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*Wetlands Regulatory Assistance Program*

# DRAFT Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual:
# Hawaii and Pacific Islands Region

U.S. Army Corps of Engineers

**Abstract:** This document is one of a series of Regional Supplements to the Corps of Engineers Wetland Delineation Manual, which provides technical guidance and procedures for identifying and delineating wetlands that may be subject to regulatory jurisdiction under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act. The development of Regional Supplements is part of a nationwide effort to address regional wetland characteristics and improve the accuracy and efficiency of wetland-delineation procedures. This supplement is applicable to the Hawaii and Pacific Islands Region, which consists of the State of Hawaii, Territory of Guam, Commonwealth of the Northern Mariana Islands, and the Territory of American Samoa.

# Contents

# Preface

This document is one of a series of Regional Supplements to the Corps of Engineers Wetland Delineation Manual. It was developed by the U.S. Army Engineer Research and Development Center (ERDC) at the request of Headquarters, U.S. Army Corps of Engineers (USACE), with funding provided through the Wetlands Regulatory Assistance Program (WRAP).

This document was developed in cooperation with the Hawaii and Pacific Islands Regional Working Group. Working Group meetings were held in Honolulu, HI, on 16-18 September 2008 and 11-12 February 2009. Members of the Regional Working Group and contributors to this document were:

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Technical reviews were provided by the following members of the National Advisory Team for Wetland Delineation: Steve Eggers, U.S. Army Engineer (USAE) District, St. Paul, MN; Michael Gilbert, USAE District, Omaha, NE; William James, U.S. Army Corps of Engineers, Washington, DC; Dan Martel, USAE District, San Francisco, CA; Norman Melvin, NRCS Central National Technology Support Center, Fort Worth, TX; Paul Minkin, USAE District, New England, Concord, MA; Stuart Santos, USAE District, Jacksonville, FL; Ralph Spagnolo, U.S. Environmental Protection Agency (EPA), Philadelphia, PA; Mary Anne Thiesing, EPA, Seattle, WA; Ralph Tiner, U.S. Fish and Wildlife Service, Hadley, MA; Katherine Trott, USAE Institute for Water Resources, Alexandria, VA; and Lenore Vasilas, NRCS, Washington, DC. In addition, portions of this Regional Supplement addressing soils issues were reviewed and endorsed by the National Technical Committee for Hydric Soils (Christopher W. Smith, chair).

Independent peer reviews were performed in accordance with Office of Management and Budget guidelines. The peer-review team consisted of ______________________.

Technical editors for this Regional Supplement were Dr. James S. Wakeley, Robert W. Lichvar, and Chris V. Noble, ERDC. William L. James was the project proponent and coordinator at Headquarters, USACE. During the conduct of this work, Dr. Morris Mauney was Chief of the Wetlands and Coastal Ecology Branch; Dr. Tim Lewis was Acting Chief, Ecosystem Evaluation and Engineering Division; Bob Lazor was Director, WRAP; and Dr. Elizabeth Fleming was Director, EL. COL Gary E. Johnston was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

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# 1 Introduction

## Purpose and Use of this Regional Supplement

This document is one of a series of Regional Supplements to the Corps of Engineers Wetland Delineation Manual (hereafter called the Corps Manual). The Corps Manual provides technical guidance and procedures, from a national perspective, for identifying and delineating wetlands that may be subject to regulatory jurisdiction under Section 404 of the Clean Water Act (33 U.S.C. 1344) or Section 10 of the Rivers and Harbors Act (33 U.S.C. 403). According to the Corps Manual, identification of wetlands is based on a three-factor approach involving indicators of hydrophytic vegetation, hydric soil, and wetland hydrology. This Regional Supplement presents wetland indicators, delineation guidance, and other information that is specific to the Hawaii and Pacific Islands Region.

This Regional Supplement is part of a nationwide effort to address regional wetland characteristics and improve the accuracy and efficiency of wetland-delineation procedures. Regional differences in climate, geology, soils, hydrology, plant and animal communities, and other factors are important to the identification and functioning of wetlands. These differences cannot be considered adequately in a single national manual. The development of this supplement follows National Academy of Sciences recommendations to increase the regional sensitivity of wetland-delineation methods (National Research Council 1995). The intent of this supplement is to bring the Corps Manual up to date with current knowledge and practice in the region. The procedures given in the Corps Manual, in combination with wetland indicators and guidance provided in this supplement, can be used to identify wetlands for a number of purposes, including resource inventories, management plans, and regulatory programs. The determination that a wetland is subject to regulatory jurisdiction under Section 404 or Section 10 must be made independently of procedures described in this supplement.

This Regional Supplement is designed for use with the current version of the Corps Manual (Environmental Laboratory 1987) and all subsequent versions. Where differences in the two documents occur, this Regional Supplement takes precedence over the Corps Manual for applications in the Hawaii and Pacific Islands Region. Table 1 identifies specific sections of the Corps Manual that are replaced by this supplement. Other guidance and procedures given in this supplement and not listed in Table 1 are intended to augment the Corps Manual but not necessarily to replace it. The Corps of Engineers has final authority over the use and interpretation of the Corps Manual and this supplement in the Hawaii and Pacific Islands Region.

