A Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Vernal Pool Depressional Wetlands in Southern California

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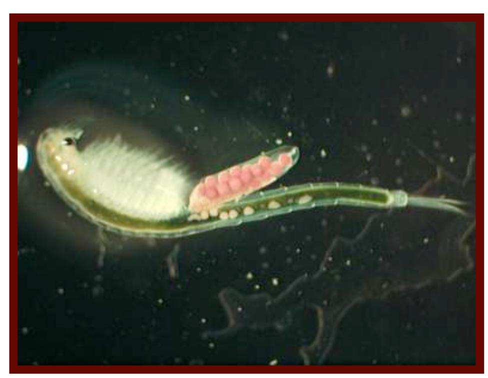

ABSTRACT: This Draft Guidebook is an assessment tool that focuses on the functioning of vernal pool wetlands within the Southern Californian eco-region, specifically San Diego County. Its purpose is to provide trained practitioners the means to achieve efficient, reproducible and logical functional assessment results for vernal pool wetlands in San Diego County, California. Results of these assessments can then be used in a variety of ways, such as evaluation of sites for restoration potential, assessment of impacts from existing or proposed projects and monitoring restoration success. Due to the high degree of variability experienced by temporary wetlands in arid climates, we have developed both direct and indirect functional indices for four of the five functions we identified. Direct assessments can only be made when there is sufficient precipitation to elicit the responses that demonstrate function, and we have sought to objectively define "sufficient." Consistent with an HGM approach, use of this Draft Guidebook should be confined to the geographic region and hydrogeomorphic class, subclass and pool types for which it was developed. Use of this methodology outside the boundaries of the reference domain is wholly inappropriate. We are hopeful that our approach can be modified for other pool types within the region, and to vernal pools in other parts of California and Oregon.

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Appendix A
Glossary

Abiotic: Not biological.

A Horizon: A mineral soil horizon at the soil surface or below the O horizon characterized by accumulation of humified organic matter intricately mixed with the mineral fraction.

Alien Species: not native; introduced purposely or accidentally into an area. See "The Jepson Manual: Higher Plants of California" (Hickman 1993)[1].

Alluviated Basin Origin: Basins or pools formed by alluvial (channel) deposition across their outlets. Such deposition is typically overbank sediment or natural levees formed during floods, often where a large stream with high sediment loads leaves deposits too extensive for a small tributary to cut through. A southern California type locality: several pools in the Ramona area on the floodplain of the larger local streams.

Assessment Model: A simple model that defines that relationship between 1) ecosystem and landscape scale variables and 2) functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a reference domain.

Assessment Objective: The reason for conducting an assessment of wetlands functions. Assessment objectives normally fall into one of three categories. These include: documenting existing conditions, comparing different wetlands at the same point in time (i.e., alternatives analysis) and comparing the same wetland at different points in time (i.e., impact analysis or mitigation success).

Assessment Team (A-Team): An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

Bare Ground: basin surface without vegetation, thatch or cobbles.

Basin: The topographic low in which a vernal pool forms. Basins are typically taken to be the entire pool area below its sill, or 'spill elevation,' at its outlet.

Basin Edge: Maximum elevation of ponding based on the expected 10-yr rainfall event.

Basin Periphery: A 20-ft band surrounding the edge of the basin.

Bedrock: The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface. See "Soil Survey of San Diego Area, California" (Bowman 1973).

Bedrock Basin Origin: Basins or pools formed in bedrock settings in which the bedrock itself is the restrictive unit. Bedrock basins are typically formed by wind or by dissolution. Type localities in southern California: various tinajas.

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1 References cited in this appendix are in References section following main text.

Biotic: Of or pertaining to life; biological.

California Floristic Province: All of California west of the dry regions of the Great Basin and the deserts and extending into southwestern Oregon and northwestern Baja California, MX. See "The Jepson Manual: Higher Plants of California" (Hickman 1993).

Catchment Area: An area from which surface water flows to a pond, channel or other surface hydrologic feature. Synonyms are 'drainage basin' or 'watershed'. (Modified from Gary et al. 1972.)

Claypan: A compact, slowly permeable soil horizon that contains more clay than the horizon above and below it. A claypan is commonly hard when dry and plastic or stiff when wet. See "Soil Survey of San Diego Area, California" (Bowman 1973).

Contributing Area: Hydrologically, an area from which groundwater percolates to a pond, spring, channel or wetland area; it is usually, but not always, the same as 'catchment area,' drainage basin,' or 'watershed,' but can differ substantially in certain geomorphic environments, such as near dunes, sandy soils or pools of tectogenic or landslide origin.

Crustacean: Any mainly aquatic arthropod usually having a segmented body and chitinous exoskeleton. A member of the class Crustacea.

Cyst: Encysted, dormant life history stage of an aquatic invertebrate. May be an egg, embryo or other stage.

Direct Impacts: Project impacts that result from direct physical alteration of a wetland (*e.g.*, the placement of dredge or fill).

Depressional Wetland: A wetland that occurs in a topographical depression with a closed elevation contour that allows accumulation of surface water. Dominant sources of water are precipitation, groundwater discharge and interflow from adjacent uplands. Direction of water movement is normally from the surrounding uplands toward the center of the depression. See "An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices" (Smith et al. 1995).

Direct Measure: A quantitative measure of an assessment model variable.

Dune Dammed Basin Origin: A basin or pool impounded by dunes or other aeolian deposits across a drainageway or swale. Type localities in southern California: Poinsettia Lane in Carlsbad (San Diego County) or the Ellwood Beach pools near the existing bluff (Santa Barbara County).

Endemic Species: native/indigenous species usually confined to a very restricted geographical area or region. See "A Dictionary of Botany" (Little and Jones 1980).

Exotic (non-native/introduced/alien) species: See alien species above.

Flowthrough Basin: a basin with both an inlet and an outlet.

Facultative (FAC): Equally likely to occur in wetlands or non-wetlands (estimated probability 34-66 percent)(Fish and Wildlife Service 1996).

Facultative Wetland (FACW): Usually occurs in wetlands (estimated probability 67-99 percent), but occasionally found in non-wetlands)(Fish and Wildlife Service 1996).

Functional Assessment: The process by which the capacity of a wetland to perform a function is measured. The approach measures capacity using an assessment model to determine a functional capacity index.

Functional Capacity: The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem and the surrounding landscape and interaction between the two.

Functional Capacity Index (FCI): An index of the capacity of a wetland to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates that the wetland performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions in a reference domain. An index of 0.0 indicates that the wetland does not perform the function at a measurable level, and will not recover the capacity to perform the function through natural processes.

Geographic Subregion: physiographic and biologic region of California based on topographic, climatic and plant-community variations. See "The Jepson Manual: Higher Plants of California" (Hickman 1993).

Geomorphic: Pertaining to the surface of the earth or the surficial features formed by geologic processes. (Modified from Gary et al. 1972.)

Groundwater: 1) Subsurface water that is in the zone of saturation, as distinct from surface waters, or water in the vadose zone or capillary fringe. 2) More loosely, all subsurface water as distinct from surface water. (Modified from Gary et al. 1972.)

Hardpan: A hardened or cemented soil horizon or layer. The soil may be sandy or clayey and cemented by various mineral substances. See "Soil Survey of San Diego Area, California" (Bowman 1973).

Headwaters Basin: A basin with no surface water-connected basins further upstream; usually with an outlet but no inlet.

Highest Sustainable Functional Capacity: The level of functional capacity achieved across the suite of functions by a wetland under reference standard conditions in a reference domain. This approach assumes that the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding landscape are undisturbed.

Hydrogeomorphic Wetland Class: The highest level in the hydrogeomorphic wetland classification system. There are five basic hydrogeomorphic wetland classes including depression, fringe, slope, riverine and flat.

Hydrogeomorphic Unit: Hydrogeomorphic units are areas within a wetland assessment area that are relatively homogenous with respect to ecosystem scale characteristics such as microtopography, soil type, vegetative communities or other factors that influence function. Hydrogeomorphic units may be the result of natural or anthropogenic processes. See Partial Wetland Assessment Area.

Hydrologic Network: A group of pools that is interconnected on the surface and often subsurface as well. Connections are determined by surveying pool groups in the field. Water movement is usually in a dendritic pattern, much like stream systems, but occasionally swales will braid.

Hydroperiod: The annual duration of flooding or ponding (in days per year) at a specific point in a wetland.

Indicator: Indicators are observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

Indirect Measure: A qualitative measure of an assessment model variable that corresponds to an identifiable variable condition.

Indirect Impacts: Impacts resulting from a project that occur concurrently, or at some time in the future, away from the point of direct impact. For example, indirect impacts of a project on wildlife can result from an increase in the level of activity in adjacent, newly developed areas, even though the wetland is not physically altered by direct impacts.

Invasive Species: Generally exotic species without natural controls that out compete native species.

In-kind Mitigation: Mitigation in which lost functional capacity is replaced in a wetland of the same regional wetland subclass.

Invert: The bottom of a channel, pipe or culvert.

Interflow: The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake.

Isolated Basin: A basin with neither an inlet nor an outlet.

Jurisdictional Wetland: Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987) or its successor.

Landscape: The area surrounding a pool or pool complex. It may or may not be greater than a pool's catchment area. Can be natural, disturbed, developed or some combination. A synonym for "the setting of a pool."

Landslide Basin Origin: Pools with an origin primarily caused by landslide activity, typically in the headscarp depression at the head of a landslide. Such pools can also form along secondary landslides within the failure mass**.** The southernmost Otay pools(San Diego County) and the Chiquita Ridge pools (Orange County) serve as southern California type localities.

Mediterranean Climate: A climate prevalent in areas surrounding the Mediterranean Sea and in four other mid-latitude coastal regions. It is characterized by rains in the winter months followed by a long drought period in the hottest months of the year.

Mitigation: Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

Mitigation Plan: A plan for replacing lost functional capacity resulting from project impacts.

Mitigation Ratio: The ratio of the FCUs (Functional Capacity Units= FCI x area) lost in a Wetland Assessment Area (WAA) to the FCUs gained in a mitigation wetland.

Mitigation Wetland: A restored or created wetland that serves to replace functional capacity lost as a result of project impacts.

Model Variable: See Assessment Model Variable.

O Horizon: A layer with more than 12 to 18 percent organic carbon (C) by weight or 50 percent by volume. Form of the organic material may be recognizable plant parts (Oi) such as leaves, needles, twigs, moss, etc., partially decomposed plant debris (Oe) or totally decomposed organic material (Oa) such as muck.

Off-site Mitigation: Mitigation that is done at a location physically separated from the site at which the original impacts occurred, possibly in another catchment.

Ombrotrophic: hydrologically isolated environment that receives all its water and nutrients from precipitation.

Organic matter: Plant and animal residue in the soil in various stages of decomposition.

Out-of-kind Mitigation: Mitigation in which lost functional capacity is replaced in a wetlands of a different regional wetland subclass.

Partial Wetland Assessment Area (PWAA): A portion of a WAA that is identified *a priori*, or while applying the assessment procedure, because it is relatively homogeneous, and different from the rest of the WAA with respect to one or more model variables. The difference may occur naturally, or as a result of anthropogenic disturbance. See Hydrogeomorphic Unit.

Pedogenic Basin Origin: Basins or pools in which the restrictive horizon impeding drainage to groundwater is a hardpan or claypan which has developed *in situ* by soil-forming processes acting over periods of geologic significance, commonly many thousands or hundreds of thousands of years. Most southern California pools are pedogenic, with the Redding-soil pools of the Miramar area serving as the type locality.

Perched Water Table: An upper water table separated from a lower one by a dry zone "Soil Survey of San Diego Area, California." (Bowman 1973). Perched water tables usually form above restrictive horizons or restrictive geologic units. They typically have a much more limited extent than a regional water table.

Pool Type: pools are classified based on their age and origin combined with their geography (coastal mesa, inland valley, etc.). See Table 5.2.

Project Alternative(s): Different ways in which a given project can be done. Alternatives may vary in terms of project location, design, method of construction, amount of fill required and others.

Project Area: The area that encompasses all activities related to an ongoing or proposed project.

Project Target: The level of functioning identified for a restoration or creation project. Conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

Red Flag Features: Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, State, regional or local level and may be official or unofficial.

Reference Domain: The geographic area from which reference wetlands are selected. A reference domain may or may not include the entire geographic area in which a regional wetland subclass occurs.

Reference Standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass. The highest level of functional capacity is assigned an index value of 1.0 by definition.

Reference Wetlands: Wetland sites that encompass the variability of a regional wetland subclass in a reference domain. Reference wetlands are used to establish the range of conditions for construction and calibration of functional indices and to establish reference standards.

Region: A geographic area that is relatively homogenous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

Regional Wetland Subclass: Wetlands within a region that are similar based on hydrogeomorphic classification factors. There may be more than one regional wetland subclass identified with each hydrogeomorphic wetland class, depending on the diversity of wetlands in a region and assessment objectives.

Restrictive Horizon: A horizon within or just below the soil which restricts the rate of infiltration, and which has developed as a result of soil-forming processes. Most such horizons are claypans or hardpans of various types.

Restrictive Unit: A horizontal or near-horizontal geologic occurrence, which restricts the rate of infiltration, sometimes leading to development of vernal pools. In addition to restrictive horizons, restrictive units can include low-permeability bedrock surfaces (such as in tinajas) or clay-rich deposits, which form in ponds, lakes, embayments or playas.

Site Potential: The highest level of functioning possible, given local constraints of disturbance history, land use or other factors. Site capacity may be equal to or less than levels of functioning established by reference standards for the reference domain, and it may be equal to or less than the functional capacity of a wetland ecosystem.

Soil Mapping Unit Inclusions: Small areas contained within the mapping unit that are not identified in the name of the map unit and are appreciably dissimilar in one or more properties. See “Soil Survey Manual” (Soil Survey Division Staff, USDA 1993).

Soil Mapping Unit: A map unit is a collection of areas defined and named the same in terms of their soil components. Each map unit differs in some respect from all others in a survey area and is uniquely identified on a soil map. See "Soil Survey Manual" (Soil Survey Division Staff, USDA 1993).

Soil Permeability: A measure of the ease of water movement in soil. See "Soil Survey Manual" (Soil Survey Division Staff, USDA 1993).

Soil Profile: Soil layers exposed by a vertical cut through the soil. See "Soil Survey Manual" (Soil Survey Division Staff, USDA 1993).

Soil Surface: The soil surface is the top of the mineral soil; or, for soils with an O horizon, the soil surface is the top of the part of the O horizon that is at least slightly decomposed.

Swale: A linear drainage feature lacking a channel (or defined bed and banks) of any kind. Many vernal pools drain to swales, or swales constitute their inlets.

Tectogenic Basin Origin: Basins or pools formed primarily along faults or as a result of geologic subsidence of natural origin. Such basins are often sag ponds or have been impounded by uplifted fault scarps. Tectogenic basins are commonly younger than other types of vernal pools. Ponding is supported by a restrictive units formed by deposition of clays originating from beyond the basin periphery, rather than the restrictive horizons developed in place that sustain many other vernal pools. A classic Southern California type locality is the Tierra Rejada vernal pool in Ventura County.

Terminal Basin: A basin with an inlet (or inlets) but no outlet. It collects moisture from a catchment area.

Throughflow: The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake. See Interflow for Comparison.

Tinaja: A pool formed as a basin in bedrock, with bedrock being the sole restrictive unit.

Type Locality: The place where a geologic or geomorphic feature is most evidently developed, frequently the locality where it was first described and recognized. (Modified from Gary *et al*. 1972.)

Uplands: Two distinct uses. 1) The area surrounding a pool, basin or other hydrologic feature lacking sufficient wetland indicators to be classified as a wetland. 2) The high ground surrounding a water-collecting feature in which water does not flow on surface or is not detained at the surface. (Modified from Gary *et al*. 1972.)

Variable: An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of a wetland to perform a function.

Variable Condition: The condition of a variable as determined through quantitative or qualitative measures.

Variable Index: A measure of how an assessment model variable in a wetland compares to the reference standards of a regional wetland subclass in a reference domain.

Water table: The highest part of the soil or underlying rock material that is wholly saturated with water. See "Soil Survey of San Diego Area, California" (Bowman 1973).

Watershed: See Catchment Area.

Wetland Ecosystem: "Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." (Corps Regulations 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, wetland ecosystems are three-dimensional segments of the natural world where the presence of water, at or near the surface, creates conditions leading to the development of redoximorphic soil conditions, and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

Wetland Assessment Area (WAA): The wetland area to which results of an assessment are applied.

Wetland Banking: The process of establishing a 'bank' of created, enhanced, or restored wetlands to serve at a future date as mitigation of project impacts.

Wetland Creation: The process of creating a wetland in a location where a wetland did not previously exist.

Wetland Enhancement: The process of increasing the capacity of a wetland to perform one or more functions. Wetland enhancement can increase functional capacity to levels greater than the highest sustainable functional capacity achieved under reference standard conditions, but this happens usually at the expense of sustainability or a reduction of functional capacity of other functions.

Wetland Functions: The normal activities or actions that occur in wetlands ecosystems, or simply the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape, and their interaction.

Wetland Restoration: The process of restoring wetland function in a degraded wetland.

Wetland Periphery: 20-ft band parallel to the basin edge.

Wetland Values: The worth of wetland functions to an individual or society.

Appendix B
Summary of Functions and Variables

Function 1. Surface and Sub-surface Water Storage

Definition

The surface and subsurface water storage function is defined as the capacity of the vernal pool wetlands complex to capture and store precipitation falling on the basin and catchment area. Moisture is stored within the depression as free water on the surface and/or in the surface and subsurface soils of the pool, swale(s) connecting pools and adjacent uplands. Water moves into and out of the basin by defined inlets and outlets and/or to and from the soil of the associated swales and adjacent uplands. It is also lost by evaporation, evapotranspiration, leakage through the sub-surface soil strata and spillage when the basin's storage capacity is exceeded, if an outlet is present. In this guidebook, we only assess free water on the surface of the basins.

