types of wetlands may have any combination of inlets and outlets or lack them completely. Vernal pools, in particular, can exhibit great seasonal variation in the direction and flow of water (Hanes et al., 1990). During the initial rainy period, precipitation is the primary source of water into the vernal pool. During the middle of the rainy season, precipitation continues to dominate, but subsurface flows and channel inflows can be significant. Late in the rainy season, subsurface flows predominate. The dominant direction of movement of water in a depressional wetland is vertical fluctuation resulting primarily from precipitation and evapotransporation. Additional water losses are from soil recharge, bottom seepage, and channel outflow, all of which can affect the hydrologic functioning of pools during a single rainy season.

Vernal pools will be further classified to reflect significant regional differences among pools within the California Floristic Province. The assessment team has not finalized the vernal pool classification to be used; but the specific subclass to be modeled will likely be based on a consideration of factors such as bioregion, geomorphic or landscape setting, and surface geology. Using these factors, for example, a specific subclass of vernal pools could be defined to include pools within the Sacramento Valley subregion of the Great Central Valley (Hickman, 1993) on high river terraces with soils containing a claypan that perches water for a short to long duration (Tugel, 1993).

TABLE 1. Hydrogeomorphic classes of wetlands.

Riverine – in floodplains and riparian corridors in association with stream channels
Depressional – in topographic depressions
Slope – on sloping land with discharges of groundwater to the land surface
Mineral Soil Flats – on interfluves, relic lake bottoms, or large floodplain terraces
Organic Soil Flats – peatlands, controlled by vertical accretion of organic matter
Lacustrine Fringe – adjacent to lakes
Estuarine Fringe – tidal wetlands along coasts and estuaries

Functions of Vernal Pools

The HGM approach involves the identification and description of functions for each subclass of wetlands. Functions are processes that characterize self-maintaining ecosystems. Functions are the result of the physical, chemical, and biological attributes or processes of wetlands and are reflected in the general categories: hydrology, biogeochemical, and habitat support. The term is used primarily as a distinction from values (i.e., goods and services). The HGM approach is not designed to assign "value" to wetland functions. The term values is associated with society's perception of ecosystem functions which can change over time or may also reflect policy issues beyond the scope of the HGM approach. Functions occur in ecosystems regardless of whether or not society benefits from their goods and services.

As of this writing, the assessment team is considering ten functions of vernal pools (Table 2). This suite of functions reflects input from a recent technical workshop to solicit peer review of the draft model. A definition of each function and a brief justification for including the function is provided here.

The draft HGM models currently include three hydrology functions that focus on surface water storage, subsurface water exchange, and surface water conveyance among vernal pools in a vernal pool complex (Hanes et al., 1993; Hanes and Stromberg, 1998; Zedler, 1987). The function entitled, Surface Water Storage in Pool, is the capacity of the pool basin to pond water seasonally and retain surface water for long duration. Changes to the surface topography or impermeable substrate can result in either too much or too little water entering and being stored in the vernal pool basins relative to the unaltered condition. The function entitled, Subsurface Water Exchange, is the capacity of the subsurface area above the restrictive layer to hold water and allow exchange of water between the pool basin and surrounding landscape. The water holding capacity of the soil is associated with discharge to the pool basin from the surrounding area and for dynamic water exchange between the pool basin and the surrounding areas. The Surface Water Conveyance function is the interstorm conveyance of concentrated flow into and out of pool basins through swales. For the purposes of this function, swales are defined as surface drainage features which convey concentrated flow, but lack a defined bed and bank. Swales convey sustained discharge of water to pools between storms;

TABLE 2. Functions of vernal pools.

HYDROLOGY	
1.	surface water storage in pool
2.	subsurface water exchange
3.	surface water conveyance
BIOGEOCHEMICAL	
4.	element cycling
5.	element removal
HABITAT SUPPORT	
6.	maintains characteristic vegetation
7.	maintains characteristic aquatic invertebrates
8.	maintains amphibian and avian populations
9.	maintains populations of sensitive taxa
10.	maintains habitat interspersion and connectivity

thereby recharging pools and allowing physical and biological processes to occur.