Indicators and procedures given in this Supplement are designed to identify wetlands as defined jointly by the Corps of Engineers (33 CFR 328.3) and Environmental Protection Agency (40 CFR 230.3). Wetlands are a subset of the “waters of the United States” that may be subject to regulation under Section 404. One key feature of the definition of wetlands is that, under normal circumstances, they support “a prevalence of vegetation typically adapted for life in saturated soil conditions.” Many waters of the United States are unvegetated and thus are excluded from the Corps/EPA definition of wetlands, although they may still be subject to Clean Water Act regulation. Other potential waters of the United States in the Hawaii and Pacific Islands Region include, but are not limited to, tidal flats and shorelines along the coast and in estuaries; coral reefs; lakes; rivers; ponds; anchialine pools; salt and mud flats; and perennial, intermittent, and ephemeral stream channels. Delineation of these waters is based on the high tide line, the "ordinary high water mark" (33 CFR 328.3e), or other criteria and is beyond the scope of this Regional Supplement.

Amendments to this document will be issued periodically in response to new scientific information and user comments. Between published versions, Headquarters, U.S. Army Corps of Engineers, may provide updates to this document and any other supplemental information used to make wetland determinations under Section 404 and Section 10. Wetland delineators should use the most recent approved versions of this document and supplemental information. See the Corps of Engineers Headquarters regulatory web site for information and updates (http://www.usace.army.mil/CECW/Pages/reg_supp.aspx). The Corps of Engineers has established an interagency National Advisory Team for Wetland Delineation whose role is to review new data and make recommendations for needed changes in wetland-delineation procedures to Headquarters, U.S. Army Corps of Engineers. Items for consideration by the team, including full documentation and supporting data, should be submitted to:

National Advisory Team for Wetland Delineation
Regulatory Branch (Attn: CECW-CO)
U.S. Army Corps of Engineers
441 G Street, N.W.
Washington, DC 20314-1000

Table 1. Sections of the Corps Manual replaced by this Regional Supplement for applications in the Hawaii and Pacific Islands Region.

| Item | Replaced Portions of the Corps Manual (Environmental Laboratory 1987) | Replacement Guidance (this Supplement) |
|---|---|---|
| Hydrophytic Vegetation Indicators | Paragraph 35, all subparts, and all references to specific indicators in Part IV. | Chapter 2 |
| Hydric Soil Indicators | Paragraphs 44 and 45, all subparts, and all references to specific indicators in Part IV. | Chapter 3 |
| Wetland Hydrology Indicators | Paragraph 49(b), all subparts, and all references to specific indicators in Part IV. | Chapter 4 |
| Growing Season Definition | Glossary | Chapter 4, Growing Season; Glossary |
| Hydrology Standard for Highly Disturbed or Problematic Wetland Situations | Paragraph 48, including Table 5 and the accompanying User Note in the online version of the Manual | Chapter 5, Wetlands that Periodically Lack Indicators of Wetland Hydrology, Procedure item 3(g) |

# Applicable Region

This supplement is applicable to the Hawaii and Pacific Islands Region, which consists of the State of Hawaii, Territory of Guam, Commonwealth of the Northern Mariana Islands, and the Territory of American Samoa (Figure 1). The area includes Land Resource Region (LRR) V (Hawaii) and portions of LRR Q (Pacific Basin) recognized by the U. S. Department of Agriculture (USDA Natural Resources Conservation Service 2006a). Most of the wetland indicators presented in this supplement are applicable throughout the entire Hawaii and Pacific Islands Region. However, some indicators are restricted to specified subregions.