Moisture retention and storage depend on a basin soil profile containing one or more restrictive layers that retard drainage. Surface soils in the depression generally have a high clay content. Underlying the surface horizons may be a cemented hardpan (or "duripan"), accumulated clays, bedrock or other poorly permeable layer(s). Ponding occurs when the soils become fully saturated above the restrictive horizon. The depth and texture of the surface soils within the basin, coupled with the permeability of the sub-layers, govern the amount of water required to initiate ponding and also affect the subsequent hydroperiod, plant rooting depth and moisture availability after surface water disappears. Initiation of the first seasonal ponding event may involve processes that differ from those which sustain ponding following mid- or late-season saturation of the pool's watershed.

In addition to water, dissolved solids (salts) move from the pool into the bank and downstream through the outlet. Virtually all vernal pools observe an annual cycle commencing with relatively higher salinities during the initial rains of the season, when ponding mobilizes evaporated salts stored on and in the bed of the pool, or in the bank. A mid-season salinity minimum coincides with rainfall onto the inundated area of the pool and flow from the pool into the adjoining banks. Water flows back into pools from adjacent banks as the water table in the surrounding soils rises. Salts are subsequently concentrated by evaporation during seasonal desiccation. Thus, vernal pools store and regulate salts within a given pool complex or network of vernal pools, and modulate the episodic release of salts at the onset of the wet season. Perhaps not surprisingly, some of the plants and animals that typically occupy pools are salt-sensitive.

As with other bodies of water, vernal pools also store and redistribute heat in their narrow niche between the atmosphere and the soils. The life cycles of biota within the pools are often governed by the onset of threshold temperatures early and late in the season.

Quantitative, direct measures for this function include catchment precipitation, water depth, salinity (or dissolved solids, generally measured as specific conductance[1]), water temperature, water table elevations and seasonal hydrographs.

Rationale for Selecting the Function

Surface and subsurface water storage modulates the movement of water in a climate known for highly seasonal, infrequent and often intense storms that generate rapid runoff. Retention of soil moisture beyond the rainy season extends the growing period. Bio-geo-chemical cycling is facilitated in a region where rates of primary productivity and decomposition are limited by aridity. Water, salt and temperature storage provide the necessary conditions for the unique wetland-dependent vernal pool plant and animal communities to develop. Standing water also excludes many species with limited to no inundation tolerance, dictating the nature of biological interactions within the pool. The role of vernal pools in storing and modulating solutes and temperatures also affects habitats further down in the watershed. Together, pools are wetland patches in a matrix of terrestrial, upland vegetation. Even vertebrate and invertebrate animals that do not require standing water of particular salinities utilize the wetland flora and fauna for food, shelter or some portion of their life cycle.

Characteristics and Processes that Influence the Function

Natural Characteristics and Processes

The primary natural influences on the water storage capacity of depressional southern Californian vernal pool wetlands are geomorphology, soil characteristics and the Mediterranean climate. The geomorphic origins of southern California's vernal pools are diverse, ranging from pedogenic to tectogenic to alluvial processes. The origin of the surface on which the pools have

[1] Specific conductance, electrical conductance and electrical conductivity are terms that are functionally synonymous and may be used interchangeably for the purposes of this guidebook. Specific conductance is used preferentially in this document, especially where use of this term can avoid confusion with hydraulic conductivity (permeability).

developed determines the soil series of the landscape that in turn affects the soil characteristics both of the upland catchment areas and the depressions themselves. Although the entire region experiences a Mediterranean climate, distance from the coast, elevation and presence of a rain shadow influence the amount and timing of precipitation, as well as the seasonal temperature regime.

The topography of the landscape affects the size and nature of the catchment area and the volume, directional flow and rate of water movement. Microtopographic features such as pool volume, the presence of inlets and/or outlets and the pool's relative position in a network or chain of pools are important factors determining each pool's unique water storage capacity and hydroperiod. Soil texture and the depth of the various soil layers affect the infiltration rate, the amount of water that can be stored in the soil and the amount and intensity of rain necessary to initiate ponding.

The timing and amount of water movement through vernal pools also regulate the transport of nutrients, organic carbon, sediments and biological propagules. Southern Californian pools on pedogenic or alluviated surfaces occur in a mosaic of hummocks (mounds), swales and depressions—all of similar scale —that direct the capture of precipitation and the flow of water salts, particulates and propagules. Other pools have developed more or less in isolation, and their physical arrangement and connections are less complex.

Regardless of the soil series of the surrounding landscape, the soil profile of pool basins must contain surface and/or sub-surface layers that retard drainage. Generally there is a clayey layer (or layers) 1-2 ft deep, often underlain by an even less permeable claypan, duripan or bedrock layer. The characteristic of the claypan and the presence or absence of the underlying duripan tend to be remarkably similar within a given soil series, even beyond southern California. For example, vernal pools situated in San Diego's Redding soils share many attributes with Central Valley vernal pools in the same soil type. Although the soil profile within pool depressions is universally different than the profile of adjacent uplands, the depression soils have not been formally named or described as a soil series, simply because they are not sufficiently extensive to meet mappable-unit criteria.

The Mediterranean climate is distinguished by a rainy season during the coolest months of the year, followed by a near absence of precipitation during the hottest months. In common with all arid climates, yearly precipitation is unpredictable in amount and within years storm patterns vary. Rainfall interacts with pool landscape position and basin morphology to affect the hydrology of both individual pools and networks of interconnected pools. The intensity, timing within a season and frequency of precipitation events is important to the number, depth and duration of ponding episodes and controls spillage from one basin to another (Bauder 2005, Knudsen *et al.* 1991, Leibowitz and Vining 2003). Because vernal pool wetlands are intermediate between dry, upland ecosystems and permanent bodies of water, even slight changes in pool hydrology can favor species that are not characteristic of vernal pools, possibly leading to major changes in biological interactions.

Mediterranean climates typically display cycles of wet and dry years. Vernal pool fields are almost unique within these landscapes because wet/dry cycle effects are minimal. This is likely due to the limited soil volume of water storage in the typically thin mantle of soils. However, seeds and cysts of some vernal pool species can persist for years or decades awaiting favorable hydrologic conditions. The limitations on water (and on nutrient and salt) storage also highlight how small the annual water storage buffer can be, and (due to the thinness of the soils) the fragility of the pool complexes in many respects.

Human Induced Influences

Human activities affect the capture, movement and storage of water in depressional vernal pool wetlands. Modifications to the uplands, wetland edge or directly to the wetland itself may greatly affect the receipt and retention of water. If catchment areas are augmented or reduced, the altered hydroperiods of individual pools will impact the biogeochemical cycles, the species composition and the phenology, life cycles and population dynamics of individual species residing in both the basins and adjacent uplands. Conversion to urban uses, blading, roads, damming, drains or culverts alter the capture and movement of water. Plowing, disking, grazing, fire and brushing can accelerate erosion of sediments into pools, reducing their volume and altering the soil profile. Soil infiltration rates may be diminished if vegetative cover is reduced or eliminated, or if the populations of burrowing animals that depend upon pools are changed. Alterations to inlets, outlets or pool connections impact the amount and delivery rate of water and the transport of other substances, as well as the persistence of flow into downstream pools and channels, even if the area of the catchment itself remains unchanged. Ripping, disking, blading and other surface and subsurface soil disturbances may alter a pool's ability to pond water by damaging or rearranging the soil layers responsible for water retention. Changes in the soil profile can also affect infiltration rates and soil storage of water within the soils of the basin and the adjacent uplands. Increased inflow can cause channels to form in the swales connecting pools, fundamentally altering their functions. Human induced changes in pool hydrology cause compositional changes to both the plant and animal communities, affect their seasonal development and population dynamics, interfere with the movement of biological propagules and genetic material and impact characteristic biological interactions such as predation, herbivory, competition and pollination.

The Hydrological Definition of a Vernal Pool

Extreme alterations to a vernal pool's hydrology can have a number of consequences. For example, retention and storage may be diminished to the point that the depression is no longer recognizable as a wetland of any type. Alternatively, above-ground water retention may be so augmented that the depression has become a permanent or semi-permanent pond, rather than a vernal pool. Although hydrological function can be viewed in absolute terms (the absolute amount of water storage a depression facilitates), we have instead chosen to define it with reference to the natural characteristics of an undisturbed vernal pool system. Specifically, a particular vernal pool functions at its highest level when it stores water at a level and for a period that is typical for an undisturbed vernal pool with the same landscape position, soil profile and level of connectivity. Thus, increases and decreases in an undisturbed vernal pool's water storage capacity lead to loss of function, and depressions that no longer fit the definition of a vernal pool have no value for this function.

Practically speaking, users of this guidebook should evaluate all depressions in terms of the definition of vernal pools as outlined at the beginning of Chapter 3 and in the "Description of the Regional Wetland Subclass" contained within that chapter. For hydrology, the critical elements of that definition are the pool's primary water source (precipitation), topography (natural depression, with or without inlets and/or outlets), seasonality (water ponds during the annual rainy season) and temporariness (ponds dry out once per annual seasonal cycle).

Functional Capacity Indices: Direct and Indirect

Direct Functional Capacity Index

The Direct FCI can only be calculated if seasonal precipitation exceeds 14 cm (See Appendix D.1).

Model Variables

$V_{TOTPRECIP}$ = Total precipitation (cm) for the rainfall year at Lindbergh Field, San Diego.

$V_{PERCENT\_2MONTHS}$ = percent of total precipitation during the rainfall season that fell during the two months with the highest rainfall amounts. Expressed as a whole number between 0 and 100.

$V_{POOLCONNECT}$ = indicator variable that characterizes surface connection of the pool to other pools. 1= none/isolated, 2= headwaters (outlet only), 3= flow through (inlet and outlet), 4=terminal/collector (inlet only)

$V_{TOTINUND}$ = total number of days during the rainy season the pool was inundated, at the lowest elevation.

$V_{PONDING\_EVENTS}$ = number of times the pool was inundated during the rainy season, at the lowest elevation.

$V_{MAXINUNDEPTH}$ = maximum depth of inundation during the season, in cm.

$V_{SC\_TOTINUND}$, $V_{SC\_PONDING\_EVENTS}$, $V_{SC\_MAXINUNDEPTH}$ are scaled versions of the previous three variables, based on $V_{POOLCONNECT}$ and $V_{TOTPRECIP}$ as follows:

Dry years: $14.0 \leq V_{TOTPRECIP} \leq 17.5$ cm
OR ($17.5 \leq V_{TOTPRECIP} \leq 25.0$ cm and $V_{PERCENT\_2MONTHS} < 50$)

$V_{TOTINUND}$			0	1-29	30-50	51+
$V_{SC\_TOTINUND}$			0.5	1	0.5	0.1
$V_{PONDING\_EVENTS}$			0	1-3	4-6	7+
$V_{SC\_PONDING\_EVENTS}$			0.5	1	0.5	0.1
$V_{MAXINUNDEPTH}$			0	0.1-11.0	11.1-40.0	40.1+
$V_{SC\_MAXINUNDEPTH}$			0.5	1	0.5	0.1

Average to Above Average years: $25.1 \leq V_{TOTPRECIP} \leq 32.0$ cm
OR ($17.5 < V_{TOTPRECIP} < 25.0$ cm and $V_{PERCENT\_2MONTHS} \geq 50$)

$V_{TOTINUND}$		0	1-16	17-54	55-140	141+
$V_{SC\_TOTINUND}$		0.25	0.5	1	0.5	0.1
$V_{PONDING\_EVENTS}$		0		1-4	5-8	9+
$V_{SC\_PONDING\_EVENTS}$		0.25		1	0.5	0.1
$V_{MAXINUNDEPTH}$		0	0.1-1	1.1-24.0	24.1-50.0	50.1+
$V_{SC\_MAXINUNDEPTH}$		0.25	0.5	1	0.5	0.1

Wet years: $32.1 \le V_{TOTPRECIP}$						
$V_{TOTINUND}$	0	1-7	8-27	28-108	109-172	173+
$V_{SC\_TOTINUND}$	0	0.25	0.5	1	0.5	0.1
$V_{PONDING\_EVENTS}$	0		1	2-7	8-10	11+
$V_{SC\_PONDING\_EVENTS}$	0		0.5	1	0.5	0.1
$V_{MAXINUNDEPTH}$	0	0.1-4.0	4.1-11.9	12.0-31.0	31.1-50.0	50.1+
$V_{SC\_MAXINUNDEPTH}$	0	0.25	0.5	1	0.5	0.1

Index of Function

The Direct FCI depends on landscape position ($V_{POOLCONNECT}$) as follows:

If ($V_{POOLCONNECT} = 1$)

Direct FCI= $(0.62 \times V_{SC\_PONDING\_EVENTS}) + (0.38 \times V_{SC\_MAXINUNDEPTH})$

If ($V_{POOLCONNECT} = 2$)

Direct FCI= $(0.31 \times V_{SC\_TOTINUND}) + (0.64 \times V_{SC\_PONDING\_EVENTS}) + (0.05 \times V_{SC\_MAXINUNDEPTH})$

If ($V_{POOLCONNECT} = 3$)

Direct FCI= $(0.15 \times V_{SC\_TOTINUND}) + (0.20 \times V_{SC\_PONDING\_EVENTS}) + (0.65 \times V_{SC\_MAXINUNDEPTH})$

If ($V_{POOLCONNECT} = 4$)

Direct FCI= $(0.40 \times V_{SC\_PONDING\_EVENTS}) + (0.60 \times V_{SC\_MAXINUNDEPTH})$

The degree to which a basin provides water storage is a complex function of its depth, length of ponding, and the number of ponding events, calibrated to its particular landscape position (*e.g.,* headwaters vs. terminal pool), and patterns of rainfall in any particular year. Each of the three primary variables for this function ($V_{TOTINUND}$, $V_{PONDING\_EVENTS}$ and $V_{MAXINUNDEPTH}$) is scaled based on precipitation patterns, with a greater amount of water retention expected in years with more rainfall. As seen in the table above, maximum values of 1.0 are obtained for intermediate levels of $V_{SC\_TOTINUND}$, $V_{SC\_PONDING\_EVENTS}$ and $V_{SC\_MAXINUNDEPTH}$ that are characteristic of reference standards. Greater amounts of rainfall facilitate greater discrimination of pool function. For example, each of the three primary variables is scaled based on only 3 bins for low rainfall years, and 5-6 bins for high rainfall years.

The three primary variables correlate to differing degrees with the direct FCI, depending on their landscape position. The total length of inundation does not predict function in isolated pools and terminal pools ($V_{POOLCONNECT}$ = 1, 4), but it is an important variable for headwater and flow through pools ($V_{POOLCONNECT}$ = 2, 3). Similarly, the number of ponding events is the most important variable for isolated and headwater pools, but the maximum inundation depth is more relevant for flow through and terminal pools.

Indirect Functional Capacity Index

Model Variables

$V_{COBBLESBA}$ = 100 X (percent of the basin covered with rounded or angular coarse pebbles or cobbles). Pebbles are 2-7.5 cm in diameter and cobbles are 7.5-25 cm in diameter (Soil Survey Manual, USDA 1993).

$V_{COBBLESBA>15}$ = indicator variable: 0 if $V_{COBBLESBA} \leq 15$,
1 if $V_{COBBLESBA} > 15$.

$V_{MAXDEPTH}$ = maximum depth of the pool in meters, as estimated with surveying equipment.

$V_{MAXDEPTH\_GR}$ = categorical groups for maximum depth of the pool:

$V_{MAXDEPTH\_GR}$ = 0.32 if $V_{MAXDEPTH} \leq 0.11$ m

$V_{MAXDEPTH\_GR}$ = 0.37 if 0.11 m < $V_{MAXDEPTH} \leq 0.35$ m

$V_{MAXDEPTH\_GR}$ = 0.00 if 0.35 m < $V_{MAXDEPTH}$

$V_{DIST1km<5}$ = indicator variable for whether disturbance in the four 1km quadrants is less than Category 5 in all cases: 0 if Dist1km-1 > 4, Dist1km-2 > 4, Dist1km-3 > 4 and/or Dist1km-4 > 4; 1 if Dist1km-1 < 5, Dist1km-2 < 5, Dist1km-3 < 5 and Dist1km-4 all less than 5. (See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2 for disturbance categories.

$V_{POOLCONNECT}$ = indicator variable that characterizes surface connection of the pool to other pools. 1= none/isolated, 2= headwaters (outlet only), 3= flow through (inlet and outlet), 4=terminal/ collector (inlet only).

$V_{DEFIN\_OR\_OUTLET}$ = 1 if pool has a defined inlet or defined outlet, 0 otherwise.

V_{LENGTH} = length of longest axis (a) in meters, using the basin edge as determined in the field.

V_{SLOPE} = Long axis slope= $V_{MAXDEPTH} / (V_{LENGTH} / 2)$.

V_{SLOPE_GR} = categorical groups for slope:

$V_{SLOPE\_GR} = 1$ if $V_{SLOPE} \leq 1.9$

$V_{SLOPE\_GR} = 2$ if $1.9 < V_{SLOPE} \leq 3.0$

$V_{SLOPE\_GR} = 3$ if $V_{SLOPE} > 3.0$

$V_{IN\_OR\_OUTLET\_WS}$ and V_{SLOPE_WS} = variables specific to the water storage function that are calculated based on $V_{POOLCONNECT}$ as follows:

$V_{POOLCONNECT} = 1$			
$V_{DEFIN\_OR\_OUTLET}$	$V_{IN\_OR\_OUTLET\_WS}$	V_{SLOPE_GR}	V_{SLOPE_WS}
0	0.05	1	0.15
1	0.00	2	0.15
		3	0.00

$V_{POOLCONNECT} = 2$			
$V_{DEFIN\_OR\_OUTLET}$	$V_{IN\_OR\_OUTLET\_WS}$	V_{SLOPE_GR}	V_{SLOPE_WS}
0	0.05	1	0.06
1	0.00	2	0.15
		3	0.00

$V_{POOLCONNECT} = 3$			
$V_{DEFIN\_OR\_OUTLET}$	$V_{IN\_OR\_OUTLET\_WS}$	V_{SLOPE_GR}	V_{SLOPE_WS}
0	0.08	1	0.08
1	0.00	2	0.12
		3	0.00

$V_{POOLCONNECT} = 4$			
$V_{DEFIN\_OR\_OUTLET}$	$V_{IN\_OR\_OUTLET\_WS}$	V_{SLOPE_GR}	V_{SLOPE_WS}
0	0.00	1	0.02
1	0.05	2	0.15
		3	0.00

Index of Function

Indirect FCI= $(0.08 \times V_{COBBLESBA>15}) + (0.35 \times V_{DIST1km<5}) + V_{MAXDEPTH\_GR} + V_{IN\_OR\_OUTLET\_WS} + V_{SLOPE\_WS}$

The Indirect FCI indicates that vernal pools with the highest capacity for water storage tend to have cobbles, lie in undisturbed landscapes, and are between 0.11 and 0.35 m deep. In all pools except terminal pools, the presence of a defined inlet or outlet correlates with some loss of function. Moderate slopes between 1.9 and 3.0 are founded in pools with the highest level of function, with more shallow pools tending to retain some level of function.