The biogeochemical functions currently being considered for vernal pools pertain to element removal and cycling (Zedler, 1987). The function entitled, Element Removal, involves the removal of imported nutrients, contaminants, and other elements and compounds through biotic and abiotic processes. This process concentrates imported chemical constituents in the vernal pool or swale where they can later be taken up by various aquatic organisms and the vernal pool soils. Because of the sensitivity of vernal pool ecosystems to pollutant loadings, the emphasis of this function is on maintaining water quality characteristic of unaltered vernal pools and swales (Eng et al., 1990). The function entitled, Element Cycling, refers to the biogeochemical processes that convert and recycle elements and compounds from one form to another. Element cycling provides the necessary nutrients, elements, and compounds in forms that can be assimilated by vernal pool flora and fauna, enabling the growth, maturation, and reproduction of vernal pool species.

Four habitat support functions focus on the maintenance of vegetation and aquatic invertebrate, amphibian, and avian taxa that are characteristic of vernal pool systems. The function entitled, Maintains Characteristic Vegetation, is the capability of perpetuating predominantly native vegetation. Plant taxa in vernal pools typically exhibit a variety of morphological, reproductive, and developmental adaptations in response to extreme environmental conditions of wetting and drying (Holland and Jain, 1988; Thorp, 1990; Thorp and Leong, 1995). The flora associated with unaltered vernal pools contains a significant proportion of regional and localized endemic species (Stone, 1990). The function entitled, Maintains Characteristic Aquatic Invertebrates, refers to the hydrologic, chemical, and temperature conditions that are necessary to support the dynamic life histories of aquatic invertebrate species associated with vernal pools (Alexander, 1976; Simovich et al., 1992). The amphibian and avian taxa are combined into one function that focuses on aspects of the vernal pool habitat that support the reproduction, larval development, and feeding of amphibian populations and the resting, feeding, hiding, and reproduction of avian populations (Jokerst, 1990; Zedler, 1987; Kaplan, 1984).

The function entitled, Maintains Habitat Interspersion and Connectivity, refers to the spatial distribution of a vernal pool or pool complex in reference to adjacent pools and other aquatic habitats. These spatial linkages between vernal pools and adjacent habitats within the surrounding landscape maintain the overall diversity of habitats and long-term persistence of characteristic vernal pool plant and animal communities (Holland, 1978; Ebert and Balko, 1984; Holland and Jain, 1981; Hanski, 1996; Hansson et al., 1995). The function entitled, Maintains Populations of Sensitive Taxa, is the capability of perpetuating populations of sensitive taxa, many of which are restricted to vernal pools. The function emphasizes the biologically rare components of the vernal pool ecosystem (Eng et al., 1990; Stebbins, 1976; Skinner and Pavlik, 1994; Stone, 1990). The assessment team has not yet determined whether to retain this function or to incorporate the concept of biological rarity as a variable of the other habitat support functions.

Variables of Vernal Pool Ecosystems

Within each index of function is a set of variables representing certain characteristics of a wetland ecosystem or the surrounding landscape that influence the capacity of a wetland to perform a function. As of this writing, the assessment team has identified forty variables to characterize the ten functions. These variables describe characteristics of vernal pools relating to substrate, vegetation composition, hydrologic regime, landscape position, and land use. Future revisions of the models of functions will likely include fewer variables as duplicative or overlapping characteristics are combined.

For the ten functions, as currently drafted, a particular variable may apply to more than one function. For example, the variable entitled, Morphometric Pool Diversity, which is defined as the variation in pool size and depth within a pool complex, applies to four of the habitat support functions. Variables may also be expressed at different geographic scales. The variable entitled, Presence of Vernal Pool Indicator Taxa, applies only to the vernal pool wetland area, whereas the variable entitled, Upland Land Use, applies to the surrounding watershed that contributes to the vernal pool. At a landscape scale, the variable entitled, Landscape Integrity, concerns the degree of connectivity between the vernal pool and adjacent aquatic habitats.