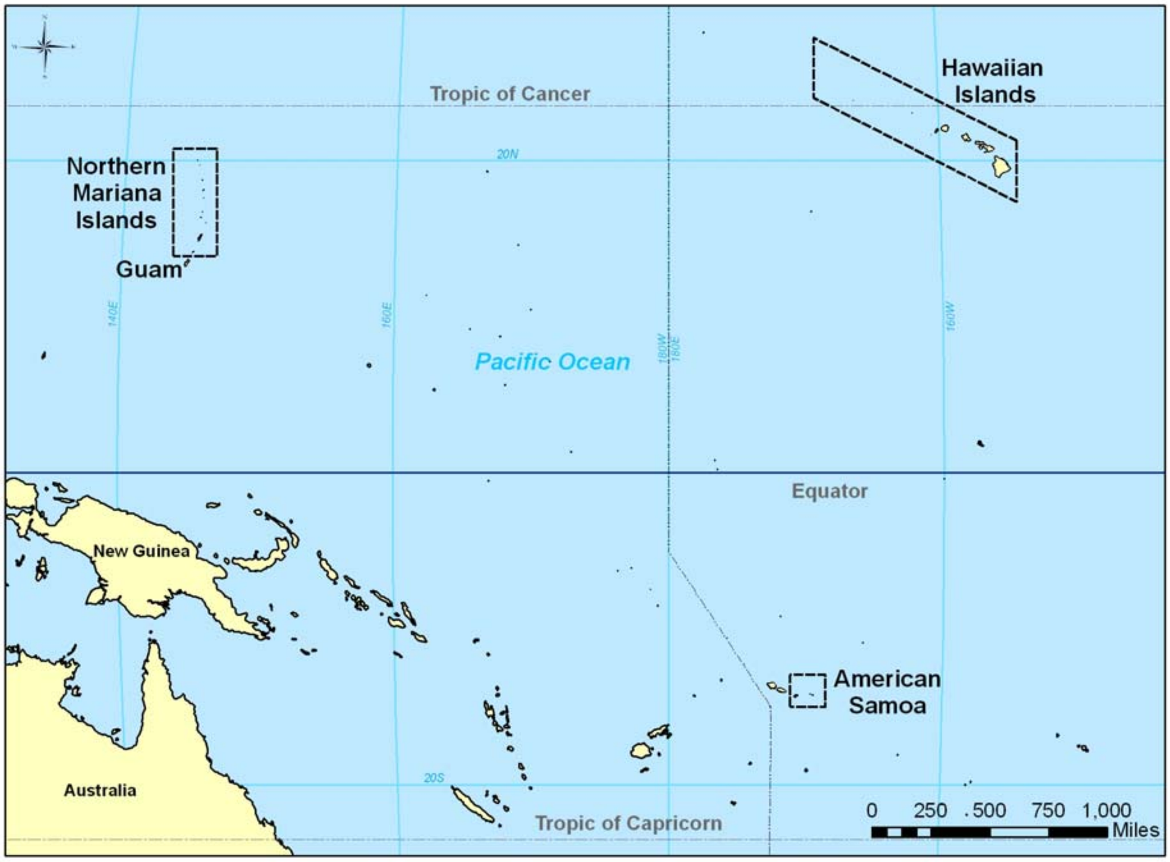

**Figure 1.** Location map of the Hawaii and Pacific Islands Region.

# Physical and Biological Characteristics of the Region

The Hawaii and Pacific Islands Region consists of island complexes scattered across the Pacific Ocean (Figure 1). The Northern Mariana Islands, Guam, and the Hawaiian archipelago are located in the northern Pacific Ocean, while American Samoa is located below the equator in the southern Pacific. These islands are separated by vast distances. The main islands of Hawaii are approximately 2,400 mi (3,900 km) southwest of the United States mainland. Guam (the southernmost of the Mariana island chain) is located an additional 3,800 mi (6,130 km) southwest of Hawaii. American Samoa is located 2,300 mi (3,710 km) southwest of Hawaii and 4,150 mi (6,695 km) from the U.S. mainland. Many of the islands are the exposed tops of partially submerged volcanic mountain ranges, although limestone terraces and coral atolls, built on the tops of submerged volcanic peaks, make up some islands. The region contains approximately 6,890 mi$^2$ (17,840 km$^2$) of land area and includes the major islands of the Hawaiian chain (Niʻihau, Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Kahoʻolawe, Maui, and Hawaiʻi), the island of Guam, the Northern Mariana Islands (including Rota, Tinian, Aguijan, and Saipan), and American Samoa (including Ofu, Olosega, Taʻu, and Tutuila) (Figure 2). Many smaller islands, some uninhabited, are also contained in the region. The island of Hawaiʻi, known as the Big Island, is the largest in the region and has the greatest topographic relief. The volcanoes of Mauna Loa and Mauna Kea dominate the island and rise to maximum elevations of 13,679 ft (4,169 m) and 13,796 ft (4,205 m) above sea level, respectively (Juvik and Juvik 1998, Natural Resources Conservation Service 2006a).

Islands in the region lie within the belt of trade winds and have tropical to subtropical maritime climates, in which the average annual variations in air temperature are generally less than daily temperature fluctuations (Natural Resources Conservation Service 2006a). However, there is considerable spatial variability in both temperature and rainfall, especially on the higher islands that have greater topographic diversity and relief.

The variety of topographic, soil, and climatic conditions across the region, along with geographic isolation, has encouraged the development of a diverse Pacific flora with many species endemic to particular islands and island groups. The natural climax communities in the region are mostly forested with tropical hardwoods, except in semi-arid areas in the lee of the higher mountains and in high-elevation areas on upper volcanic slopes. Waves of human colonizers added large numbers of introduced and invasive plants to the flora. Early Polynesian settlers carried with them a number of important food plants, including taro (*Colocasia esculenta*), sweet potatoes (*Ipomoea batatas*), breadfruit (*Artocarpus altilis*), bananas (*Musa acuminata*), and yams (*Dioscorea* spp.) (Juvik and Juvik 1998). However, prior to European discovery and settlement, most of the islands remained dominated largely by hardwood forests. Discovery by Europeans (and, later, by Japanese and others) led to large-scale agricultural development, primarily for sugarcane (*Saccharum officinarum*) production. Following World War II, lands in sugarcane production were converted to pastureland, secondary agro-forestry, and subsistence agriculture (Nakamura 1984, Young 1989, Natural Resources Conservation Service 2006a). Large-scale agriculture (e.g., for pineapple [*Ananas comosus*] and coffee [*Coffea* spp.]) remains prevalent in some areas, along with small commercial enterprises that grow food for local consumption. Many areas have become urbanized and industrialized with large areas utilized for tourism and military purposes.