Function 2. Hydrologic Networks

Definition

Hydrologic networks are the water bodies through which water moves to the local master stream in a vernal pool landscape. The links include pools, the swales or subsurface flowpaths that connect them or the drainages of various types through which flows move into the master stream. Integrated surface/sub-surface water systems are the general rule in California vernal pools (*cf.*, Rains *et al.* 2006, Rains *et al.* 2008) and prairie potholes (Leibowitz and Vining 2003), although subsurface connections between small, surface-isolated wetlands are not well detailed (see Winter and LaBaugh 2003).

Pools with neither inlets nor outlets are hydrologically isolated and self-contained, unless the depression's substrata leak water to the sub-surface water table or are structured so as to facilitate underground water movement (Knudsen *et al*. 1991, Rains *et al.* 2006, Rains *et al.* 2008, Winter and LaBaugh 2003). Underground flow fields are more complex when isolated depressions are separated by ridges or mounds (Winter and LaBaugh 2003). Pools isolated on the surface export soil, organic carbon, nutrients or biological propagules primarily by wind and animal vectors.

Pools with inlets and/or outlets are part of an interconnected hydrologic system that may be primarily dendritic and linear, or more anastomosing and reticulate (*cf.*, Hickson and Hecht 1991). The topography of the catchment directs water to the basins. The intensity, timing within a season and frequency of precipitation events is important to the number, depth and duration of ponding episodes and controls spillage from one basin to another (Bauder 2005, Knudsen *et al.* 1991, Leibowitz and Vining 2003). Pools may spill and recharge differently under different precipitation patterns, depending on the height and location of potential inlets and outlets and position in the network or pool order (Bauder 2005). Groundwater connections also vary in response to short or long term changes in the weather (Rains *et al.* 2008, Winter and LaBaugh 2003) and the extent to which the summer soil cracks intrinsic to many southern California pools have seasonally annealed or closed in response to the first storms of the year (Hecht *et al.* 1998, Weitkamp *et al.* 1996).

Soil surface texture is important to the rate of moisture infiltration, the storage of water and the time it takes for ponding to occur, or if it does occur. The presence and morphology of poorly permeable sub-surface layers affects how water moves through the soil—laterally, vertically or both—and to what degree pools are hydrologically interconnected below ground. Within those pools with deep soil cracks, connections typically change over the course of a season.

Direct, quantitative measures of the movement of water include dissolved constituent concentrations observed over time (Figure 3.6; see also Rains *et al.* 2008), hydrographs of pools in the network (Figure 3.5) and observations on surface flows.

Rationale for Selecting the Function

Water moving through an interconnected system of pools will generally move more slowly and have greater opportunity to infiltrate the soil in and adjacent to the pool basins, swales and channels. Some of the infiltrated water may discharge into the pools and swales (or channels) further downstream. Longer travel times for the water facilitates retention of more moisture in the system for longer periods of time, recharging the ground-water table, perched or not. Longer periods of moisture availability extend the growing season, a significant effect in arid ecosystems with limited and unpredictable precipitation (Bauder 1989, Hecht and Napolitano 1993).

Hydrological interconnections are important for the export and import of nutrients, organic carbon and sediments. Important elements of the food chain such as aquatic invertebrates, algae, fungi, bacteria, plant parts and seeds become mobile when water spills between basins. The movement of sexual or asexual propagules provides the potential for the species composition of pools to change in response to variable or systematically changing conditions (*i.e.*, climate change). Hydrologic connections can also mitigate the genetic drift that can occur in small isolated populations or provide founders for populations that have become locally extinct.

Characteristics and Processes that Influence the Function

<u>Natural Characteristics and Processes</u>

Hydrologic interconnections between pools result from the interplay of catchment and pool topography, climate and soils. The topography of the catchment directs the surface movement of water over the landscape. Along with the soil profile, the shape and depth of individual basins determine the volume of surface water that can be stored, hence the amount required for spillage. Configurations of basin inlets and outlets depend on the location of swales and channels in the landscape, coupled with small differences in elevation along pool margins. The number and area of basins upstream will influence the duration of flows into a networked vernal pool, as well as the duration of ponding. The locations of inlets and outlets may change with the rate and amount of water flowing through the system or with changes in vegetation growth, sediment and debris deposition and related soil development. The catchment area determines the volume of water that enters and moves through pools, with vegetative cover and soil type playing lesser roles.

The regional Mediterranean climate is characterized by scant precipitation concentrated in the coolest months of the year (Bauder 2005). The amount and pattern of rainfall events is unpredictable within rainy seasons and between rainfall years (July 1-June 30). This climatic variability means that connectedness is a function of the rainfall events in a particular rainfall year, and yearly variation is substantial (Bauder 2005).

Human Induced Influences

Changes to the size and topography of the catchment affect the volume of water entering the pools and the rate and direction of flow. Roads act as dams that diminish flow in some areas, and collect and redirect water. Pools deprived of water may lose their hydrologic connection to other pools or be connected more infrequently. They then become artificially isolated and more vulnerable to local extinctions and invasion by plants and animals with different moisture requirements or tolerances. The potential of "rescue" by propagule import from other pools is diminished.

If a culvert or pipe adds water to the system or if grading connects catchments, the increased volume, rate of movement and force of water can cause spillage where there was none, scour channels and basins, alter inlet and outlet elevations, deliver excess sediment and pollutants and flush basins of nutrients and biological propagules such as seeds and cysts. Trenching that breaches the upper several feet (or more) of the claypan or hardpan, although limited in area, can sharply alter flow within the networks, particularly in dry years. Drainage through backfill placed in utility trenches, if not sufficiently baffled, can permanently re-direct inflows to pools or change their hydroperiods. Catchments that have been bladed, brushed or disked will have different infiltration parameters and be more likely to erode. Deep ripping or conversions to hardscape have even more severe impacts on the normal spillage regime of pools and the nature of their hydrological connections. Conversion of any portion of the catchment—or, in some cases, the landscape—to grazing, agriculture, roads or urban uses, alters the amount of water that can be stored and the timing and direction of water moving through the system. Trails (especially equestrian) and vehicle tracks (off-road, motorcycles, trucks, etc.) can act as drains and dewater an area (Bauder 1994).

Functional Capacity Indices: Direct and Indirect

The functional capacity index for hydrologic networks was developed from observations made in three pool networks: two networks (n=4 and n=8 pools) that were bladed and disked or cultivated over 60 years ago, and a nearly undisturbed pool network of 10 pools. All three networks are of pedogenic origin and developed in the Redding soil series. Data collected from these pool networks indicate that the position within a network influences how often a pool will fill and drain (or evaporate). More rainfall is typically required to establish ponding in pools that are higher in the network, while pools that are lower in the network pond earlier and experience more frequent ponding episodes (See Figure 3.5). Therefore, a network of pools represents an array of interacting pool-specific hydrologic regimes in close proximity to each other. Geomorphic and topographic indicators strongly interact with hydrologic variables to dominate pool network functionality. The Direct FCI can only be calculated if seasonal conditions of precipitation amount are met (See Appendix D.1). In this guidebook, the FCIs for Hydrologic Networks are based on surface connections only.

<u>Direct Functional Capacity Index</u>

Model Variables

$V_{NETPONDING}$ = number of pools in the network that continuously pond ≥ 5 days during the rainy season.

$V_{HEADWATERPOND}$ = number of headwater pools that simultaneously hold water at their lowest elevation.

$V_{FILLEDMAX}$ = the number of headwater basins that filled to their maximum depth at least once during the rainy season.

$V_{TOTINUND}$ = total number of days during the rainy season a pool was inundated, at the lowest elevation.

The variables are scaled according to Table 4.1.

<u>Index of Function</u>

$$\text{Direct FCI} = (V_{NETPONDING} + V_{HEADWATERPOND} + (1.5 \times V_{FILLEDMAX}) + (V_{TOTINUND}/2)) / 4$$

Table 4.1. Direct Assessment of the Hydrologic Network Function	
Variables* $V_{NETPONDING}$= Number of pools in the network that continuously pond water ≥ 5 days during the rainy season. $V_{HEADWATERPOND}$=Number of headwater pools that simultaneously hold water at their lowest elevation. $V_{FILLEDMAX}$= Number of headwater pools filled to their maximum depth at least once during the rainy season. $V_{TOTINUND}$= Total number of days during the rainy season a pool was inundated, at the lowest elevation.	
$V_{NETPONDING}$	
Measurement or condition- $V_{NETPONDING}$	Index
The number of pools in the network continuously ponding ≥5days is ≥ 7.	1
The number of pools in the network continuously ponding ≥5days is 4-6.	0.5
The number of pools in the network continuously ponding ≥5days is 3.	0.4
The number of pools in the network continuously ponding ≥5days is 2.	0.25
Zero or one pool in the network continuously ponds ≥ 5 days.	0
$V_{HEADWATERPOND}$	
Measurement or condition- $V_{HEADWATERPOND}$	Index
Three or more headwater pools pond at the same time.	1
Two headwater pools pond at the same time.	0.75
One headwater pool ponds.	0.5
No headwater pools pond.	0.25
No headwater pools pond when >35 cm of rain falls in a 3-month period.	0
$V_{FILLEDMAX}$	
Measurement or condition- $V_{FILLEDMAX}$	Index
Three or more headwater pools fill to their maximum depth.	1
Two headwater pools fill to their maximum depth.	0.75
One headwater pool fills to its maximum depth.	0.4
No headwater pools fill to their maximum depth.	0.25
Only the terminal pool fills to its maximum depth.	0
$V_{TOTINUND}$	
Measurement or condition- $V_{TOTINUND}$	Index
One or more pools in the network pond for a seasonal total of ≥40≤60 days.	1
One or more pools in the network pond for a seasonal total of ≥30≤40 days.	0.75
One or more pools in the network pond for a seasonal total of ≥15≤30 days.	0.4
One or more pools in the network pond for a seasonal total of ≥0≤15 days.	0.25
No pools in the network pond during the rainy season.	0
$FCI= (V_{NETPONDING} + V_{HEADWATERPOND} + 1.5 \times (V_{FILLEDMAX}) + (V_{TOTINUND}/2))/4$	
* Scoring of variables is more fully explained on the data forms in Appendix C.	

The network functional capacity increases as the number of pools in the network holding water 5 days or more increases, the number of headwater pools simultaneously holding water increases, the number of basins reaching their maximum capacity increases (which favors spillage) and with the total number of days water stands at the lowest elevation within the basins.

<u>Indirect Functional Capacity Index</u>

Model Variables

$V_{NUMPOOLS}$ = number of pools in a network of pools as determined by field surveys.

$V_{DOMIDISTBA\text{-}NET}$ = indicator variable for the dominant disturbance within the basins in a network. (See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2 for disturbance categories.)

$V_{DOMDISPERI\text{-}NET}$ = indicator variable for the dominant disturbance in the 20-ft peripheral band surrounding the basins in a network. (See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2 for disturbance categories.)

$V_{DOMDISCA\text{-}NET}$ = indicator variable for the dominant disturbance in the catchment area of the pool network. (See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2 for disturbance categories.)

$V_{MODIFCAT\text{-}NET}$ = indicator variable for the type of modification made to the catchment area of the pool network. (1= none, 2= draining/diminishment/truncation, 3= addition/augmentation)

$V_{SEDFILLBA\text{-}NET}$ = indicator variable for the observable deposition of sediment or fill in most of the basins in the network as indicated by deltaic deposition patterns or soil discontinuities in texture or color (1= none, 2= <25% of basin surface, 3= ≥25% of basin surface).

$V_{INLETELEV\text{-}NET}$ = indicator variable for the discernible modification to the inlet elevations of the basins in the network. (1= none, 2= raised, 3= lowered, 4= trenched/ditched)

$V_{OUTLETELEV\text{-}NET}$ = indicator variable for the discernible modification to the outlet elevations of the basins in the network. (1= none, 2= raised, 3= lowered, 4= trenched/ditched)

The variables are scaled according to Table 4.2.

Index of Function

$$\text{Indirect FCI} = (V_{NUMPOOLS} + V_{DOMDISTBA\text{-}NET} + V_{DOMDISTPERI\text{-}NET} + (V_{DOMDISTCA\text{-}NET} /2) + (V_{MODIFCAT\text{-}NET} /2) + V_{SEDFILLBA\text{-}NET} + V_{INLETELEV\text{-}NET} + V_{OUTLETELEV\text{-}NET}) / 7$$

Factors that correlate with hydrologic network function are the number of pools in the network (more connections lead to greater between-basin movement of water, nutrients and

Table 4.2. Indirect Assessment of the Hydrologic Network Function

Variables*

$V_{NUMPOOLS}$= Number of pools in a network of pools as determined by surveying.
$V_{DOMDISTBA-NET}$= Dominant disturbance within the basins in a network.
$V_{DOMDISTPERI-NET}$= Dominant disturbance in the 20-ft peripheral band surrounding the basins in a network.
$V_{DOMDISTCA-NET}$= Dominant disturbance in the catchment area of the pool network.
$V_{MODIFCAT-NET}$= Type of modification made to the catchment area of the network.
$V_{SEDFILLBA-NET}$= Observable deposition of sediment or fill in the basins in the network.
$V_{INLETELEV-NET}$= Discernible modification to the inlet elevations of pools in the network.
$V_{OUTLETELEV-NET}$= Discernible modification to the oulet elevations of pools in the network.

$V_{NUMPOOLS}$

Measurement or condition- $V_{NUMPOOLS}$	**Index**
The number of pools in the network is ≥7.	1
The number of pools in the network is 4-6.	0.5
The number of pools in the network is 3.	0.4
The number of pools in the network is 2.	0.25
The pool is isolated.	0

$V_{DOMDISTBA-NET}$

Measurement or condition- $V_{DOMDISTBA-NET}$	**Index**
Dominant disturbance in the basins of the network is Category 1 or 2.	1
Dominant disturbance in the basins of the network is Category 3.	0.75
Dominant disturbance in the basins of the network is Category 4.	0.5
Dominant disturbance in the basins of the network is Category 5.	0.25
Dominant disturbance in the basins of the network is Category 6.	0

$V_{DOMDISTPERI-NET}$ and $V_{DOMDISTCA-NET}$

Measurement or condition- $V_{DOMDISTPERI-NET}$ and $V_{DOMDISTCA-NET}$	**Index**
Use the same scale as the one used for $V_{DOMDISTBA-NET}$	

$V_{MODIFCAT-NET}$

Measurement or condition- $V_{MODIFCAT-NET}$	**Index**
Catchment area for the pool network has no modifications.	1
Catchment area for the pool network has been added to/augmented by < 15%.	0.8
Catchment area for the pool network has been increased by > 35% but < 50%.	0.5
Catchment area for the pool network has been drained or diminished; truncated by < 15%.	0.5
Catchment area for the pool network has been drained or diminished; truncated by > 25%.	0.25
Catchment area has been drained, diminished or augmented by a net > 50%.	0

(continued)

Table 4.2. Indirect Assessment of the Hydrologic Network Function	
$V_{SEDFILLBA\text{-}NET}$	
Measurement or condition- $V_{SEDFILLBA\text{-}NET}$	**Index**
No observable deposition of sediment or fill in most of the basins in the network.	1
Observable deposition of sediment or fill covers <25% of most basins in the network.	0.5
Observable deposition of sediment or fill covers ≥25% of most basins in the network.	0.25
$V_{INLETELEV\text{-}NET}$ and $V_{OUTLETELEV\text{-}NET}$	
Measurement or condition- $V_{INLETELEV\text{-}NET}$ and $V_{OUTLETELEV\text{-}NET}$	**Index**
The inlets/outlets in most of the basins in the network have no discernible modification.	1
The inlets/outlets in most of the basins in the network have been lowered.	0.5
The inlets/outlets in most of the basins in the network have been raised.	0.3
The inlets/outlets in most of the basins in the network have been lowered and trenches or ditches connect most pools.	0.2
(concluded)	
FCI= $(V_{NUMPOOLS} + V_{DOMDISTBA\text{-}NET} + V_{DOMDISTPERI\text{-}NET} + (V_{DOMDISTCA\text{-}NET}/2) + (V_{MODIFCAT\text{-}NET}/2) + V_{SEDFILLBA\text{-}NET} + V_{INLETELEV\text{-}NET} + V_{OUTLETELEV\text{-}NET})/7$	
* Scoring of variables is more fully explained on the data forms in Appendix C.	

propagules) and the extent of disturbance. This includes disturbance in the basin and surrounding area (periphery, catchment), deposition of sediment or fill and alteration of basin inlets or outlets.

Function 3: Maintain Characteristic Biogeochemical Processes

Definition

Like other wetland ecosystems, vernal pools process and cycle elements (*e.g.*, carbon, nitrogen, phosphorus) that are important to sustaining viable populations and communities in the catchment basin and downstream. The cycling of nutrients and other elements in these small systems is driven in part by the import-export of materials through hydrological transport (Bedford 1996, Jocqué *et al*. 2007, Rains *et al.* 2006, Rains *et al.* 2008) and in part by metabolism of organisms, including anabolic (*e.g.*, primary and secondary production) and catabolic processes (*e.g.*, respiration, decomposition) (Boon 2006, Cronk and Fennessy 2001). Wetlands are well known to have biogeochemical processing rates that exceed those in most terrestrial ecosystems (Mitsch and Gosselink 2000, Schlesinger 1997). Due to the arid climate of the San Diego region, this difference is more pronounced, even though vernal pools may be immersed for only part of a year. Undisturbed San Diego vernal pools are oligotrophic ecosystems, because water inputs in undisturbed pools are largely via rainfall or local interflow among pools, rather than overland flow throughout catchment basins, and because pools are located on ancient, well-leached soils and have relatively brief hydroperiods. Anthropogenic eutrophication, alterations to hydrology (*e.g.*, enhanced overland flow via impermeable surfaces or artificial conveyance structures) and soil disturbances in the basin or its catchment (*e.g.*, earth-moving, alteration of inlets and outlets, etc.) can all alter the typically oligotrophic vernal pool biogeochemical functions.