In order to estimate a specific function, direct measurements or indirect visual indicators of each applicable variable are assigned a series of subindices ranging from a 1.0 (fully functioning condition) to 0.0 (indicating the absence of function). The scaled variables are combined into an equation or index of function that expresses the level of function of the wetland, relative to the unaltered condition, to sustain the characteristic function. The subindices are based on data from reference wetlands.

Reference Wetlands

Reference wetlands are the most critical component of the HGM approach. The HGM approach utilizes "reference" wetlands as a means for establishing the scale, or index, against which other wetlands of the same type in a particular geographic area can be compared. The reference framework provides a basis for determining which wetlands are functioning at characteristic and sustainable levels.

Reference wetlands are selected to encompass the known variation and range of conditions that a particular wetland subclass may exhibit, from relatively unaltered to highly degraded. The reference domain includes all wetlands that belong to a single subclass of wetlands within a defined geographic region. The reference domain cannot be determined until the subclass of wetlands to be covered is clearly defined. Although the vernal pool models for a particular subclass will be developed using reference data from vernal pools within a subregion of the Great Central Valley, it is anticipated that certain components of these models will be applicable to vernal pools throughout the California Floristic Province. The reference standards, with an index of 1.0, are conditions exhibited by a group of reference wetlands that are unaltered or least altered, and thus function at sustainable levels across the 'suite of functions' performed by the regional wetland subclass. The functional indices that result from the calibration procedure provide a basic measure of the functional capacity of a wetland.

Status of Vernal Pool Model

Thus far, the assessment team has prepared a set of draft models which includes descriptions of the functions, variables, and measures that relate to each variable. These models are currently being revised, based on input from a technical workshop that was conducted in May, 1996.

The U.S. Army Corps of Engineers (1996a) published a draft National Action Plan to develop the HGM approach which includes a protocol for developing regional guidebooks. According to the protocol outlined in Table 3, the assessment team is early in the process of completing the HGM regional guidebook for vernal pools. Over the next year, the assessment team plans to identify the specific subclass of vernal pools to be modelled, define the reference domain, and develop a draft regional guidebook. Additional tasks involve developing the reference framework, refining the classification and calibrating the functional indices, field testing the models and completing the draft guidebook. An end product of the assessment team's efforts is an Operation Draft Regional Guidebook which includes the vernal pool profile and synthesis of the relevant literature, the models of functions, the methods for measuring and applying the models, a report documenting the reference sites and reference standards, and the procedure used to develop and calibrate the models. Peer review is critical to this process and will be solicited at various points in developing the regional guidebook (Table 3). The Corps anticipates publishing an Operational Draft Regional Guidebook within two years. The Guidebook will then be field tested over a two-year period and revised, as appropriate.

Potential Applications of HGM

There are several potential applications of the HGM approach. In a regulatory context, the method can assist agencies, such as the Corps and EPA, in determining whether or not a proposed discharge of dredged or fill material into waters of the United States, including wetlands, complies with the Section 404(b)(1) Guidelines (Guidelines), the environmental criteria that must be met to qualify for a permit under the provisions of Section 404 of the Clean Water Act. For instance, the HGM models can be used to compare pre- and post-project conditions to detect significant changes in functions and to evaluate alternatives that avoid or minimize impacts to waters of the United States, as required by the Guidelines [40 CFR 230.10(a)]. Once the least environmentally damaging practicable alternative has been identified, the HGM models can provide a framework for developing mitigation to offset unavoidable impacts to waters of the United States [40 CFR 230.10(d)].

The assessment results estimate the projected change in the functional condition of the target wetland from the proposed project and mitigation. It is subsequently up to the Corps, EPA and other resource agencies to determine if the functional changes are consistent with the Guidelines and other applicable regulations and policies. The determination of whether or not a permit may be issued is essentially an administrative procedure, with HGM providing a technical tool to assist the agencies in this decision making process.