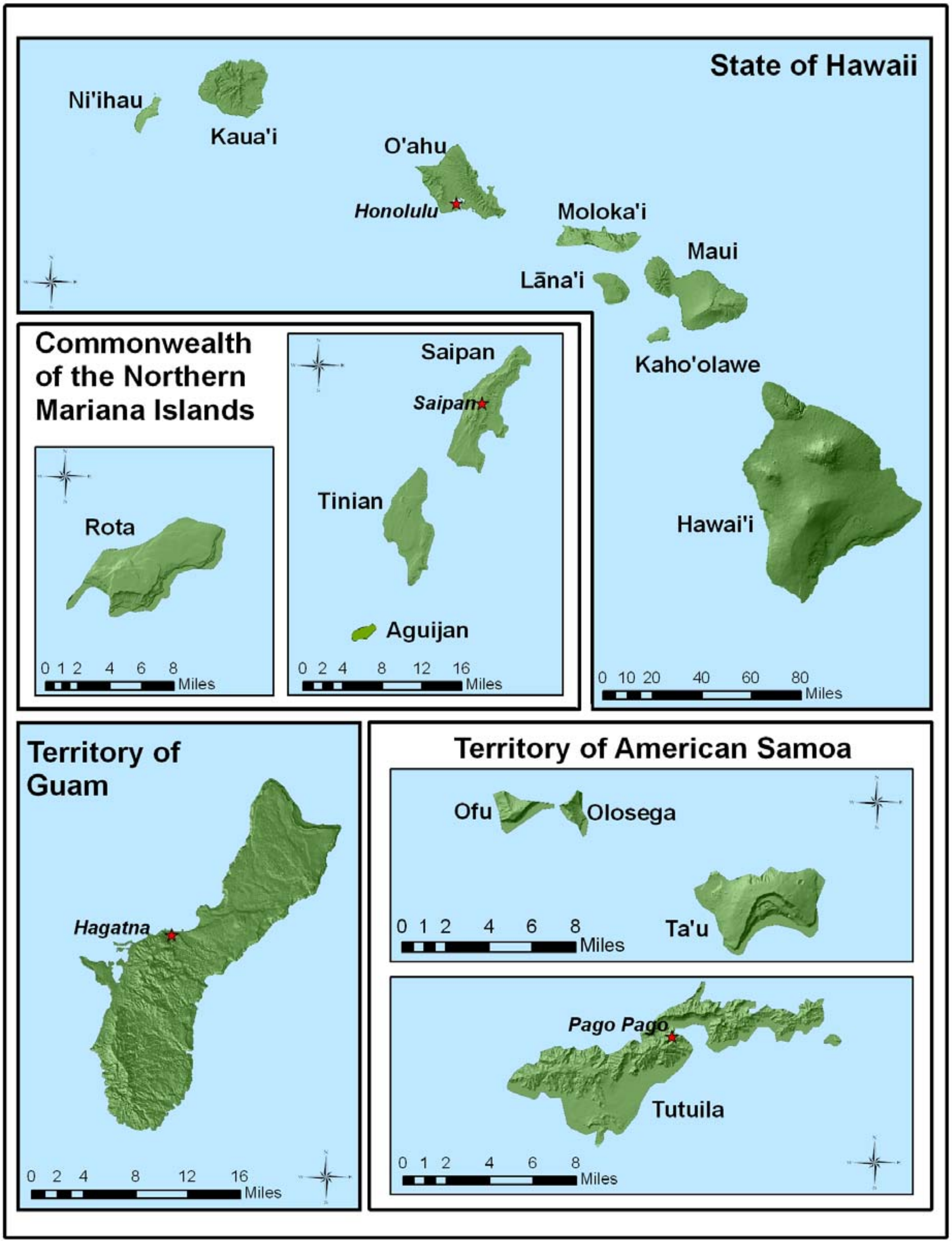

**Figure 2.** Principal islands of the Hawaii and Pacific Islands Region.

## The Hawaiian Islands

In the Hawaiian Islands, the average daily high temperature is about 84 °F (29 °C) and the average daily low temperature is 67 °F (19 °C) at sea level. However, temperatures at high elevations regularly dip below freezing during the winter (Juvik and Juvik 1998). Average annual rainfall is about 70 in. (1,780 mm), but varies greatly by site location in relation to northeasterly trade winds and topographic relief. Annual rainfall ranges from about 10 to 60 in. (254 to 1,524 mm) on leeward slopes, and from 60 to more than 400 in. (1,524 to more than 10,160 mm) on windward slopes. The summit of Mt. Wai‘ale‘ale on the island of Kaua‘i receives some of the highest rainfall totals on earth, with about 445 in. (11,300 mm) of precipitation per year. The islands have two seasons – a warm summer season with moderate rainfall from May through September and a cooler, rainy, winter season from October through April (Juvik and Juvik 1998, Natural Resources Conservation Service 2006a). The amount of winter rainfall varies on a four- to seven-year cycle due to the El Niño Southern Oscillation (Juvik and Juvik 1998).

Soil parent materials on the main Hawaiian Islands consist of lava flows up to 5 million years old flanked by younger marine sediments and reef deposits (Juvik and Juvik 1998, Deenik and McClellan 2007). Each of the islands consists of one or more extinct volcanoes that have undergone significant erosion. Active volcanoes are present on Maui and the Big Island. Deeply incised valleys are common on most of the islands. Soils of the Hawaiian Islands are extremely diverse, with ten of the twelve soil orders represented (Deenik and McClellan 2007).

Common forest trees in the Hawaiian Islands include the native ‘ōhi‘a lehua (*Metrosideros polymorpha*), koa (*Acacia koa*), olapalapa (*Cheirodendron trigynum*), and treeferns (*Cibotium* spp.), and the introduced eucalyptus (*Eucalyptus* spp.), common ironwood (*Casuarina equisetifolia*), rose apple (*Syzygium jambos*), albizia (*Albizia* spp.), and strawberry guava (*Psidium cattleianum*). More than 1,000 species of non-native and invasive plants have become established on the Hawaiian Islands. As of 1997, nearly 300 native Hawaiian plant species were listed as threatened or endangered under the U.S. Endangered Species Act (Juvik and Juvik 1998).