Rationale for selecting the function

Biogeochemical processes represent an integrative measure of the ecological function of an ecosystem, and so represent an overall measure of ecosystem functional integrity, including the effects of anthropogenic eutrophication, soil disturbances, sediment and chemical runoff, and landscape-scale disturbances. As such, biogeochemical cycling and processing provide a tool to evaluate vernal pool function not provided by other HGM functions that focus on biota or physical variables.

Characteristics and Processes that Influence the Function

Hydrology, soil structure and composition and vegetation are key to biogeochemical processes. Hydrology drives the import and export of materials, as well as the oxidative state of the water and underlying sediment, and thus the selective conditions for vegetative and microbial uptake and processing of materials. Soil structure (or conversely, soil disturbance) is critical because deposition and leaching of materials occur in soils. The long-term development of aerobic/anaerobic interfaces also determines nutrient availability and organic matter processing rates. Soil composition affects the supply of particular minerals, the cation exchange capacity and pH. Vegetation responds to both hydrology and soils, and serves as a major processor of nutrients and organic matter production.

An assessment of biogeochemical function requires integrative analyses over extended time periods. Ideally, this would include variables related to phosphorus and nitrogen flux, and organic matter processing. Direct measures of this function would include estimates of primary productivity for algae and flowering plants, documentation of litter decomposition rates and the presence, concentration and form of various elements and compounds tied to specific processes (*e.g*., denitrification), breakdown of organic compounds and changes in availability of various compounds related to changes in pH and oxidation states. It is clear from the literature that the hydrology, soils and geomorphology of basins and catchments are all strongly related to biogeochemical processes occurring in wetlands. Thus, variables such as seasonal hydrographs, catchment area, network position and basin morphometry might be good candidates for indirect indicators of function.

For this HGM, we had intended to do chemical and textural analysis of soils collected from the adjacent uplands, basin edge and pool bottom. Due to equipment failure in the analytical laboratory, we were not able to use these data. We had also prepared for chemical analysis of water samples collected three times during the rainy season. Unfortunately, San Diego experienced its driest year on record during that particular rainy season, and no basins held water. Vegetative cover data were unusable, due to the extreme drought.

Function 4. Maintain Characteristic Plant Community

Definition

The plant community function is defined as the capacity of the wetland habitat to support persistent populations of plant species characteristic of vernal pools in southern California. These populations consist of actively growing plants; dormant structures such as roots, stems, caudices, corms, and bulbs; and the soil seed bank. Soil type and depth, pool hydrology and catchment topography interact with climate to provide suitable conditions for the growth and reproduction of this plant community known as vernal pool ephemeral (Thorne 1976).

Direct measures of this function include plant surveys, estimates of native plant cover, recovery or germination of propagules from the soil and the collection of multi-year population data for key species. Indirect measures would include indicators of a suitable soil profile and capacity to pond.

Rationale for Selecting the Function

This function is important for the intrinsic value of the plant community, which is dominated by endemic species, many of which have very limited distributions. It is also important to numerous wetland processes such as productivity and biogeochemical cycling as well as providing food and habitat for animal communities.

Characteristics and Processes that Influence the Function

Natural Characteristics and Processes

The primary natural influences on the capacity of depressional southern Californian vernal pool wetlands to support the characteristic plant community are shared by the "Surface and sub-surface water storage" function. These are geomorphology, soil and the Mediterranean climate. Various combinations of geomorphology, soil series and local climatic conditions result in a multiplicity of unique wetland habitats even within the reference domain (Bauder and McMillan 1998). Elevation and distance from the coast cause deviations from the prevailing regional climate. The pattern of local, unique wetland habitats extends along the western coast of North American from Baja California MX to the State of Washington.

The numerous, unique combinations of environmental conditions have promoted endemism, often very narrow. For example, the genus *Pogogyne* has three species in San Diego County and adjacent Baja California MX. Each species is faithful to a different soil type, and there is no indication their distributions ever overlapped (Bauder and McMillan 1998). Other genera sort out according to elevation. There are two species of *Downingia* in San Diego County. One, *Downingia cuspidata*, occurs near the coast and in the inland valleys. The other species, *Downingia concolor* var. *brevior*, is found in the county's montane wetlands where winter temperatures are lower and yearly precipitation is greater.

Geomorphology is important to the delivery and ponding of water in pool basins, hydrologic connections between pools and the relationship of pools to adjacent uplands. Soils buffer moisture losses and gains by storing and releasing water from pool basins and the surrounding uplands. Plants can use soil water during dry periods between rainstorms and long after standing water has disappeared at the end of the rainy season. Soil moisture and ponding water promote the growth of dense stands of herbaceous plants quite different from the vegetation in the catchment or landscape. These plants provide animals with a broader diet for a longer period of time than does the upland plant community. The species are less woody and likely more palatable and nutritious compared to the xerophytes that dominate the area, although this has never been examined.

Plants that regularly occur in southern California's vernal pool wetlands are well adapted to the bi-phasic nature of the habitat (wet and dry) and the high variability in moisture conditions within and between years. Within rainfall years (July 1-June 30), precipitation varies widely in total amount, storm intensity and the distribution of storms across the wet season (Bauder 2005). To persist in this variable and unpredictable environment, both plants and animals must cope with rising and falling water levels during the rainy season, a large among-year variation in the longest continuous period of inundation, rapid changes from terrestrial to aquatic conditions and back again, and long periods of high air and soil temperatures coupled with lack of moisture. Various traits have been associated with persistence in such stressful or fluctuating environments. These include dormant eggs, cysts or seeds (Baskin and Baskin 1989, Salisbury 1970, Venable and Burquez 1989, Williams 1998), production of drought resistant underground structures such as taproots, corms, caudices or bulbs (Bauder 1992, Crawley 1986ab, Harper 1977, Mueller-Dombois and Ellenberg 1974, Sheikh 1978), morphological plasticity (Crawford 1987; Deschamp and Cooke 1983, 1984; Hook 1984; Horton 1992; van der Sman *et al.* 1991) and physiological plasticity (Keeley and Morton 1982, Keeley *et al.* 1983), precise requirements for breaking of dormancy (Griggs 1976; Leck 1989; Salisbury 1970; Toy and Willingham 1996, 1967; van der Walk & Davis 1978), precocious reproduction, *i.e.* an annual life history (Barrett *et al.* 1993), and tolerance of lengthy periods of inundation (Bauder 1987a, Crawford 1989, Hook 1984, Jackson and Drew 1984).

Long-term studies along transects spanning the full range of elevations (hence moisture conditions) in vernal pool basins indicate that individual species occupy different portions of the soil moisture/inundation gradient in a series of overlapping distribution curves (Bauder 2000). Natural changes in pool hydrology due to climatic changes could favor some species in relation to others through the direct impacts of longer or shorter, more or fewer periods of ponding. Indirectly, competitive interactions can be altered by changes in hydrology (Bauder 1987a, 1989).

Human Induced Influences

Human activities affect vernal pool vegetation in numerous ways. Pool hydrology is changed by increases or decreases in the catchment area. The catchment area can be augmented or decreased by grading and development. Culverts and channels often connect the catchment to a wider area, thus increasing the amount of water delivered to the pools. Another source of augmented water supply is runoff from hard surfaces or irrigation. Artificial conveyance structures concentrate water flow, thus increasing the force of water entering the catchment. Berms, roads, channels, brow ditches or pipes frequently deprive pools of their normal amount of water. Most development results in drainage and runoff management that directs water away from the area to storm drains.

Too much water can favor herbaceous wetland perennials such as *Typha* spp. and *Eleocharis* spp. Exotic wetlands grasses like *Agrostis avenacea* and *Polypogon monspeliensis* thrive in wetter conditions. These species produce a dense thatch that inhibits seedling growth and reproduction of native pool species (Bauder 1988, Bauder *et al.* 2002). If pools have less water, upland species, particularly those introduced from Asia, can become dense in pool basins. In the absence of inundation sufficiently long to kill them (about 10 continuous days), they outcompete the small, vernal pool annuals (Bauder 1987a, 1989). Water arriving with great force scours channels and inlets and delivers sediment and debris into the basins. Most of the native pool species are diminutive, and sediment and debris bury seeds, seedlings and plants. Changes in topography interrupt the normal drainage patterns in the catchment and often separate pools from their associated uplands. Isolated pools are no longer part of the original hydrological network that determined both hydrology and input and output of nutrients and propagules. Loss of the hydrological buffering provided by uplands favors wider fluctuations in basin ponding frequency and depth and soil moisture content which in turn lead to population fluctuations of pool species (Bauder 1987b). Overland transport of seeds or genes via pollen is diminished or eliminated when uplands are brushed, bladed, graded, cultivated, grazed or developed. Herbivory can increase or decrease when the natural predator/prey relationships are interrupted by truncation of the natural upland habitat. Rabbit and rodent populations in the absence of natural predators such as coyotes or raptors would likely increase. Heavy grazing promotes thick sheets of algae that smother plants (Bauder 1994), as does turf management of golf courses, parks and schoolyards.

Reduction of the landscape or catchment area also exposes pools to more disturbances, often termed "edge effects." Urban "edge effects" include irrigation runoff that frequently contains nitrates, petroleum-based products, herbicides and other chemicals toxic or damaging to vernal pool plants and animals. Domestic pets prey upon native birds and mammals that are part of the native plant and animal community (Soule *et al.* 1992). Landscape plants and irrigation can change the insect fauna by augmenting resources for native or introduced species, especially during the annual drought period. Honeybees, an introduced species, are frequently seen in vernal pools, and it is likely they have impacted the native pollinators such as solitary ground-dwelling bees (J. Mills unpub. data, Schiller *et al.* 1998). Introduced ant species are strongly associated with irrigation and an augmented water supply (Bolger 1997, Suarez *et al.* 1998). Horse, foot, bicycle and vehicle traffic crushes plants, removes soil and creates channels that can dewater an area (Bauder 1994). Dumping of furniture, appliances, construction debris and other forms of trash impacts pools by covering the soil surface and interrupting drainage patterns (Bauder 1986, 1987b; Bauder *et al.* 1998).

Functional Capacity Indices: Direct and Indirect

The direct functional capacity index for maintenance of characteristic plant communities was developed from floral surveys in the basin and adjacent uplands (periphery) of vernal pools in southern California. From these data, both direct and indirect functional capacity indices were created. Because the direct index estimates the function with more precision, it should be used whenever possible, using the protocol described in Chapter 5 and forms in Appendix C. Personnel with taxonomic training specific for southern Californian vernal pools will be required, and the pools will need to be surveyed in at least two separate years with average or above average precipitation (see Table 5.4 and Appendix D.1). The direct index may be estimated in either the wet or dry phase. If the standing water is too deep or if the dry phase follows a year of below average precipitation, the direct index cannot be successfully estimated.

An indirect functional capacity index is also included, although the information it provides is limited. Because function in the plant community can only be assessed accurately through actual examination of the species that are present, the indirect functional capacity index is considered to be only an approximation.

Plant distribution categories are described more fully in Table 5.6 and descriptions of disturbance categories can be found in Table 5.5 and Appendix D.2.

Direct Functional Capacity Index

Model Variables

V_{BA}= total number of plant species in the basin

$V_{BADI\ 1>0}$ = indicator variable for the presence of any species from distribution category 1 in the pool basin. (0 = none, 1 = one or more species present). Category 1 includes 5 vernal pool species that are state or federally listed as endangered, threatened or rare. (See Table 5.6).

$V_{PERIDI\ 12345}$= total number of plant species from distribution categories 1, 2, 3, 4 and 5 that are found in the uplands (20-ft. peripheral band). This includes all species that are not introduced and excludes upland species that are found in the pool basin (Category 6).

$V_{DI\ 2>0}$= indicator variable for the presence of any species from distribution category 2 in the pool basin or uplands. (0 = none, 1 = one or more species present). Category 2 includes 5 basin species and 27 upland species that are narrowly endemic to southern California. If a typical upland species is found in the basin, it is placed in distribution Category 6 rather than Category 2.

$V_{DI\ 67>17}$ = indicator variable for whether there are more than 17 species from distribution Categories 6 and 7 in the pool basin and uplands (0 = 17 or fewer species, 1 = 18 or more species). If a non-introduced species that is typically found in the uplands (20-ft. peripheral band) is instead found in the basin, it is placed in Category 6. Category 7 consists of 66 species known to be introduced to the reference domain.

Index of Function

Direct FCI = (0.02 x V_{BA}) + (0.19 x $V_{BADI\ 1>0}$) + (0.01 x $V_{PERIDI\ 12345}$) +
(0.13 x $V_{DI\ 2>0}$) - (0.23 x $V_{DI\ 67>17}$)

The characteristic plant community function is enhanced by the presence of listed species and other natives, especially those with restricted distributions. The function is diminished by the presence of species out of place, *i.e.*, upland plants in the basin, or species introduced into the region. Because upland plants are usually intolerant of inundation, their presence in the basin indicates the absence of standing water in the current season and a less hospitable environment for temporary wetlands endemics.

Indirect Functional Capacity Index

Model Variables

$V_{DIST1km<6}$= indicator variable for whether disturbance in the four 1km quadrants is less than Category 6 in all cases. (0 = Dist1km-1, Dist1km-2, Dist1km-3 and/or Dist1km-4 equal to 6; 1= Dist1km-1, Dist1km-2, Dist1km-3 and Dist1km-4 all less than 6).). (See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2 for disturbance categories).

$V_{DOMDISTPERI\_VEG}$= indicator variable for the dominant disturbance in the 20-ft. peripheral band, recoded for the vegetation function.
(1 = $V_{DOMDISTPERI} < 3$;
0 = $V_{DOMDISTPERI} = 3$;
-1 = $V_{DOMDISTPERI} > 3$).

$V_{DOMDISTBA=1}$= indicator for whether the basin is undisturbed per the 6 disturbance categories.
(0 = Domdistba greater than one, 1 = Domdistba equal to one).

$V_{MAXDEPTH<0.36}$= indicator variable for whether $V_{MAXDEP} < 0.36$ m.
(0 = V_{MAXDEP} greater than or equal to 0.36 m,
1 = V_{MAXDEP} less than 0.36 m).

Index of Function

Indirect FCI = 0.2 + (0.2 x $V_{DIST1km\ <6}$) + (0.2 x $V_{DOMDISTPERI\_VEG}$) +
(0.2 x $V_{DOMDISTBA=1}$) + (0.2 x $V_{MAXDEPTH<0.36}$)

The characteristic plant community function is diminished by substantial to severe disturbance in the landscape (within a circle of 1 km radius centered on the pool basin), the basin periphery (20-ft. peripheral band) and the basin itself. Basins that are too deep do not support endemic vernal pool flora because these species have limited tolerance for deep water that stands for long periods of time.

Function 5: Maintain Characteristic Faunal Community

Definition

Ephemeral pools provide habitat for a diverse faunal community adapted to the bi-phasic nature of the resource. The faunal community function refers to the capacity of the vernal pool to provide food, cover, and reproductive opportunities for animal taxa for which these wetlands are essential for some or all parts of their life cycle.

Two estimates of the faunal community function are provided: a direct measure based on crustacean community composition, and an indirect measure based on hydrogeomorphic surrogates. Because no single species or suite of species is a reliable indicator for a functional vernal pool, the direct measure of faunal support is specifically calibrated for a subset of pools found in the HGM reference domain.

The indirect version of the model has been calibrated with crustacean community data from the same subset of pools used for the direct model. Further validation could potentially be provided through expanded faunal surveys that include non-crustacean aquatic invertebrates, aquatic and semiaquatic vertebrates, and terrestrial vertebrates and invertebrates that use vernal pools. Because vernal pool inundation patterns are highly variable depending on the timing and amount of precipitation, additional samples from a greater number of inundation events could also be used to refine model calibration. These data sets can be analyzed with general linear models to derive the best indirect functional capacity index. For each non-Boolean HGM variable, scatterplots or boxplots should be examined for potential threshold effects; as such effects are present in the indirect functional capacity indices described below. Details regarding statistical model development are provided in Chapters 2 and 5 of this HGM guidebook.

Rationale for Selecting the Function

Vernal pools provide habitat that is used by a wide variety of animals throughout their life cycle. Vernal pools that have a high degree of faunal functionality maintain this characteristic set of species. In addition to the opportunities for food and reproduction provided by the pool itself (during either the wet or dry phase), connectivity among pools at the landscape level may also be important for some species. This is because 1) their life cycle requires access to both ephemeral pools and other habitat types, or 2) the ecological and evolutionary consequences of dispersal and gene flow among pools in a complex are essential for persistence in individual pools. The second set of processes may be addressed in terms of metapopulation processes, source sink dynamics or maintenance of genetic diversity, depending on the context. Spatial linkages among vernal pools and adjacent habitats within the surrounding landscape facilitate the long-term persistence of a diversity of habitats and characteristic vernal pool plant and animal communities (Ebert and Balko 1987, Holland 1976, Holland and Jain 1981, Hanski 1996, Hansson *et al.* 1995, Simovich, 1998, Thorp and Leong 1998).

The maintenance of characteristic assemblages of invertebrates and vertebrates are typically included in draft models for depressional wetlands, including vernal pools. However, thus far, there has been little success in developing a rapid assessment technique to directly estimate this function. This is due to the taxonomic complexity and variability of animals within and among vernal pools. Vertebrates and terrestrial invertebrates that utilize vernal pools do not easily lend themselves to functional assessment, due to difficulty in accurate field assessments and/or few previous studies. Consequently, this HGM assesses faunal function for vernal pool crustaceans as a surrogate for the entire fauna. Crustaceans are the most numerically important invertebrate faunal group, and include two federally endangered species.