An HGM-based functional assessment will not be required for all projects authorized under Section 404 of the Clean Water Act. The HGM approach is intended to be a relatively 'rapid assessment' method and does not preclude or replace the need for more detailed analyses to meet other requirements, such as the Endangered Species Act of 1973, as amended. In addition, many fill activities having minimal adverse impacts to waters of the United States are authorized under one or more Nationwide General Permits that do not require an alternatives analysis or a functional assessment (U.S. Army Corps of Engineers, 1996b).

TABLE 3. Steps in development of model guidebooks.

PHASE I. Organization of Regional Assessment Team
Identify and train A-Team members in HGM classification and assessment
PHASE II. Identification Regional Wetland Assessment Needs
Identify and prioritize regional wetland subclasses
Define reference domains
Initiate literature review
PHASE III. Draft Model Development
Review existing models of wetland functions
Identify reference wetland sites, functions, variables, and measures for subclass
Develop functional indices
PHASE IV. Draft Regional Wetland Model Review
Obtain peer-review of draft models/conduct workshop to critique models
Revise model to reflect recommendation from peer-review and workshop
Obtain second peer-review of draft model
PHASE V. Model Calibration
Collect data from reference wetland sites
Calibrate functional indices using reference wetland data
Field test accuracy and sensitivity of functional indices
PHASE VI. Draft Model Guidebook Publication
Develop draft model guidebook and obtain peer-review
Publish as an Operational Draft of the Regional Wetland Subclass HGM Functional Assessment Guidebook to be used in the field
PHASE VII. Implement Draft Model Guidebook
Identify and train users in HGM classification and evaluation
PHASE VIII. Review and Revise Draft Model Guidebook

Another regulatory application of the HGM approach is for making ‘minimal effects determinations’ under provisions of the Food Security Act. The HGM approach can be used to identify specific mitigation requirements under this authority and to monitor progress in functional gains from mitigation projects.

In a non-regulatory context, the HGM approach can support local wetland planning and restoration projects. The HGM variables and reference data provide a template for designing and more accurately tracking functional gains from wetland restoration efforts. The functional profile that is developed through the HGM approach, in concert with other sources of information, can assist the public and agencies in establishing goals regarding protection, restoration, and management of wetlands in a planning area.

The EPA is also interested in exploring opportunities for applying an HGM approach in the states' wetland water quality standards programs. For example, the HGM wetland functions identified during implementation of the HGM approach provide a basis for refining state-designated uses for wetlands. The reference data and relevant measurements of variables could be used for establishing narrative or numeric criteria to protect the designated uses of these wetlands.

CONCLUSIONS

The assessment team faces certain technical challenges in developing a meaningful set of models for vernal pools. The models should accurately capture the full suite of functions performed by vernal pools while, at the same time, result in a rapid assessment of these wetland functions. Considerable diversity exists among the vernal pools within the Great Central Valley. Therefore, the specific subclass of vernal pools needs to be relatively homogeneous to avoid applying the model to vernal pools that naturally function quite differently. The models also should reflect the significant seasonal and year-to-year variation that is characteristic of vernal pool ecosystems.

Notwithstanding these challenges, the HGM approach offers potential benefits for managing vernal pool resources. By providing a more accurate and consistent way to determine differences and changes in functional performance of vernal pools, the HGM approach can improve our ability to analyze project alternatives, articulate explicit goals for compensatory mitigation, and provide a template to which restoration can be designed. The HGM models and reference framework provide the data to make better local management decisions regarding wetlands and to measure our progress toward national wetland goals to increase the quality and quantity of our wetland resource, including vernal pools. Finally, the HGM approach utilizes the ecosystem as the fundamental unit of assessment and in this sense, promotes more integrated strategies for managing this important and threatened aquatic resource.

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