## Guam and the Northern Mariana Islands

Seasonal northeast trade winds dominate the climate of Guam and the Northern Mariana Islands. Guam has a tropical maritime climate with air temperatures ranging from an average daily high of about 86 °F (30 °C) to an average daily low of 76 °F (24 °C). Average annual rainfall is about 86 in. (2,180 mm) and falls mainly during the rainy season from July through November (Young 1988, Natural Resources Conservation Service 2006a, CIA 2008). There is a moisture deficit from January to June (Young 1988). Occasional monsoonal storms and typhoons can produce very heavy rainfall. Annual rainfall totals are strongly influenced by the El Niño Southern Oscillation; during El Niño events, regional drought conditions may develop across the western Pacific. The Northern Mariana Islands have a similar climate with about two-thirds of the average annual rainfall occurring during the rainy season from July to November. Annual rainfall ranges from about 79 to 98 in. (200 to 250 cm) depending upon location, aspect, and elevation. The average daily high temperature is about 86 °F (30 °C) and the average daily low temperature is about 68 °F (20 °C) (Young 1989).

The northern half of the island of Guam consists of a large limestone plateau of Eocene to Pleistocene age, bounded by cliffs (Carroll and Hathaway 1963, Tracey et al. 1964). The southern half of the island is a dissected, Quaternary-age, volcanic upland with limestone deposits along the eastern shoreline. Fringing reefs surround most of the island (Tracey et al. 1964). The soils of Guam are a diverse group of clays, silts, and sands developed on limestone and volcanic substrates (Carroll and Hathaway 1963). In the Northern Marianas, the islands of Saipan and Tinian are dominated by limestone plateaus of Pliocene and Pleistocene age. The volcanic core is exposed on about 10 percent of Saipan and less on Tinian (Natural Resources Conservation Service 2006a). Aguijan and Rota consist of concentric limestone plateaus with steep escarpments and a volcanic core that is emerging in places (Young 1989).

Common trees of limestone areas on Guam include tangantangan (*Leucaena leucocephala*), kafu‘ (*Pandanus tectorius*), pago (*Hibiscus tiliaceus*), mapunao (*Aglaia mariannensis*), paipai (*Guamia mariannae*), nonak (*Hernandia sonora*), fadang (*Cycas micronesica*), fagot (*Neisosperma oppositifolia*), gagu (*Casuarina equisetifolia*), and niyok (*Cocos nucifera*). On Saipan, in addition to the above, gulos (*Cynometra ramiflora*) and sosugi (*Acacia confusa*) are also common. Volcanic substrates on Guam and the Northern Marianas support patches of pago, kafu‘, puting (*Barringtonia racemosa*), ladda (*Morinda citrifolia*), and ahgao (*Premna obtusifolia*) in a largely fire-maintained savanna landscape dominated by grasses, such as *Pennisetum polystachyon* and *Miscanthus floridulus* (Young 1989, Natural Resources Conservation Service 2006a).

### American Samoa

American Samoa has a climate dominated by seasonal easterly and southeasterly trade winds, which produce a wet season from November to April. The territory receives abundant rainfall, averaging about 125 in. (3,175 mm) at sea level and more than 200 in. (5,100 mm) at higher elevations (Nakamura 1984, Natural Resources Conservation Service 2006a, CIA 2008). The total land area of American Samoa is about 76 mi$^2$ (197 km$^2$). Tutuila, the largest island, has an area of 54 mi$^2$ (140 km$^2$) and its highest peak, Mount Matafao, rises 2,142 ft (653 m) above the waters of Pago Pago Bay. The remaining 22 mi$^2$ (57 km$^2$) include the three Manu‘a Islands of Ofu, Olosega, and Ta‘u, which has the highest peak in the territory, Lata Mountain, at 3,050 ft (930 m). Other islands in American Samoa include the islet of Aunu‘u near the eastern tip of Tutuila; Rose Atoll, 65 mi (105 km) east of the Manu‘as; and Swains Island, a small atoll located 200 mi (322 km) north of Pago Pago. The larger islands are characterized by steep volcanic mountainsides, small incised valleys, and a narrow coastal fringe. Soil characteristics vary widely between coastal fringes, mountains, and valleys (Nakamura 1984).

Most of American Samoa is forested with a variety of tropical hardwoods and palms. Common indigenous species include maota mea (*Dysoxylum huntii*), laga‘ali (*Aglaia samoensis*), mamalava (*Planchonella samoensis*), futu (*Barringtonia asiatica*), nui (*Cocos nucifera*), pu‘a (*Hernandia nymphaeifolia*), and fau (*Hibiscus tiliaceus*) (Natural Resources Conservation Service 2006a, Ragone and Lorence 2006).