Broad Faunal Categories

Vernal Pool Obligates: These are organisms whose entire life cycle is completed within the pool. The most obvious examples are crustaceans, but this group also includes, nematodes, rotifers and other taxa. The life cycle of obligates is precisely tied to the pools, and these species typically persist through the dry phase as dormant propagules in the pool sediments. Dormant propagules (typically encysted eggs or embryos) hatch when the pools fill, and the organisms quickly mature and reproduce before the pool dries. Some are generalists found in pools that span a variety of abiotic conditions. However, most exhibit limited tolerance ranges for water temperature, chemistry (pH, salinity, alkalinity, turbidity, etc.) and pool duration (due to minimum developmental times). As a result, most vernal pool obligates are narrow endemics found only in a limited geographic area. These organisms feed on those lower in the food chain including algae, bacteria, smaller animals and detritus. They are in turn fed upon by amphibian larva and migratory waterfowl. Dispersal among pools and pool complexes is often mediated by vectors such as birds and mammals. Thus, gene flow, recolonization and potential rescue of pools with low density are all dependent upon maintenance of appropriate vectors.

Vernal pools in the reference domain contain at least three species of fairy shrimp: the San Diego fairy shrimp *Branchinecta sandiegonensis*, Lindahl's fairy shrimp (also known as the versatile fairy shrimp) *B. lindahli* and the Riverside fairy shrimp *Streptocephalus woottoni*. The San Diego fairy shrimp and the Riverside fairy shrimp are federally endangered species; so appropriate USFWS permitting issues must be addressed before sampling pools in which these species may be present. The distributional patterns of the two *Branchinecta* species have been characterized well enough that their presence figures prominently into the Functional Capacity Index. *B. sandiegonensis* is commonly found in vernal pools with high function. However, within the reference domain for this HGM guidebook, *B. lindahli* tends to occur only in disturbed pools. *S. woottoni* is relatively rare in the HGM reference domain, and was not present in pools that were used to calibrate this function. As a result, this species is not used as a specific indicator of function despite its endangered status. If encountered during sampling, it should be treated like any other crustacean species when calculating $V_{CRUSTSPP}$.

Lifestyle Dependent Organisms: These are organisms that spend only a part of their life cycle in the pools or are dependent on other pool organisms at a certain stage. The most obvious in this group are the amphibians. While some species such as tree frogs can breed in intermittent streams as well, spadefoot toads are in large part dependent on predator-free ephemeral pools. The adults spend the dry season under the ground or in the uplands, rather than the pools. Spadefoots take advantage of rodent burrows to help them get up to a meter deep in the ground. Although tree frogs may exhibit an extended period of activity in the wet season, spadefoots are more precisely adapted to the pool cycle. After emerging during heavy rains (thought to be cued by the sound) they quickly move to pools and breed in one or a very few nights. The adults then return to shallow burrows in the uplands and emerge at night to feed for a short period of time. Tadpoles develop quickly eating pool vegetation, and even more quickly if fairy shrimp are available as prey. Upon metamorphosis, they too return to the uplands.

A large variety of insects also utilize vernal pools, generally for the development of their larval stage. Terrestrial (aerial) insect adults come to the pools to deposit eggs. Many insect larvae are predators on other vernal pool animals. Most vernal pool insects with aquatic larvae will also utilize other water sources, and are thus not totally reliant on ephemeral pools. However, some insect pollinators are obligately dependent on vernal pool plants, with which they have co-evolved specific pollination syndromes.

Opportunists: These are organisms that will take advantage of pools when available. Included are some insects and migratory waterfowl (which may have been more dependent on these pools in the past when they were more abundant). These use the pools as resting and feeding stations (Baker *et al.* 1992). Some species breed around pools. Mammals will also use pools for water sources, and garter snakes feed on tadpoles when available.

Characteristics and Processes that Influence the Function

Natural Characteristics and Processes

In general, it is widely recognized that vernal pools support a unique assemblage of fauna due to the timing and duration of inundation phases; these are in turn dictated by climate, soil characteristics, hydrology and the microtopography of the pool basin (*e.g.*, Bauder *et al.* 1998, Hanes and Stromberg 1998, Keeley and Zedler 1998, Smith and Verrill 1998, Sutter and Francisco 1998). Although vernal pools are sometimes thought of as isolated "bathtubs" driven solely by precipitation and evaporation, they are often linked hydrologically to the remainder of the landscape by groundwater flow through perched aquifers (Rains *et al.* 2006). General descriptions of the origin of southern California's vernal pools, their hydrogeology (water sources and hydrodynamics) soil characteristics and hydrologic variability are found in Chapter 3.

As in many other areas, both rainfall patterns and vernal pool inundation patterns are highly variable in southern California (*e.g.*, Bauder 2005). For animals such as crustaceans that live in these temporary habitats, the fraction of cysts that hatch has evolved to match environmental predictability. To persist in a pond that does not always remain full long enough for maturation and mating, < 100% of cysts hatch during any particular hydration. This phenomenon has been very well studied theoretically and empirically (*e.g.*, Brendonck 1996, Philippi *et al.* 2001, Brendonck and De Meester 2003, Brock *et al.* 2003). For example, in the San Diego fairy shrimp, only 6% of *B. sandiegonensis* cysts hatch during laboratory hydrations (Simovich and Hathaway 1997), and the average pool containing *B. sandiegonensis* fills long enough to allow reproduction approximately once in every three inundation events (Philippi *et al.* 2001).

No single species or taxonomic group is diagnostic for a functional vernal pool. For example, considerable regulatory effort has focused on the San Diego fairy shrimp due to its status as an endangered species, but it is not found in highly functional pools with short inundation times. Thus, an assessment of vernal pool functionality with regards to fauna requires an accurate survey of community composition across the full range of hydroperiods within the geographic and hydrologic domain of the HGM.

Human Induced influences

As described in Chapter 3, human modifications to the uplands, wetland edge or the wetland itself can affect the receipt and retention of water, and thus inundation patterns. Plant and animal communities characteristic of undisturbed vernal pools are generally not present in pools with altered hydrology, and individual species are restricted to pools with particular inundation periods (*e.g.*, Helm 1998, Platenkamp 1998, Simovich 1998, Bauder 2000). For example, disturbed pools tend to facilitate populations of mosquitoes, which are rare or absent in undisturbed pools (*e.g.*, Rogers 1998). In general, many vernal pool crustaceans that are characterized as obligates seem to be more tolerant of human-influenced hydrologic changes than obligate vernal pool plants.

Functional Capacity Indices: Direct and Indirect

The functional capacity index for faunal support focuses on the crustacean community as a surrogate for all vernal pool fauna. We present both a direct and an indirect functional capacity index. The direct index must be based on samples from the wet season, using protocol described in Chapter 5 and Appendix B, and taxonomic identification by personnel with freshwater crustacean training. Such training, for example, would exceed that required for identifying fairy shrimp, as fairy shrimp constitute only one component of the crustacean fauna in a vernal pool.

An indirect functional capacity index is also included, although the information it provides is limited. Thus, the indirect functional capacity index should be considered to be only an approximation. Faunal function can only be assessed accurately through actual collection and analysis of the species that are present. However, if function needs to be assessed when the pool is not holding water, only indirect assessment is possible.

<u>Direct Functional Capacity Index</u>

Model Variables

$V_{MAXDEPTH}$ = maximum depth of the pool in meters, as estimated with surveying equipment.

$V_{CRUSTSPP}$ = total number of crustacean species present.

$V_{FAUNIND}$ = proportion of all crustacean species present that are found in the following list of 14, which are termed "Faunal Indicators":

Cladocera (water fleas): *Alona cf diaphana*, *Ceriodaphnia dubia*, *Macrothrix hirsuticornis*, *Moina micrura*, *Scapholeberis ramneri*, *Simocephalus* sp.

Copepoda (copepods): *Hesperodiaptomus franciscanus*

Ostracoda (ostracods, seed shrimp): *Cypridopsis*, *Cypris pubera*, *Eucypris virens*, *Eucypris* sp., *Herpetocypris*, *Limnocythere*, *Strandesia* sp.

V_{SDFS} = indicator variable for the San Diego fairy shrimp *Branchinecta sandiegonensis*: 0 if absent, 1 if present.

V_{LFS} = indicator variable for the fairy shrimp *Branchinecta lindahli*: 0 if absent, 1 if present.

Dependence on $V_{MAXDEPTH}$

The faunal index can only be estimated directly if $V_{MAXDEPTH} \geq 0.07$ m. There is currently no data set that can be used to describe the characteristic fauna of very shallow pools. Moderately shallow pools, defined as (0.07 m $\leq V_{MAXDEPTH} < 0.15$ m), support fewer crustacean species than deep pools, defined as ($V_{MAXDEPTH} \geq 0.15$ m). This is accounted for in the first row of the functional capacity index below.

Index of Function

The direct faunal index is inferred by evaluating against the most restrictive conditions (where the index = 1.0). If these conditions are not met, move down through successive rows until all index conditions in the row are met.

Generic functional definition	**Index conditions**	**Index**
Pool is functioning at its optimum level and will do so for the foreseeable future.	{ ($V_{CRUSTSPP} > 10$) and ($V_{FAUNIND} \geq 0.6$) and ($V_{SDFS} = 1$) and ($V_{LFS} = 0$) } or { ($V_{MAXDEPTH} < 0.15$) and ($V_{SDFS} = 1$) and ($V_{LFS} = 0$) }	1.0
Pool is functioning at its highest level but is declining, or is functioning at near-optimal levels and will do so for the foreseeable future.	($V_{FAUNIND} \geq 0.5$) and ($V_{SDFS} = 1$) and ($V_{LFS} = 0$)	0.75
Pool has high functionality, is declining, but is recoverable. Alternatively, the pool retains some functionality, is stable or improving, and is recoverable with moderate external effort.	[{ ($V_{FAUNIND} \geq 0.5$) or ($V_{SDFS} = 1$) } and ($V_{LFS} = 0$)]	0.65
Pool retains some function, but is declining and not recoverable. Alternatively, pool has low function but has the potential for self-recovery or restoration.	($V_{FAUNIND} > 0.0$)	0.25
Pool has low function and probably incapable of recovery.	($V_{CRUSTSPP} > 0$)	0.1
Pool retains no functionality.	($V_{CRUSTSPP} = 0$)	0.0

Indirect Functional Capacity Index

Model Variables

$V_{INLETMOD}$ = Indicator variable for discernible modification to inlet: 0= no, 1= raised, 2= lowered.

$V_{MOUNDPRES}$ =Indicator variable for mounds present: 0= no, 1= yes.

$V_{SURFCRACKS}$ = Indicator variable for surface cracks 0= no, 1= shallow, 2= deep (deep=>1 cm wide & 1 dm deep).

Log ($V_{CATCHAREA}$)= logarithm, base 10, of the catchment area (est.) in acres.

Log ($V_{MAXDEPTH}$)= logarithm, base 10, of maximum depth of the pool in meters, as estimated with surveying equipment.

$V_{COBBLESBA}$ = 100 X (percent of basin covered with rounded or angular coarse pebbles or cobbles). Pebbles are 2-7.5 cm in diameter and cobbles are 7.5-25 cm in diameter (Soil Survey Manual, USDA 1993).

Dependence on $V_{MAXDEPTH}$

The faunal index can only be estimated indirectly if $V_{MAXDEPTH} \geq 0.07$ m. There is currently no data set that can be used to calibrate an indirect function for the characteristic fauna of very shallow pools. Moderately shallow pools, defined as ($0.07 \text{ m} \leq V_{MAXDEPTH} < 0.15$ m), differ from deep pools, defined as ($V_{MAXDEPTH} \geq 0.15$ m), in terms of crustacean communities and hydrogeomorphic variables. Accordingly, separate indirect functional capacity indices are presented for moderately shallow and deep pools.

Index of Function for Moderately Shallow Pools

If ($0.07 \text{ m} \leq V_{MAXDEPTH} < 0.15$ m), the indirect faunal index is calculated as:

Indirect FCI = 0.40 + (0.50 x ($V_{INLETMOD}$ = 0)) + (0.33 x Log ($V_{CATCHAREA}$)) + (0.20 x ($V_{COBBLESBA} > 10$))

Note that ($V_{COBBLESBA} > 10$) is a Boolean expression, receiving a value of 1 for ($V_{COBBLESBA} > 10$) and a value of 0 otherwise.

If ($V_{MAXDEPTH} \geq 0.15$ m), the indirect faunal index is calculated as:

Indirect FCI = 0.40 + (0.3 x ($V_{INLETMOD}$ = 0)) + (0.20 x $V_{MOUNDPRES}$) + (0.20 x ($V_{SURFCRACKS} > 1$)) + (0.15 x Log ($V_{CATCHAREA}$)) + (0.75 x Log ($V_{MAXDEPTH}$))

Note that ($V_{INLETMOD} = 0$) and ($V_{SURFCRACKS} > 1$) are both Boolean expressions, receiving a value of 1 if the expression is true, and a value of 0 otherwise.

The Indirect FCI reflects the fact that vernal pools with a characteristic crustacean community tend to have large catchment areas in landscapes where mounds are present. Modifications to the pool inlet disrupt hydrologic cycles, negatively impacting crustaceans. Within the basin, features such as cobbles (in shallow pools) and surface cracks (in deeper pools) are also indicative of low disturbance and characteristic hydrologic cycles. For basins deeper than 0.15 m, increases in maximum depth do correlate to some extent with higher crustacean community function.

Appendix B Variable Table

Direct Assessment Variables

Variable symbol	Variable definition	Function(s) used
$V_{TOTINUND}$	total number of days during the rainy season a pool was inundated, at the lowest elevation.	1,2
$V_{TOTPRECIP}$	total precipitaion (cm) for the rainfall year at Lindbergh Field, San Diego.	1
$V_{PONDING\ EVENTS}$	number of times the pool was inundated during the rainy season, at the lowest elevation.	1
$V_{SC\_(\quad)}$	scaled versions of $V_{TOTINUND}$, $V_{PONDING\ EVENTS}$ and $V_{MAXINUNDEPTH}$ based on $V_{POOLCONNECT}$ and $V_{TOTPRECIP}$.	1
$V_{PERCENT\text{-}2MONTHS}$	percent of total precipitation during the rainfall season that fell during the two months with the highest rainfall amounts. Expressed as a whole number between 0 and 100.	1
$V_{MAXINUNDEPTH}$	maximum depth of inundation during the season, in cm.	1
$V_{NETPONDING}$	number of pools in the network that continuously pond ≥5 days during the rainy season.	2
$V_{HEADWATERPOND}$	number of headwater pools that simultaneously hold water at their lowest elevation.	2
$V_{FILLEDMAX}$	the number of headwater basins filled to their maximum depth at least once during the rainy season.	2
V_{BA}	total number of plant species in the basin.	4
$V_{BADI\ 1>0}$	indicator variable for the presence of any species from Category 1 in the pool basin. (0=none, 1=one or more species present). Category 1 includes 5 vernal pool species that are state or federally listed as endangered, threatened or rare. See Table 5.6.	4
$V_{PERIDI\ 12345}$	total number of plant species from distribution categories 1, 2, 3, 4 and 5 that are found in the uplands (20-ft. peripheral band). This includes all species that are not introduced and excludes upland species that are found in the pool basin (Category 6). See Table 5.6.	4
$V_{DI\ 2>0}$	indicator variable for the presence of any species from distribution Category 2 in the pool basin or periphery. (0=none, 1=one or more species present). Category 2 includes 5 basin species and 27 upland species that are narrowly endemic to southern California. If a typical upland species is found in the basin, it is placed in distribution Category 6 rather than Category 2. See Table 5.6.	4
$V_{DI\ 67>17}$	indicator variable for whether there are more than 17 species from distribution Categories 6 & 7 in the pool basin and 20-ft. peripheral band (0=17 or fewer species, 1=18 or more species). If a non-introduced species that is typically found in the uplands/periphery is instead found in the basin, it is placed in Category 6. Category 7 consists of 66 species known to be introduced into the reference domain. See Table 5.6.	4
$V_{CRUSTSPP}$	total number of crustacean species present.	5

(continued)

$V_{FAUNIND}$	proportion of all crustacean species present that are found in the "Faunal Indicators" list of 14 species.	5
V_{SDFS}	indicator variable for the San Diego fairy shrimp, *Branchinecta sandiegonensis*: (0=absent, 1=present).	5
V_{LFS}	indicator variable for the fairy shrimp, *Branchinecta lindahli*: (0=absent, 1=present).	5
Indirect Assessment Variables		
Variable symbol	**Variable definition**	**Function(s) used**
$V_{COBBLESBA}$	100 X (percent of the basin covered with rounded or angular coarse pebbles or cobbles). Pebbles are 2-7.5 cm in diameter and cobbles are 7.5-25 cm in diameter (Soil Survey Manual, USDA 1993).	1, 5
$V_{COBBLESBA>15}$	indicator variable: 0 if $V_{COBBLESBA\leq15}$, 1 if $V_{COBBLESBAS>15}$.	1
$V_{POOLCONNECT}$	indicator variable that characterizes surface connection of the pool to other pools. 1=none, isolated, 2=headwaters (outlet only), 3=flow through (inlet and outlet), 4=terminal, collector (inlet only).	1
$V_{MAXDEPTH}$	maximum depth of the pool in meters, as estimated with surveying equipment.	1, 5
$V_{MAXDEPTH\_GR}$	categorical groups for maximum depth of the pool. $V_{MAXDEPTH\_GR}$= 0.32 if $V_{MAXDEPTH}\leq0.11$ m, = 0.37 if 0.11 m < $V_{MAXDEPTH}$ ≤0.35 m and = 0.00 if 0.35m < $V_{MAXDEPTH}$.	1
V_{LENGTH}	length of longest axis (a) in meters, using the basin edge as determined in the field.	1
V_{SLOPE}	long axis slope= $V_{MAXDEPTH}/(V_{LENGTH})/2)$.	1
V_{SLOPE_GR}	categorical groups for slope: $V_{SLOPE\_}GR$= 1 if $V_{SLOPE}\leq1.9$, =2 if $1.9<V_{SLOPE}\leq3.0$ and =3 if $V_{SLOPE}>3.0$.	1
$V_{DEFIN\_OR\_OUTLET}$	1 if a pool has a defined inlet or defined outlet; 0 otherwise.	1
$V_{IN\_OR\_OUTLET\_WS}$ V_{SLOPE_WS}	variables specific to the water storage function that are calculated based on $V_{POOLCONNECT.}$ See Function 1, Indirect Functional Capacity Index, Model Variables.	1
$V_{DIST\ 1km<5}$	indicator variable for whether disturbance in the four 1 km quadrants is less than 5 in all cases. (0=Dist1km-1, Dist1kkm-2, Dist1km-3 and/or Dist1km-4 equal to 6; 1=Dist1km-1, Dist1kkm-2, Dist1km-3 and Dist1km-4 all less than 5). See Chapter 5 "Assessment of Disturbance levels" and Appendix D.2.	1
$V_{NUMPOOLS}$	the number of pools in a network of pools as determined by field surveys.	2
$V_{DOMDISTBA\text{-}NET}$	indicator variable for the dominant disturbance within the basins of a network. See Appendix D.2.	2
$V_{DOMDISTPERI\text{-}NET}$	indicator variable for the dominant disturbance in the 20-ft peripheral band surrounding the basins of a network. See Appendix D.2.	2
$V_{DOMDISTCA\text{-}NET}$	indicator variable for the dominant disturbance in the catchment area of the pool network. See Appendix D.2.	2
$V_{MODIFCAT\text{-}NET}$	indicator variable for the type of modification made to the catchment area of the network. (1= none, 2= draining/diminishment/truncation, 3= addition/augmentation	2

(continued)

$V_{SEDFILLBA-NET}$	indictor variable for the observable deposition of sediment or fill in the basins of the network as indicated by deltaic deposition patterns or soil discontinuities in texture or color (1= none, 2= < 25% of basin surface, 3= ≥ 25% of basin surface).	2
$V_{INLETELEV-NET}$	indicator variable for the discernible modification to the inlet elevation of the pools of the network (1= none, 2= raised, 3= lowered, 4= trenched/ditched).	2
$V_{OUTLETELEV-NET}$	indicator variable for the discernible modification to the outlet elevation of the basins of the network (1= none, 2= raised, 3= lowered, 4= trenched/ditched).	2
$V_{DIST\ 1km<6}$	indicator variable for whether disturbance in the four 1 km quadrants is less than Category 6 in all cases. (0=Dist1km-1, Dist1kkm-2, Dist1km-3 and/or Dist1km-4 equal to 6; 1=Dist1km-1, Dist1kkm-2, Dist1km-3 and Dist1km-4 all less than 6). See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2.	4
$V_{DOMDISTPERI\ -VEG}$	indicator variable for the dominant disturbance in the 20-ft. peripheral band around the basin edge, recoded for the vegetation function ($1 = V_{DOMDISTPERI} < 3$; $0 = V_{DOMDISTPERI} = 3$; $-1 = V_{DOMDISTPERI} > 3$).	4
$V_{DOMDISTBA=1}$	indicator variable for whether the basin is undisturbed (0=Domdistba greater than one, 1= Domdistba equal to one). See Chapter 5 "Assessment of Disturbance Levels" and Appendix D.2.	4
$V_{MAXDEPTH<0.36m}$	indicator variable for whether $V_{MAXDEPTH}$ <0.36 m (0=$V_{MAXDEPTH}$ greater than or equal to 0.36m, 1=$V_{MAXDEPTH}$ less than 0.36 m).	4
$V_{INLETMOD}$	indicator variable for discernible modification to the basin inlet (0=no, 1=yes).	5
$V_{MOUNDPRES}$	indicator variable for whether mounds are present (0= no, 1= yes).	5
$V_{SURFCRACKS}$	indicator variable for the presence of surface soil cracks (0= no, 1= shallow, 2= deep —deep=> 1cm wide and 1 dm deep).	5
$Log(V_{CATCHAREA})$	logarithm, base 10, of the catchment area estimated in acres.	5
$Log(V_{MAXDEPTH})$	logarithm, base 10, of the maximum depth of the pool in meters, as estimated with surveying equipment.	5
	(concluded)	

Appendix C
Data Collection Forms

C.1. WAA assessment data form

C.2. Pool scale base map Data form

C.3. Landscape level disturbance data form

C.4. Hydrology direct assessment data form

C.5. Hydrologic network direct assessment data form

C.6. Vegetation direct assessment data form

C.7. Fauna (Crustacean) direct assessment data form

SoCal VP Guidebook

Wetland Assessment Area Data Form

Date_____ Data by _____________________

Location______________________________________

Conditions____________________________________

Purpose and General Objectives of the Assessment

Pre-existing Sources of Information

Source	Information obtained

Red Flag Screening Results

List the numbers of items in Table 5.1 that are present. The importance of each red flag may depend on the purpose & objectives of the assessment.

Wetland Assessment Area

Area (acres)__________ Number of pools__________

Description of WAA

Pool sub-class and type

Sub-class ____________________________ Type ______________________________

Justification

Precipitation Regime Context*

Season of assessment ________________ Avg. total seasonal precipitation for the WAA_______

Weather station used for precip. total ___________

Total precipitation up to time of assessment ___________

Precipitation pattern up to time of assessment ____

Continuous ponding events Number _____ Days each event ____________________________

Direct data can be collected for listed functions:____

____

No direct data can be collected__________

* Use the Precipitation Regime Context and Data Collection Guidelines (Appendix D.1).

SoCal VP Guidebook

Pool Scale Base Map Data Form

Pool #_______________

Date_______ Data by ____________________

Location ________________________________

GPS Coordinates____________________________

Inlets and Outlets

Visible surface inlet(s)

No_____
Yes_____
If yes,
Defined channel?_____
Swale?_____
How supplied?________________
Modified?
No_____
Yes_____
If yes,
Raised_____ Ditched/trenched_____
Lowered_____

Visible surface outlet(s)

No_____
Yes_____
If yes,
How many?_____
Any modified?
No_____
Yes_____
If yes,
Raised_____
Lowered_____
Ditched/trenched_____

Catchment

Long axis__________ Short axis__________ Area__________

Mounds present? No_____ Yes_____

Basin

Elevations (relative)

Outlet(s)_____ _____ Deepest point__________

Maximum depth (absolute)__________

Edge

Indistinct_____
Distinct______

If distinct, list indicators

__________ __________ __________
__________ __________ __________

Dimensions

Long axis (avg. length)__________ Short axis (avg. length) __________
Long axis slope_______________
Pool area__________ Pool volume__________

Surface features

Cobbles (% cover)__________
Surface cracks No_____ Shallow_____ Deep^_____

^= > 1cm wide & 1 dm deep.

Soil texture

Basin__________ Peripheral band__________

Dominant Disturbance—Basin, Periphery & Catchment

Soil disturbances

Type	Location*	Depth	% cover	DD Category@
______________________	______________	______	______	_____
______________________	______________	______	______	_____
______________________	______________	______	______	_____
______________________	______________	______	______	_____
______________________	______________	______	______	_____
______________________	______________	______	______	_____
______________________	______________	______	______	_____

Dominant Disturbance Category@ Basin_____ Periphery_____ Catchment_____

*=Catchment, Periphery or Basin. @See Table 5.5 and Appendix D.2.

SoCal VP Guidebook

Landscape Level Disturbance Data Form

Date_______ Data by ____________________

Location ________________________

GPS Coordinates__________________________________

Basin # ___________

	Q1	Q2	Q3	Q4
	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*
Total				

Basin # ___________

	Q1	Q2	Q3	Q4
	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*
Total				

Basin # ___________

	Q1	Q2	Q3	Q4
	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*
Total				

Basin # ___________

	Q1	Q2	Q3	Q4
	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*
Total				

Basin # ___________

	Q1	Q2	Q3	Q4
	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*	% X Dist Cat*
Total				

* See definitions of Disturbance Categories and sample calculations in Appendix D.2.

SoCal VP Guidebook

Direct Assessment Data Form

Hydrology

Pool #_______ Location__________________________________

Date	Time	Obs.*	Depth or DTW (ft)	HWM validity (E,G,F,P,N,D)	HWM cleaned? (Y or N)	SPECIFIC CONDUCTANCE^ (umhos/cm in field)	(umhos/cm at 25°C)	Field Temp. (°C)	COMMENTS

*Obs.= initials of observer, data taker DTW= Depth to Water E= Excellent, G= Good, F= Fair, P= Poor, N= None and D= doubtful.

For example, excellent means that the HWM is clear, credible and generally observable at more than one location in the pool.

^Not employed in the model FCIs.

SoCal VP Guidebook
Hydrologic Network Data Form
Direct and Indirect Assessment
Network # (if >1 in WAA)________________

Date_______ Data by ______________________

Location ____________________________________

Indirect Assessment Variables*

Catchment Area Modification-Network

Net change (drained, diminished &/or augmented) _______%

Inlet/Outlet modification
Lowered _______# basins   Raised _______# basins
Lowered with ditches or trenches _______# basins

Added to, increased or augmented _______% ____

Drained, diminished or truncated _______% ____

Dominant disturbances @

Basins in the network (Dom dis cat)_____%_____
Basin sediment/fill _____%
Network catchment(Dom dis cat)_____%_____

Periphery of the basins in the network
(Dom dis cat)_____%_____

Network size

Number of pools in the network______

Direct Assessment Variables~

Pool #	Network position^	Total days inundated	Inund depth max?	# Precipitation events to pond, with cm/event°
Pool_____				
Pool_____				
Pool_____				
Pool_____				
Pool_____				
Pool_____				
Pool_____				
Pool_____				
Pool_____				
Pool_____				

*Use data on landscape and pool scale base maps and forms.
@ Use Appendix D.2 for Disturbance Categories.   ~ Use data from the hydrology direct assessment forms.
^ Connections: 1= isolated, 2= headwater, 3= flowthrough, 4= terminal
° See Table 5.4. May not be needed for FCIs.

SoCal VP Guidebook
Direct Assessment Data Form
Vegetation

Date_____ Pool #_____ Data by ___________________
Location____________________________________
Conditions______________________________ Page ___

SPECIES	CATEGORY		SPECIES	CATEGORY	
	BA*	PERI*		BA*	PERI*
Pogogyne abramsii	1	1			
Downingia cuspidata	3				
Jepsonia parryi	6	2			
Hypochaeris glabra	7	7			
Agrostis avenacea	7				

* BA= basin, PERI= 20-ft wide band parallel to basin edge.

DISTRIBUTION CATEGORIES

1=**listed**; endangered, threatened or rare (State or Federal list)(excluding category 6).
2=narrow endemic; native to an area south of the Transverse Ranges in California, including Baja MX (excluding category 6).
3=**regional**; native to the California Floristic Province (excluding category 6).
4=**New World, Mediterranean climate**; native to the west coast of N/S America (excluding category 6).
5=**cosmopolitan**; distributed east of the Sierras and/or worldwide, in addition to southern California (excluding category 6). No known introduction into southern California.
6=encroaching upland; species from categories 1-5 that is found in the pool basin but usually occurs in the uplands.
7=**introduced**; known introduction into California.

Definitions and assignments to distribution categories are based primarily on Hickman, James C., ed. 1993. The Jepson manual: Higher plants of California, University of California Press, Berkeley, CA.

VCRUSTSPP	Total number of crustacean species present

Record:

USER NOTE: All samples from all dates for the same pool are entered on the same record sheet(s)

Pool number/name/site:

	Sample date	Collected by
Net size (rectang. area)	Lab analysis date	Identified by
Length/depth of sweep 1	Length/depth of sweep 2	Length/depth of sweep 3
Volume of sweep 1	Volume of sweep 2	Volume of sweep 3

For pools > 30 cm deep:

Length/depth of sweep 4	Length/depth of sweep 5	Length/depth of sweep 6
Volume of sweep 4	Volume of sweep 5	Volume of sweep 6
Length/depth of sweep 7	Length/depth of sweep 8	Length/depth of sweep 9
Volume of sweep 7	Volume of sweep 8	Volume of sweep 9

Species name	# found	Species name	# found	Species name	# found

Sample number 2	Date ponding began	
	Sample date	Collected by
Net size (rectang. area)	Lab analysis date	Identified by
Length/depth of sweep 1	Length/depth of sweep 2	Length/depth of sweep 3
Volume of sweep 1	Volume of sweep 2	Volume of sweep 3

For pools > 30 cm deep:

Length/depth of sweep 4	Length/depth of sweep 5	Length/depth of sweep 6
Volume of sweep 4	Volume of sweep 5	Volume of sweep 6
Length/depth of sweep 7	Length/depth of sweep 8	Length/depth of sweep 9
Volume of sweep 7	Volume of sweep 8	Volume of sweep 9

Species name	# found	Species name	# found	Species name	# found

USER NOTE: Duplicate sheet for >2 samples

VCRUSTSPP	Total number of crustacean species present	**Summary page**

Record:

USER NOTE: All samples from all dates for the same pool are entered on the same record sheet(s)

Pool number/name/site:

Number of samples	Number of ponding events
	Total water volume sampled

Species name	# found	Species name	# found	Species name	# found

VCRUSTSPP	# of Faunal Indicators	VFAUNIND
VLFS		VSDFS

Appendix D
Resources

D.1. Precipitation Regime Context and Data Collection Guidelines

D.2. Disturbance Categories and Sample Calculations

D.3. Coastal SD Vernal Pool Species List

D.4 Guidelines for Assessing the Effects of Proposed Projects on Rare, Threatened, and Endangered Plants and Natural Communities

D.5. Key to CDFG Special Plants List

D.6. Pre-analysis *a priori* FCI descriptions applicable to any function

Appendix D.1. Precipitation Regime Context and Data Collection Guidelines*

1. What season will the assessment will be performed?

   Dormant/drought season—period post-flowering up to the time when sufficient rain has fallen to germinate plants and stimulate regrowth of perennials. Go to 2.

   Growing/rainy season—period following sufficient rainfall to germinate seeds of annual plants and to stimulate regrowth of perennials up to the end of flowering. Go to 3.

2. Was the total precipitation in the preceding rainy/growth season ≥ the long-term average for the assessment area? If not, no direct functional assessments can be performed during the dormant/drought season.

3a. In the year of assessment, has ≥ 14 cm of precipitation fallen?

   If yes, direct assessment of Function 1 (Surface and Sub-Surface Water Storage) can be performed and direct assessment of Function 4 (Plant Community) can be performed by field workers who have experience with the flora over a period of time representing a range of variation in total seasonal precipitation. If <14 cm of precipitation has fallen, direct assessment of Function 1 cannot be performed and direct assessment of Function 4 may not be reliable. Two years of data are recommended.

3b. In the year of the assessment, has sufficient precipitation fallen to meet the criteria for an average to above average or wet year? (See Chapter 4, Function 1 (Surface and Subsurface Water Storage, Direct Functional Capacity Index: Model Variables).

   If yes, a direct assessment can be made of Function 2 (Hydrologic Networks).

3c. In the year of the assessment, has there been continuous ponding ≥ 2 weeks?

   Direct assessment of Function 5 (Faunal Community) may be made with the understanding that all species supported in the community will not be observed without repeat sampling over a period of time. If water has not ponded for at least 2 continuous weeks, direct assessment of Function 5 is not possible.

***These guidelines have been developed and tested on vernal pools in coastal San Diego on soils of pedogenic origin. They may or may not apply to other pool types (age and origin) in different locations (sub-regional climates). See also Table 5.4.**

Appendix D.2. Disturbance Categories* and Sample Calculations

1 minimal disturbance/no disturbance

no known disturbance
light past grazing or brushing
ungraded tracks or trails

2 light to moderate disturbance --not recent, self-recovered or restorable

brushing, blading, disking, cultivation and/or vehicles (not recent)
grazing
trash/dumping
fire
sediment deposition

3 moderate to substantial disturbance --restorable or has been restored; some potential for self-recovery

disking, blading and/or plowing (cultivation)- may or may not be recent
sediment deposition
vehicle damage
landscape altered by roads, culverts, and/or loss of mounds

4 substantial disturbance--restoration potential, but extensive restoration efforts needed

on-going grazing, frequent fires and/or recent blading/brushing
extensive vehicle damage
landscape altered by roads, culverts, and/or loss of mounds
past extensive blading, bulldozing, plowing (cultivation) or grading

5 substantial disturbance--developed or restoration potential low

blading, grading, trenching or filling
extensive development with hard surfaces, roads, culverts
severe or ongoing disturbance (brushing, blading, disking, grading, bulldozing, irrigation, cultivation, vehicles)

6 severe disturbance—surrounding landscape dominated by development, restoration potential minimal to none

deep blading, extensive trenching or ripping
native soil profile no longer evident
artificial landscape dominates, either hardsurface or cultivated turf and landscaping
few or no vestiges of the natural topography

* The disturbance categories are used to score the following variables:

$V_{DIST1km<5}$, $V_{DOMIDISTBA-NET}$, $V_{DOMDISPERI-NET}$, $V_{DOMDISCA-NET}$, $V_{DIST1km<6}$, $V_{DOMDISTPERI\_VEG}$, $V_{DOMDISTBA=1}$.