## Types and Distribution of Wetlands

The interplay of hydrology, salinity, and geomorphic setting determines the types and distribution of wetlands in Pacific island landscapes. Wetland water sources and flow regimes are varied and can be derived predominantly from groundwater, surface water, or direct precipitation. Groundwater and surface water can be saline or brackish in near-coastal areas, or influenced by fresh water from higher elevations, precipitation, or cloud drip. The tidal range in the Hawaiian Islands is about 3.3 ft (1 m) (Juvik and Juvik 1998) and is similar on other Pacific islands, which limits the areas subject to regular tidal inundation. In addition to their hydrologic regimes, wetland types can be differentiated by vegetation type (often dominated by non-native or invasive plant species) and substrate type, which may include bedrock (limestone or basaltic), organic soils, or mineral soils (Erickson and Puttock 2006). The principal wetland types in the region are described briefly below.

Depressional wetlands occur on coastal plains behind beach or river berms. Their main water source is groundwater, which can be fresh to hypersaline in the dry season and may be influenced by storm surges. In the main Hawaiian Islands, these wetlands typically are found on mudflats or in sandy areas, and support herbaceous vegetation (e.g., *Batis maritima*) and/or woody vegetation (e.g., mangroves) (Figure 3). In the Marianas and other Pacific islands, they can also be forested with *Nypa* palms, *Barringtonia racemosa*, or other species. Examples of these wetlands can be found on the south shore of Molokaʻi, at Nukoliʻi on Kauaʻi, in the Kawainui Marsh and James Campbell National Wildlife Refuge on Oʻahu, and in the Kīhei wetlands on Maui.

**Figure 3.** Coastal wetland on Kauaʻi dominated by *Batis maritima* and mangroves. Photo courtesy of the U.S. Fish and Wildlife Service.

Sloped marshlands or fern wetlands obtain their hydrology from shallow groundwater that may rise to the surface infrequently. They occur mainly in volcanic areas on slopes greater than 10 percent, particularly in the Mariana Islands. They typically have mineral soils and support mainly herbaceous vegetation (e.g., *Nephrolepis* ferns, *Phragmites karka*, and sedges), with scattered *Pandanus tectorius* trees. Examples include the Shell wetlands and Nimitz Hill marshlands on Guam and the upper Waipā Valley wetlands on Kauaʻi.

Hanging bogs occur on steep volcanic slopes of 25 percent or more. Their hydrology is derived from rain water that is perched over an aquitard of ironstone sheath. The soils are organic (e.g., peats, mucks) and the vegetation is mainly herbaceous with stunted trees and shrubs (e.g., *Metrosideros polymorpha*). Examples can be found in the Waipā Valley of Kaua‘i and on high-elevation slopes in the Ko‘olau Mountains on O‘ahu.

Montane bogs are found mainly in volcanic areas that have flat to rolling topography, abundant precipitation (up to 445 in. [11,300 mm] per year), and a high water table and/or surface flow. They are found in the Alakai Swamp on Kaua‘i (Figure 4), on Mount Ka‘ala on O‘ahu, in the Kamoku Preserve on Moloka‘i, on Mount Eke and Hāna Ranch on Maui, and in the Mauna Loa bogs on Hawai‘i. Montane bogs are dominated by native herbaceous, fern, shrub, and stunted forest species. In addition, higher-elevation forested wetlands are found on all of the larger Hawaiian islands with the exception of Kaho‘olawe and Ni‘ihau.

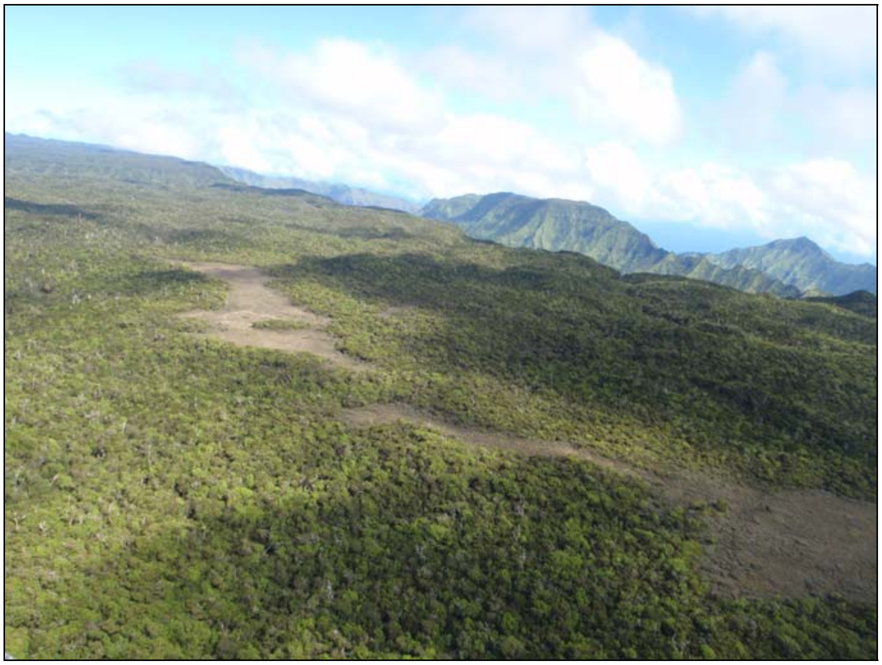

**Figure 4.** Aerial view of the Alakai Swamp, Kaua‘i, showing both forested and montane bog wetlands. Photo courtesy of the U.S. Fish and Wildlife Service.