	Sample calculations of quadrant disturbance scores			
Pool	**Q1**	**Q2**	**Q3**	**Q4**
Pool 1	0.6x1+ 0.4x5= 2.6	0.2x2+ 0.1x6+ 0.7x1= 1.7	.85x2+ .15x4= 2.3	0.75x5+ 0.25x1= 4.0
Pool 2	.20x5+ .35x3+ .45x1= 2.5	.35x2+ .65x6= 4.6	.25x2+ .35x4+ .35x6= 4	.25x4+ .45x1+ .30x2= 2.05

PLANTS THAT IN COASTAL SAN DIEGO COUNTY OCCUR PRIMARILY IN VERNAL POOLS		
SPECIES	INDICATOR CATEGORYΔ	HABITAT DESCRIPTION (CITATION)
Agrostis microphylla	FACW	moist or rather dry open ground (A); vp (B); sometimes vp (J); vp (M); beds & margins of vp, around seepy places (W); common near vp, usually not in basin (Z)
Alopecurus howellii	FACW+	meadows & wet places (A); about drying mud flats (B); wet places, drying mud flats (M); wet ground (MA); vp (P); vernally wet pools & marshes (*T); grassy openings (W); vp (Z)
Anagallis minimus	FACW	moist places (A); vp & other moist spots (B); vp, moist places (J); vp & other moist spots (M) & (M&K); vp (P); vernally wet pools & marshes (T); moist or muddy habitats (W); vp (Z)
Boisduvalia glabella	OBL	dry mud flats & vp (A); vp & other ephemeral ponds (B); floodlands & beds of former vp (MA); mudflats & vp (M); vernally wet pools & marshes (*T); beds of vp on mesas, clay soil in valleys, wet sands of arroyos (W); vp (Z)
Brodiaea orcuttii	OBL	heavy adobe soil on mountains/mesas of SD (A); grass, near v streams & pools (B); grassland near streams, vp (J); streams, vp, seeps (M); vp but not restricted to (P); margins & beds of vp, margins of cienegas (W); vp & adjacent habitats (Z)
Callitriche marginata	OBL	borders of vp in mud or submerged shallow water (A); often vp (J); moist cool places, terrestrial (MA); drying mud of vp (M); vernally wet pools & marshes (*T); muddy margins of vp (W); vp (Z)
Callitriche longipedunculata	OBL	bottom of desiccated winter pools (A); vp (B); rooted aq (MA); water of vp & later on mud (M); vernally wet pools & marshes (*T); vp (Z)
Crassula aquatica	OBL	mud (A); vp, other moist places (B); salt marshes, vp, mudflats, ponds (J); wet ground or vp (MA); dry mud flats (M) vernally wet pools & marshes (T); vp (Z)
Deschampsia danthonioides	FACW	open ground (A); mud flats, vp (B); moist to drying open sites, meadows, streambanks, temporary ponds (J); vp, moist to wet meadows (MA); moist places (M); vp (P); grassy areas (W); vp (T); vp (Z)
Downingia cuspidata	OBL	clay soils of desiccated vp & flats (A); vp (B); vp, lake margins, meadows (J); vp & wet soil (MA); vp (M); vernally wet pools & marshes (T*); margins of vp (W); vp (Z)
Elatine brachysperma	FACW	margins of ponds (A); vp (B); muddy shores, shallow pools (J); shallow water or muddy shores of vp, ponds or ditches (MA); many plant communities (M); vp (P); vernally wet pools & marshes (T*); vp (Z)
Elatine californica	OBL	margins of ponds & pools (A); lake marg, vp (B); pools, ponds, stream banks (J); ponds, vp, rice fields, & margins of streams & ditches (MA); water borders, mudflats (M); vp (P)
Eryngium aristulatum ssp. *parishii*	OBL	vp & salt marshes (A); vp (B); vp (H); vp, marshes (J); vp & salt marshes (MA); vp (M); vp (P); vernally wet pools & marshes (*T); playas & beds of vp (W); vp (Z)
Isoetes howellii	OBL	border of lakes & ponds (A); vp (B); vp, lake margins (J); ponds, streams or vp (MA); in water & on mud (M) & (M&K); vp (P); vernally wet pools & marshes (*T); along streams & in shallow pools (W); vp (Z)
Isoetes orcuttii	OBL	mesas in low depressions (A); vp, ephemeral ponds (B); vp (J); margins of pools or along streams (MA); water of vp & on mud (M); water of vp (M&K); vp on mesas & plateaus (W); vp (Z)
Juncus triformis	FACW	moist places (A); vp, ephemeral ponds (B); vp, granitic seeps (J); moist open places (M); vp (P); vp (T*); vp & other aquatic, marsh, orseepage areas (Z)

PLANTS THAT IN COASTAL SAN DIEGO COUNTY OCCUR PRIMARILY IN VERNAL POOLS		
SPECIES	INDICATOR CATEGORYΔ	HABITAT DESCRIPTION (CITATION)
Lepidium latipes	OBL	alkaline flats or balsas (A); ephemeral ponds (B); alkaline soils, fields, vp, grasslands (J); former beds of alkaline pools (MA); alkaline flats & beds of winter pools (M); vernally wet pools & marshes (*T); vp & adjacent habitats (Z)
Lilaea scilloides	OBL	mud about lakes, pools & slow running streams (A); shallow ponds, slow streams, vp (B); vp, ditches, streams, ponds, lake margins < 1700 m (J); wet soil around ponds, lakes, streams (MA); muddy & marshy places (M); vp (P); vp (T); mud around lakes, ponds & vp (W); vp (Z)
Lythrum hyssopifolia	FACW	moist ground (A); vp, other moist places (B); marshes, drying pond edges (J); wet soil in marshes & at margins of streams & ponds (MA); moist places (M); vp (P); vernally wet pools & marshes (*T); vp (Z)
Marsilea vestita	OBL	edge of ponds, ditches & rivers (A); ponds & reservoirs (B); creek beds, flood basins, vp (J); muddy banks, edges of ponds, esp about vp (M); ponds & ditches (MA); vernally wet pools & marshes (T); vp (Z)
Mimulus latidens	OBL	wet adove soil (A); vp (B); vernally wet depressions < 900 m (J); drying mud flats in heavy soil (M); wet adobe & clay soil, margins of vp (W); vp (Z)
Myosurus minimus var. *apus*	OBL	mesas back of SD (A); vp (B); vp (H); wet places, vp, marshes (#J); vp & alkaline marshes (MA); vp (M); vp (P); vernally wet pools & marshes (#T); vp (#Z)
Myosurus minimus var. *filiformis*	OBL	moist places (A); vp (B); vp (H); wet places, vp, marshes (#J); vp & vernally wet meadows (MA); vp (M); vp (P); vernally wet pools & marshes (#T); grassy hillsides (W); vp (#Z)
Navarretia fossalis		species not described (A); vp & ditches (B); vp (H); vp & ditches (J); vernally wet pools & marshes (*T); vp & man-made depressions & pools (W); vp & adjacent habitats (Z)
Navarretia intertexta	OBL	no habitat given (A); wet meadows & muddy shorelines (B); open wet areas, meadows, vp (J); vps & moist places (M) & (M&K); drying vp (W); common near vp, usually not in basin (Z)
Navarretia prostrata	OBL	no habitat given (A); Kearny Mesa (B); alkaline floodplains, vp (J); vp & low places (MA); vp & moist places (M); vp (Z)
Orcuttia californica	OBL	no habitat given (A); vp & slump ponds (B); vp (H); vp (J); vp & mud flats (MA); drying mud flats (M); vernally wet pools & marshes (*T);drying beds of vp (W); vp (Z)
Phalaris lemmonii	FACW-	no habitat given (A); mud flats, vp (B); moist areas, shrublands, woodlands (J); low wet places, dried mud flats (MA); moist places < 2000 ft (M); vp (P); vernally wet pools & marshes (*T); creosote bush scrub (W); vp (Z)
Pilularia americana	OBL	clayey depressions & desiccating pools (A); vp, ephemeral ponds (B); vp, mud flats, lake margins, reservoirs (J); margins of ponds & vp (MA); occasional in heavy soil, largely of vp (M); vp (P); vernally wet pools & marshes (T); in water on mesas (W); vp (Z)
Plagiobothrys acanthocarpus	OBL	vp & adobe flats (A); mesas & vp (B); vp, moist clay soils (J); vp & adobe flats (MA); moist flats, winter pools (M); vernally wet pools & marshes (*T); vp (Z)
Plagiobothrys bracteatus	OBL	dry beds of pools & ditches (A); vernally moist places (B); vp, wet places in grassland (J); wet places (MA); moist places or dried ditches (M); moist places or beds of pools & ditches, <5000 ft (M&K); vp (P); vp (Z)
Plagiobothrys undulatus		moist adobe or dry soils in valleys & mesas near the coast (A); vp near Ramona (B); moist places & beds of vp (MA); mud flats, < 1200 ft (M&K); vp (Z)

PLANTS THAT IN COASTAL SAN DIEGO COUNTY OCCUR PRIMARILY IN VERNAL POOLS		
SPECIES	INDICATOR CATEGORYΔ	HABITAT DESCRIPTION (CITATION)
Plantago bigelovii	OBL	salt marshes along coast & inland alkaline flats (A); vp (B); saline & alkaline places, beaches, vp (J); saline & alkaline places (M); vp (P); vp & adjacent habitat (Z)
Pogogyne abramsii	OBL	dried bottom of winter rain pools, on mesas n of SD (A); vp (B); vp (H); vp coastal terraces (J); beds of dried pools (M) & (M&K); vernally wet pools & marshes (*T); vp (Z)
Pogogyne nudiuscula	OBL	dry bottom of winter pools (A); vp (B); vp (H); vp (J); beds of vp (MA); moist flats (M) & (M&K); dry beds of vp (W); vp (Z)
Psilocarphus brevissimus	OBL	dried beds of vp & moist places (A); ponds (B); vp & flats (J); dried beds of vp (MA) & (M); vp (P); dried beds of vp (W); vernally wet pools & marshes (*T); vp (Z)
Psilocarphus tenellus	FAC	dried vp & dry open places (A); shores of drying ponds (B); dry disturbed soil, rarely vp (J); drier habitats (MA); dried vp (M) & (M&K); vp (P); foothills & mesas (W); vp (Z)
Sibara virginica	OBL*	desiccated vp (A); ephemeral ponds (B); borders of vp, streambanks, open ground (J); about drying pools (M); vp (Z)

PLANTS THAT ARE COMMON IN COASTAL SAN DIEGO VERNAL POOLS, BUT NOT RESTRICTED TO POOLS		
SPECIES	INDICATOR CATEGORYΔ	HABITAT DESCRIPTION (CITATION)
Bergia texana	OBL	moist ground (A); moist, disturbed soils, sand bars along rivers, margins of pools (J); margins of pools or floodplains (MA); occasional on mud flats (M); at margins of pools & on seeps (W)
Brodiaea jolonensis		species not described (A); grass (B); grassland, foothill woodland on clay (J); clay depressions (M); depressions in clay soil (W); vp & adjacent habitats (Z)
Cotula coronopifolia	FACW+	tidal flats along the coast, inland in wet places (A); wet places (B); saline & freshwater marshes (J); marshy, often almost aquatic; freq salt marshes (MA); mud & moist banks, salt marshes (M); vp (P); wet places & water margins (W); vp & other aquatic, marsh & seepage areas (Z)
Cressa truxillensis	FACW	saline soils (A); alkaline areas (B); saline & alkaline soils (J); lowland alkaline areas (MA); saline & alkaline places (M); alkaline or moderately saline soils (W); vp & other aquatic, marsh & seepage areas (Z)
Eleocharis acicularis	OBL	moist grounds (A); moist habitats (B); muddy river banks, meadows, vp & marshes (MA); marshes, meadows, riverbankds, vp (J); muddy banks, meadows, vp & marshes (M) & (M&K); widespread (W); vp & other aquatic, marsh & seepage areas (Z)
Eleocharis macrostachya	OBL	moist soil (A); wet places (B); marshes, pond margins, vp, ditches (J); marshes, vp, ditches, flooded lands (MA); marshes & wet places (M); vp (P); along pools & intermittent streams (W); vp & other aquatic, marsh & seepage areas (Z)
Gastridium ventricosum	FACU	open ground & waste places (A); weed (B); open, generally dry, disturbed sites (J); dry ground, along streams, vp (MA); weed (M); around vp, on grassy slopes (W); vp & adjacent habitats (Z)

PLANTS THAT ARE COMMON IN COASTAL SAN DIEGO VERNAL POOLS, BUT NOT RESTRICTED TO POOLS		
SPECIES	INDICATOR CATEGORYΔ	HABITAT DESCRIPTION (CITATION)
Juncus bufonius	FACW+	dried up pools, border of streams (A); wet habitats (B); moist (sometimes saline) open or disturbed places (J); along streams or in dried pools (MA); moist, open places (M); vp but not restricted to (P); vp & other aquatic, marsh & seepage areas (Z)
Juncus dubius	FACW*	mountain meadows & stream bankds (A); wet places < 1100 ft (B); wet places (J); moist places (M); wet places (M&K);
Lepidium nitidum		vp (P); stream banks (W) grassy hills, valleys & plains (A); open places (B); meadows, alkaline flats, vp, < 1500 m (J); open places (M); vp but not restricted to (P); open grassy plains & hillsides (W); vp & adjacent habitats (Z)
Lolium perenne	FAC*	roadsides & waste places (A); weed (B); disturbed sites, abandoned fields, lawns (J); scattered (M); weed (W); vp & adjacent habitats (Z)
Montia fontana	OBL	floating in streams or drying pools (A); shaded slopes, pool margins, montane (B); ponds, streams, vp, seeps, ditches, <3200 m (J); muddy stream margins, pools (MA); rain pools (M); muddy stream margins, floating in pools (MA); vp & other aquatic, marsh & seepage areas (Z)
Nama stenocarpum	OBL	muddy shores of lakes & on river banks (A); muddy shore of ponds & lakes, < 300 m (B); intermittently wet areas (J); occasional, muddy places < 1000 ft (M); moist sand in arroyos, canyons & valley floors, basins of vp, deltas (W)
Navarretia hamata		no habitat given (A); coastal sage scrub, chaparral (B); dry, sandy, rocky places (J); dry, rocky places (M) vp but not restricted to (P); dry hillsides & ridges (W); near, but usually not in vp (Z)
Ophioglossum californicum	FACW	moist stony mesas (A); grass, around vp (B); vp (H); grassy pastures, chaparral, vp margins (J); vp (M) & (M&K); moist habitats, often margins of vp (W); near but not usually in vp (Z)
Plantago erecta		grassy hillsides & flats (A); around vp (B); vp (P); dry open places (M) & (M&K); grassy hillsides (W); vp & adjacent habitats (Z)
Polypogon monspeliensis	FACW+	waste places & along irrigating ditches (A); weed moist places (B); moist places, along streams, ditches (J); moist places (MA); weed low places (M); disturbed soil & other grassy areas (W); vp & other aquatic, marsh & seepage areas (Z)
Rotala ramosior	OBL	swamps & edges of ponds (A); irrigated fields, lake & pond margins, streams (J); wet places, < 4000 ft (MA)
Trifolium amplectans		grassy hillsides & valleys (A); grass (B); wet meadows, ditches, grasslands, roadsides, open spring-moist heavy soils (J); grassy places (M); grassy areas (W); vp & adjacent habitats (Z)
Verbena bracteata	FACW	roadsides & waste places in heavy or sandy soil (A); wet places, < 150 m (B); open, disturbed places, pond or lake margins (J); near water in marshes, floodlands (MA); occasional in waste places, < 5000 ft (M); waste areas (W)
Veronica peregrina	OBL	moist ground (A); not habitat given (B); moist places < 3100 m (J); wet places on margins of ditches & ponds (MA); moist places (M); vp (P); moist habitats (W); vp & other aquatic, marsh & seepage areas (Z)

Citations: A= Abrams (1940, 1944, 1951 & 1960), B= Beauchamp (1986), H= Holland (1986), J= Hickman (1993), MA= Mason (1957), M= Munz (1974), M & K= Munz & Keck (1968), P= Purer (1937), T= Thorne (1976), W= Wiggins (1980) and Z= Zedler (1987)
Δ Fish and Wildlife Service (1988)
*T when Thorne (76) gives genus only; # when no subspecies is given

Appendix D.3. Coastal SD Vernal Pool Species List (compiled by E.T. Bauder, SDSU, for the City of San Diego Wetlands Advisory Board, 6/93, rev 2/97 & 5/05).

Guidelines for Assessing the Effects of Proposed Projects on Rare, Threatened, and Endangered Plants and Natural Communities*

State of California
THE RESOURCES AGENCY
Department of Fish and Game
December 9, 1983
Revised May 8, 2000
[Note: Update in process June 2009]

The following recommendations are intended to help those who prepare and review environmental documents determine **when** a botanical survey is needed, **who** should be considered qualified to conduct such surveys, **how** field surveys should be conducted, and **what** information should be contained in the survey report. The Department may recommend that lead agencies not accept the results of surveys that are not conducted according to these guidelines.

1. Botanical surveys are conducted in order to determine the environmental effects of proposed projects on all rare, threatened, and endangered plants and plant communities. Rare, threatened, and endangered plants are not necessarily limited to those species which have been "listed" by state and federal agencies but should include any species that, based on all available data, can be shown to be rare, threatened, and/or endangered under the following definitions:

   A species, subspecies, or variety of plant is "endangered" when the prospects of its survival and reproduction are in immediate jeopardy from one or more causes, including loss of habitat, change in habitat, over-exploitation, predation, competition, or disease. A plant is "threatened" when it is likely to become endangered in the foreseeable future in the absence of protection measures. A plant is "rare" when, although not presently threatened with extinction, the species, subspecies, or variety is found in such small numbers throughout its range that it may be endangered if its environment worsens.

   Rare natural communities are those communities that are of highly limited distribution. These communities may or may not contain rare, threatened, or endangered species. The most current version of the California Natural Diversity Database's List of California Terrestrial Natural Communities may be used as a guide to the names and status of communities.

2. It is appropriate to conduct a botanical field survey to determine if, or to the extent that, rare, threatened, or endangered plants will be affected by a proposed project when:

   a. Natural vegetation occurs on the site, it is unknown if rare, threatened, or endangered plants or habitats occur on the site, and the project has the potential for direct or indirect effects on vegetation; or
   b. Rare plants have historically been identified on the project site, but adequate information for impact assessment is lacking.

3. Botanical consultants should possess the following qualifications:

   a. Experience conducting floristic field surveys;
   b. Knowledge of plant taxonomy and plant community ecology;
   c. Familiarity with the plants of the area, including rare, threatened, and endangered species;
   d. Familiarity with the appropriate state and federal statutes related to plants and plant collecting; and,

e. Experience with analyzing impacts of development on native plant species and communities.

4. Field surveys should be conducted in a manner that will locate any rare, threatened, or endangered species that may be present. Specifically, rare, threatened, or endangered plant surveys should be:

   a. Conducted in the field at the proper time of year when rare, threatened, or endangered species are both evident and identifiable. Usually, this is when the plants are flowering.