Riverine and open-water fringe wetlands are present throughout the region. Their hydrology is derived mainly from the adjacent stream, lake, or pond. They are generally fresh water but may be brackish to saline at their confluence with marine waters. The vegetation of fringe wetlands ranges from trees (e.g., *Xylocarpus moluccensis* and other mangroves, java plum [*Syzygium cumini = Eugenia cumini*]) to herbaceous (e.g., *Paspalum vaginatum*, *Sporobolus virginicus*). Throughout the region, this wetland type represents the greatest acreage of remaining low-elevation wetlands. Hundreds of acres were used previously for the production of taro or rice (*Oryza sativa*); however, most wetland agriculture has now been phased out. Examples of riverine and open-water fringe wetlands can be found at Lake Susupe on Saipan, the Masefau Wetland on Tutuila, the lower Hanalei River on Kaua‘i, the Waipi‘o Valley on Hawai‘i, and Kawainui Marsh on O‘ahu.

Salt-flat and mud-flat wetlands are found along the immediate coastline and are subject to coastal over-wash and spray. They have mineral substrates and herbaceous vegetation often dominated by *Batis maritima* and *Sporobolus virginicus*. Examples include those at Hanapēpē on Kaua‘i and Paikō Lagoon on O‘ahu.

Anchialine pools are found along the coasts, generally on young lava flows but occasionally in coastal limestone and karst. Their hydrology is derived mainly from subterranean ocean water. They often contain very little soil or vegetation, and they are habitat for the small, native red shrimp *Halocaridina rubra* (common Hawaiian name ‘ōpae‘ula). Anchialine pools can be found at Waikoloa on Hawai‘i and at the Ahihi-Kinau coastal ponds on Maui.

# 2 Hydrophytic Vegetation Indicators

## Introduction

The Corps Manual defines hydrophytic vegetation as the community of macrophytes that occurs in areas where inundation or soil saturation is either permanent or of sufficient frequency and duration to exert a controlling influence on the plant species present. The manual uses a plant-community approach to evaluate vegetation. Hydrophytic vegetation decisions are based on the assemblage of plant species growing on a site, rather than the presence or absence of particular indicator species. Hydrophytic vegetation is present when the plant community is dominated by species that can tolerate prolonged inundation or soil saturation during the growing season. Hydrophytic vegetation in the Hawaii and Pacific Islands Region is identified by using the indicators described in this chapter.

Many factors besides site wetness affect the composition of the plant community in an area, including regional climate, local weather patterns, topography, soils, natural and human-caused disturbances, and current and historical plant distributional patterns at various spatial scales. The insular floras of the Pacific basin are the result of development over different time spans and under influences from different source regions. The native floras of the Hawaiian Islands and American Samoa, for example, differ substantially from that of the Marianas, including Guam (Mueller-Dombois and Fosberg 1998). The Hawaiian and Samoan Islands are within the Polynesian Region and are influenced by an Indo-Pacific flora with strong representation of American, New Zealand, and Antarctic components (Takhtajan 1986). The Mariana island chain is within the Micronesian Region and its flora is influenced by an Indo-Malaysian flora with strong connections to those of the Philippines, Indonesia, and Asia. The flora of the Marianas lacks an American or boreal component. Unlike floras in some other parts of the Pacific basin, the floras of the Hawaiian Islands, Samoan Islands, and Marianas are composed mainly of species derived from plant colonists that took advantage of new habitats created by volcanic action. The regional floras of Polynesia and Micronesia historically were a mix of local endemics, Pacific regional endemics, and species associated with other nearby continental floras. All have suffered a heavy influx of invasive species resulting from human settlement, agriculture, and urban development. Many wetlands in the region are dominated by hydrophytes that are not native to these islands. The wetland flora of the Hawaiian Islands includes more than 1,000 taxa, while that of Guam and the Northern Mariana Islands includes approximately 800 taxa (U.S. Army Corps of Engineers 2009).

Hydrophytic vegetation decisions are based on the wetland indicator status (Reed [1988] or current approved list) of species that make up the plant community. Species in the facultative categories (FACW, FAC, and FACU) are recognized as occurring in both wetlands and uplands to varying degrees. Although most wetlands are dominated mainly by species rated OBL, FACW, and FAC, some wetland communities may be dominated primarily by FACU species and cannot be identified by dominant species alone. In those cases, other indicators of hydrophytic vegetation must also be considered, particularly where indicators of hydric soils and wetland hydrology are present. This situation is not necessarily due to inaccurate wetland indicator ratings; rather, it is due to the broad tolerances of certain plant species that allow them to be widely distributed across the moisture gradient.

Hydrophytic vegetation indicators and procedures presented in this chapter are designed to identify the majority of wetland plant communities in the region. However, some wetland communities may lack any of these indicators, at least at certain times. These situations are considered in Chapter 5 (Difficult Wetland Situations in the Hawaii and Pacific Islands Region).

## Guidance on Vegetation Sampling and Analysis

General guidance on sampling of vegetation for wetland-delineation purposes is given in the Corps Manual for both the routine and comprehensive methods. Those procedures are intended to be flexible and may need to be modified for application in a given region or on a particular site. Vegetation sampling done as part of a wetland delineation is designed to characterize the site in question rapidly. A balance must be established between the need to accomplish the work quickly and the need to characterize the site's heterogeneity accurately and at an appropriate scale. The following guidance on vegetation sampling is intended to supplement the Corps Manual for applications in the Hawaii and Pacific Islands Region.