      When rare, threatened, or endangered plants are known to occur in the type(s) of habitat present in the project area, nearby accessible occurrences of the plants (reference sites) should be observed to determine that the species are identifiable at the time of the survey.

   b. Floristic in nature. A floristic survey requires that every plant observed be identified to the extent necessary to determine its rarity and listing status. In addition, a sufficient number of visits spaced throughout the growing season are necessary to accurately determine what plants exist on the site. In order to properly characterize the site and document the completeness of the survey, a complete list of plants observed on the site should be included in every botanical survey report.

   c. Conducted in a manner that is consistent with conservation ethics. Collections (voucher specimens) of rare, threatened, or endangered species, or suspected rare, threatened, or endangered species should be made only when such actions would not jeopardize the continued existence of the population and in accordance with applicable state and federal permit requirements. A collecting permit from the Habitat Conservation Planning Branch of DFG is required for collection of state-listed plant species. Voucher specimens should be deposited at recognized public herbaria for future reference. Photography should be used to document plant identification and habitat whenever possible, but especially when the population cannot withstand collection of voucher specimens.

   d. Conducted using systematic field techniques in all habitats of the site to ensure a thorough coverage of potential impact areas.

   e. Well documented. When a rare, threatened, or endangered plant (or rare plant community) is located, a California Native Species (or Community) Field Survey Form or equivalent written form, accompanied by a copy of the appropriate portion of a 7.5 minute topographic map with the occurrence mapped, should be completed and submitted to the Natural Diversity Database. Locations may be best documented using global positioning systems (GPS) and presented in map and digital forms as these tools become more accessible.

5. Reports of botanical field surveys should be included in or with environmental assessments, negative declarations and mitigated negative declarations, Timber Harvesting Plans (THPs), EIR's, and EIS's, and should contain the following information:

   a. Project description, including a detailed map of the project location and study area.

   b. A written description of biological setting referencing the community nomenclature used and a vegetation map.

   c. Detailed description of survey methodology.

d. Dates of field surveys and total person-hours spent on field surveys.

e. Results of field survey including detailed maps and specific location data for each plant population found. Investigators are encouraged to provide GPS data and maps documenting population boundaries.

f. An assessment of potential impacts. This should include a map showing the distribution of plants in relation to proposed activities.

g. Discussion of the significance of rare, threatened, or endangered plant populations in the project area considering nearby populations and total species distribution.

h. Recommended measures to avoid impacts.

i. A list of all plants observed on the project area. Plants should be identified to the taxonomic level necessary to determine whether or not they are rare, threatened or endangered.

j. Description of reference site(s) visited and phenological development of rare, threatened, or endangered plant(s).

k. Copies of all California Native Species Field Survey Forms or Natural Community Field Survey Forms.

l. Name of field investigator(s).

m. References cited, persons contacted, herbaria visited, and the location of voucher specimens.

*Source: California Department of Fish and Game, Natural Diversity Database. April 2009. Special Vascular Plants, Bryophytes, and Lichens List. Quarterly publication. 71 pp. (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPPlants.pdf)

Appendix D.4. Guidelines for Assessing the Effects of Proposed Projects.

SPECIAL PLANTS
Last updated March 23, 2007*
California Natural Diversity Database (CNDDB)
California Department of Fish and Game

"Special Plants" is a broad term used to refer to all the plant taxa inventoried by the Department of Fish and Game's California Natural Diversity Database (CNDDB), regardless of their legal or protection status. Special Plants include vascular plants and high priority bryophytes (mosses, liverworts, and hornworts) which are a recent addition. Special Plant taxa are species, subspecies, or varieties that fall into one or more of the following categories:

- Officially listed by California or the Federal Government as Endangered, Threatened, or Rare;

- A candidate for state or federal listing as Endangered, Threatened, or Rare;

- Taxa which meet the criteria for listing, even if not currently included on any list, as described in Section 15380 of the California Environmental Quality Act (CEQA) Guidelines; these taxa may indicate "none" under listing stats, but note that all CNPS List 1 and 2 and some List 3 plants may fall under Section 15380 of CEQA.

- A Bureau of Land Management, U.S. Fish and Wildlife Service, or U.S. Forest Service Sensitive Species;

- Taxa listed in the California Native Plant Society's *Inventory of Rare and Endangered Plants of California*;

- Taxa that are biologically rare, very restricted in distribution, or declining throughout their range but not currently threatened with extirpation;

- Population(s) in California that may be peripheral to the major portion of a taxon's range but are threatened with extirpation in California; and

- Taxa closely associated with a habitat that is declining in California at a significant rate (e.g., wetlands, riparian, vernal pools, old growth forests, desert aquatic systems, native grasslands, valley shrubland habitats, etc.).

This list contains taxa that are actively inventoried by the CNDDB (Note: GIS'ed taxa have a "yes" in the right column of the list) as well as an almost equal number of taxa which it tracks but as yet has only quad and county level geographic information.

For the latter taxa, we [**CNDDB**] maintain site and other information in manual files along with internet access to the quad and county level information via our "**CNDDB Quick Viewer**." These plants will be added to the computerized inventory as time permits or when we have enough information to determine that they fulfill our rarity and/or endangerment criteria. For more copies of this list or other CNDDB information, call (916) 324-3812 or email Kristina Donat, Information

Services, at kdonat@dfg.ca.gov.

NOTE: We [**CNDDB**] have removed the designation "**Federal Species of Concern**." Please do not be concerned; the federal species of concern list was an internal FWS list maintained by their Sacramento office of taxa that were formerly designated C1 and C2 plus some other miscellaneous taxa. Once we discovered that the list was seldom updated and generated only from Sacramento without review by other FWS offices, we decided we were not doing you a service by including this designation. The taxa are just as important as before and should be given consideration in your environmental work.

California Heritage (CNDDB) Element Ranking For Plants

Last updated March 23, 2007

All Heritage Programs, such as the California Natural Diversity Database (CNDDB) use the same ranking methodology, originally developed by The Nature Conservancy and now maintained by Natureserve. It includes a **Global rank** (G rank), describing the rank for a given taxon over its entire distribution and a **State rank** (S rank), describing the rank for the taxon over its state distribution. For subspecies and varieties, there is also a "T" rank describing the global rank for the subspecies. The second page of this document details the criteria used to assign element ranks, from G1 to G5 for the Global rank and from S1 to S5 for the State rank. Procedurally, state programs such as the CNDDB develop Global ranks which are checked for consistency and logical errors by Natureserve at the national level.

The first step to ranking is based on *rarity*, and involves counting total occurrences, counting the number of "good" (highly ranked) occurrences and counting individuals for a given plant. An occurrence for a plant is defined as any population or group of nearby populations located more than 0.25 miles from any other population. Element occurrences can be ranked A-D, depending on apparent degree of viability and habitat condition. Usually the two biggest factors are population size and habitat quality. However, there is more to ranking than just counting element occurrences and individuals. Some of the other considerations specific to plants or lichens include:

- An aerial view of the extent of the distribution. Is the taxon very narrowly distributed (even if it has lots of occurrences), or is it scattered over a wide area?
- Are the element occurrences very large, very small, or mixed in size? Are small occurrences viable over time?
- What is the total acreage of the element occurrences?
- Is the element located in a vulnerable habitat type, such as in wetlands?
- What aspects of the biology and ecology of the element should we consider when ranking it? Some aspects to consider are life form, life span, demographic concerns, persistence of seed bank, reaction to disturbance, dependence on pollinators or seed dispersal agents, restriction to soil type and other "niche breadth" concerns, and more.
- Is anything known about trends for the element? Do we think the species is increasing, decreasing or stable?

With the above considerations in mind, refer to the next page for the numerical definitions for G1-5 and S1-5. A taxon's ranking status may be adjusted up or down depending upon the considerations above.

ELEMENT RANKING

GLOBAL RANKING

The *global rank* (G-rank) is a reflection of the overall condition of an element throughout its global range.

SPECIES OR NATURAL COMMUNITY LEVEL

G1 = Less than 6 viable element occurrences (Eos) OR less than 1,000 individuals OR less than 2,000 acres.
G2 = 6-20 Eos OR 1,000-3,000 individuals OR 2,000-10,000 acres.
G3 = 21-80 Eos OR 3,000-10,000 individuals OR 10,000-50,000 acres.
G4 = Apparently secure; this rank is clearly lower than G3 but factors exist to cause some concern; i.e., there is some threat, or somewhat narrow habitat.
G5 = Population or stand demonstrably secure to ineradicable due to being commonly found in the world.

SUBSPECIES LEVEL

Subspecies receive a **T-rank** attached to the G-rank. With the subspecies, the G-rank reflects the condition of the entire species, whereas the T-rank reflects the global situation of just the subspecies or variety. For example: *Chorizanthe robusta* var. *hartwegii*. This plant is ranked G2T1. The G-rank refers to the whole species range i.e., *Chorizanthe robusta.* The T-rank refers only to the global condition of var. *hartwegii*.

STATE RANKING

The *state rank* (S-rank) is assigned much the same way as the global rank, except state ranks in California often also contain a threat designation attached to the S-rank.

S1 = **Critically Imperiled—**Critically imperiled in the site because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province**.**
S2 = **Imperiled**—Imperiled in the state because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation of state/province
S3 = **Vulnerable**—Vulnerable in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
S4 = **Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5 = **Secure**—Common, widespread, and abundant in the state.

Notes:

1.	Other considerations used when ranking a species or natural community include the pattern of distribution of the element on the landscape, fragmentation of the population/stands, and historical extent as compared to its modern range. It is important to t	3.	Other symbols: GH All sites are historical; the element has not been seen for at least 20 years, but suitable habitat still exists (SH = All California sites are historical). GX All sites are extirpated; this element is extinct in the wild (SX = GXC Extinct in the wild; exists in cultivation. G1Q The element is very rare, but there are **taxonomic questions** associated with it. T Rank applies to a subspecies or variety.
2.	Uncertainty about the rank of an element is expressed in two major ways: By expressing the ranks as a range of values: e.g., S2S3 means the rank is somewhere between S2 and S3. By adding a ? to the rank: e.g., S2? This represents more certainty than S2S3, but less certainty than S2.		

SPECIAL LICHENS

Last updated March 23, 2007

There are a few lichens in California for which we [**CNDDB**] have adequate information to place them on the list of Special taxa. They appear after the bryophytes at the beginning of the list. We are not including lichens for which little is known, even if they are only known from a few sites in California because the level of information is not developed enough. As information on individual taxa becomes better developed, more lichens may be added. Lichen statuses are developed in coordination with the California Lichen Society (CALS) and relevant experts

Note that lichens are not plants, but a symbiotic relationship between a fungus and either green algae or cyanobacteria (aka bluegreen algae).

The California Native Plant Society's (CNPS) Lists

- **1A. Presumed extinct in California**
- **1B. Rare or Endangered in California and elsewhere**
- **2. Rare or Endangered in California, more common elsewhere**
- **3. Plants for which we need more information - Review list**
- **4. Plants of limited distribution - Watch list**

List 1A: Plants Presumed Extinct in California

The plants of List 1A are presumed extinct because they have not been seen or collected in the wild in California for many years. Although most of them are restricted to California, a few are found in other states as well. In many cases, repeated attempts have been made to rediscover these plants by visiting known historical locations. Even after such diligent searching, we are constrained against saying that they are extinct, since for most of them rediscovery remains a distinct possibility. Note that care should be taken to distinguish between "extinct" and "extirpated." A plant is extirpated if it has been locally eliminated, but it may be doing well elsewhere in its range.

List 1B: Plants Rare, Threatened, or Endangered in California and Elsewhere.

The plants of List 1B are rare throughout their range. All but a few are endemic to California. All of them are judged to be vulnerable under present circumstances or to have a high potential for becoming so because of their limited or vulnerable habitat, their low numbers of individuals per population (even though they may be wide ranging), or their limited number of populations. Most of the plants of List 1B have declined significantly over the last century.

List 2: Plants Rare, Threatened, or Endangered in California, but More Common Elsewhere

Except for being common beyond the boundaries of California, the plants of List 2 would have appeared on List 1B. From the federal perspective, plants common in other states or countries are not eligible for consideration under the provisions of the Endangered Species Act. Until 1979, a similar policy was followed in California. However, after the passage of the Native Plant Protection Act, plants were considered for protection without regard to their distribution outside the state.

List 3: Plants About Which We Need More Information - A Review list

The plants that comprise List 3 are united by one common theme--we lack the necessary information to assign them to one of the other lists or to reject them. Nearly all of the plants remaining on List 3 are taxonomically problematic.

List 4: Plants of Limited Distribution - A Watch list

The plants in this category are of limited distribution or infrequent throughout a broader area in California, and their vulnerability or susceptibility to threat appears low at this time. While we cannot call these plants "rare" from a statewide perspective, they are uncommon enough that their status should be monitored regularly. Should the degree of endangerment or rarity of a List 4 plant change, we will transfer it to a more appropriate list or deleted from consideration.

Threat ranks:
Recently, CNPS added a decimal threat rank to the List ranks to parallel that used by the CNDDB. This extension replaces the E (Endangerment) value from the R-E-D Code. CNPS ranks therefore read like this: 1B.1, 1B.2, etc.

New Threat Code extensions and their meanings:

.1 - Seriously endangered in California

.2 – Fairly endangered in California

.3 – Not very endangered in California
Note that all List 1A (presumed extinct in California) and some List 3 (need more information- a review list) plants lacking any threat information receive no threat code extension. Also, these Threat Code guidelines represent a starting point in the assessment of threat level. Other factors, such as habitat vulnerability and specificity, distribution, and condition of occurrences, are also considered in setting the Threat Code.

*Source: California Department of Fish and Game, Natural Diversity Database. April 2009. Special Vascular Plants, Bryophytes, and Lichens List. Quarterly publication. 71 pp. (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPPlants.pdf)

Appendix D.5. Key to CDFG Special Plants List.

Appendix D.6. Pre-analysis *a priori* FCI Descriptions Applicable to Any Function

1.0 = Pool is functioning at its optimum level and will do so for the foreseeable future.
Defined practically as the amount (and kind) of function characteristic for pools in the subclass that are of the same type (Table 5.2), location (Table 3.1) and landscape position ($V_{POOLCONNECT}$, Appendix B) in the absence of disturbance to both basin and uplands (periphery and catchment). This will usually occur when there is no known disturbance, light past grazing or brushing, or ungraded tracks or trails. However, a score of 1.0 may be possible for some functions even when more severe disturbance has occurred.

0.75 = Pool is functioning at its highest level but is declining, or is functioning at near-optimal levels and will do so for the foreseeable future.

a. The pool is fully functional but biotic and/or abiotic features of the pool or surrounding landscape make it very likely that this functionality cannot be sustained. Restored or created pools are typically unstable for a number of years. They may or may not sustain function at this level. Various other features contributing to functional decline could include disturbance, demographic or other ecological processes affecting native species, increasing frequency of invasive species, or hydrological changes. For example, vernal pools may retain characteristic flora and fauna for some period of time after dramatic hydrologic impacts have taken place, due to the moderating effects of older dormant propagules.
b. Full functionality is not found, but at least the major characteristics of the function have been captured. Functionality is not in decline. Pools in this category will typically have minimal disturbance to basin and/or moderate disturbance to uplands (periphery and catchment). Pools that are demonstrably self-recovering from previous disturbances such as limited fill, trenching, agriculture, fire and/or vehicles are likely to have a score of 0.75.

0.65 = Pool has high functionality, is declining, but is recoverable. Alternatively, the pool retains some functionality, is stable or improving, and is recoverable with moderate external effort.

a. Full functionality is not found, but at least the major characteristics of the function have been captured. Functionality is declining or unstable, often due to ongoing disturbances or in connection with restoration, enhancement or creation activities. Pools in this category will typically have moderate disturbance to the basin and moderate to high disturbance to uplands (periphery and catchment). The pool can be restored or stabilized with moderate effort. Removal of ongoing disturbances would likely lead to self-recovery and improved function.
b. Substantial functionality has been lost, typically due to moderate to substantial disturbance in the basin and uplands. Possible sources include draining, dams, filling, trenching, severe agricultural alterations or vehicle damage. The pool is improving in function or at least stable. Restoration to a higher level of function is feasible.

0.5 = Pool retains moderate function, but is in decline or stable. Restoration to near full function is feasible with extensive effort or pool has undergone major restoration. If portions of the catchment are developed or un-restorable, it is unlikely that full or substantially improved function can be achieved.

a. Significant functionality has been lost, typically due to moderate to substantial on-going or recent disturbance in the basin and uplands. Possible sources of disturbance include draining, dams, filling, trenching, severe agricultural alterations or vehicle damage. The pool is declining in function but restoration is feasible with extensive effort. Removal of ongoing disturbances could result in self-recovery and improved function.
b. Significant functionality has been lost, typically due to moderate to substantial disturbance in the basin and uplands, often in the past rather than recently. The pool is stable or possibly improving. Restoration to near full functionality would require extensive effort.
c. Full functionality is not found, but the major characteristics have been restored and ongoing disturbance has been removed. Uplands and the watershed have been restored or are mostly intact. Level of function may or may not be sustainable.

0.25 = Pool retains some function, but is declining and not recoverable. Alternatively, the pool has low function but has some potential for self-recovery or restoration. If portions of the catchment are developed or un-restorable, it is unlikely that substantially improved function can be achieved.

a. Significant functionality has been lost, typically due to moderate to substantial disturbance in the basin and uplands. The pool is in decline. If ongoing disturbances are removed, function could improve, but restoration potential is limited and restoration would require extreme effort.
b. Function is low because there is substantial disturbance to basin, periphery and catchment. Mounds may have been lost due to blading or grading. Shape and soil surface of basin may be severely impacted. There may be permanent changes to the pool and surrounding landscape, such as domination of the landscape by hard surfaces, or severe hydrological and physical disturbances. The pool is stable or in the process of limited self-recovery or at least restoration to better functionality is feasible.

0.1 = Pool has low function, severe on-going disturbance and/or is probably incapable of recovery due to severe disturbance.

a. Function is low because there is substantial disturbance to basin, periphery and catchment. Mounds may have been lost due to blading or grading. Shape and soil surface of basin may be severely impacted. There may be permanent changes to the pool and surrounding landscape, such as domination of the landscape by hard surfaces or severe hydrological and physical disturbances. If low levels of functionality are stable, then it is clear that restoration potential is minimal (even with a large expenditure of resources). It is more likely that the pool is in decline towards zero functionality. There may be few or no vestiges of the natural basin and mound topography, and the native soil profile of uplands and basin is no longer evident.

0.0 = Pool retains no functionality.