The first step is to identify the major landscape units or vegetation communities on a site so they can be evaluated separately. This may be done in advance using an aerial photograph or topographic map, or by walking over the site. In general, routine wetland determinations are based on visual estimates of percent cover of plant species that can be made either (1) within the vegetation community as a whole or (2) within one or more sampling plots established in representative locations within each community. Percent cover estimates are more accurate and repeatable if taken within a defined plot. This also facilitates field verification of another delineator's work.

The appropriate size and shape for a sample plot depend on the type of vegetation (i.e., trees, shrubs, herbaceous plants, etc.) and the size or shape of the plant community or patch being sampled. The plot needs to be large enough to include adequate numbers of individuals in all strata, but small enough so that plant species or individuals can be separated and measured without duplication or omission, and the sampling can be done in a timely fashion (Cox 1990, Barbour et al. 1999). For hydrophytic vegetation determinations, the abundance of each species is determined by using areal cover estimates. Plot sizes should make visual sampling both accurate and efficient. The sizes and shapes of sampling plots, if used, may be modified as appropriate to adapt to site conditions and should be recorded on the field data form if they deviate from those recommended in the Corps Manual. When sampling near a plant-community boundary, and particularly near the wetland boundary, it may be necessary to adjust plot size or shape to avoid overlapping the boundary and extending into an adjacent community having different vegetation, soils, or hydrologic conditions.

If it is not possible to locate one or a few plots in a way that adequately represents the vegetation unit being sampled, then percent cover estimates for each species can be made during a meandering survey of the broader community. If additional quantification of cover estimates is needed, then the optional procedure for point-intercept sampling along transects (see Appendix B) or other sampling procedures may be used to characterize the vegetation unit. To use these sampling methods, soil and hydrologic conditions must be uniform across the sampled area.

Vegetation sampling guidance presented here and in the Corps Manual should be adequate for hydrophytic vegetation determinations in most situations. However, many variations in vegetation structure, diversity, and spatial arrangement exist on the landscape and cannot be addressed adequately in this supplement. A list of references is given in Table 2 for more complex sampling situations. If alternative sampling techniques are used, they should be derived from the scientific literature and described in field notes or in the delineation report. The basic data must include abundance values for each species present. Typical abundance measures include basal area for tree species, percent areal cover, stem density, or frequency based on point-intercept sampling. In any case, the data must be in a format that can be used in the dominance test or prevalence index for hydrophytic vegetation (see the section on Hydrophytic Vegetation Indicators).

In this supplement, absolute percent cover is the preferred abundance measure for all species. For percent cover estimates, it is not necessary for all plants to be rooted in the plot as long as they are growing under the same soil and hydrologic conditions. It may be necessary to exclude plants that overhang the plot if they are rooted in areas having different soil and hydrologic conditions, particularly when sampling near the wetland boundary.

**Table 2**
**Selected references to additional vegetation sampling approaches that could be used in wetland delineation.**

| Reference | Comment |
|---|---|
| Kent, M., and P. Coker. 1992. *Vegetation Description and Analysis: A Practical Approach.* New York, NY: Wiley. | Contains simple and clear methods for setting up a study, and collecting and analyzing the data. Initial chapters are helpful for data collection and sampling approaches in wetland delineation. |
| Mueller-Dombois, D., and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. New York, NY: Wiley. | A standard text in vegetation ecology, sampling, and analysis. This reference provides many sampling and analytical methods that are helpful in complex delineations. |
| Tiner, R.W. 1999. *Wetland indicators: a guide to wetland delineation, classification, and mapping.* Boca Raton, FL: CRC Press. | Includes reviews of various sampling techniques and provides a list of vegetation references. |
| USDI Bureau of Land Management. 1996. *Sampling vegetation attributes.* BLM/RS/ST-96/002+1730. Denver, CO. | Describes many aspects of vegetation sampling, including sampling protocols, data collection, and analysis. |
| USDI Bureau of Land Management. 1998. *Measuring and monitoring plant populations*. BLM/RS/ST-98/005+1730. Denver, CO. | Describes sampling design, measuring techniques, and analytical methods. |

## Definitions of Strata

Vegetation strata within the sampled area or plot are sampled separately when evaluating indicators of hydrophytic vegetation. In the Hawaii and Pacific Islands Region, the vegetation strata described in the Corps Manual are recommended (see below). Unless otherwise noted, a stratum for sampling purposes is defined as having 5 percent or more total plant cover, unless it is the only stratum present. If a stratum has less than 5 percent cover during the peak of annual plant growth, then those species and their cover values may be combined with another stratum for hydrophytic vegetation determinations. For example, a sparse tree layer could be combined with the sapling/shrub layer. Depending upon their location in the canopy, a sparse woody vine stratum could be incorporated into the tree or sapling/shrub strata.

1. *Tree stratum* – Consists of woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

2. *Sapling/shrub stratum* – Consists of woody plants less than 3 in. DBH and greater than 3.28 ft (1 m) tall.

3. *Herb stratum* – Consists of all herbaceous (non-woody) plants, including herbaceous vines, regardless of size, and woody plants less than 3.28 ft tall.

4. *Woody vines* – Consists of all woody vines greater than 3.28 ft in height.

# Hydrophytic Vegetation Indicators

The following indicators should be applied in the sequence presented. The stepwise procedure is designed to reduce field effort by requiring that only one or two indicators, variations of the dominance test, be evaluated in the majority of wetland determinations. However, hydrophytic vegetation is present if any of the indicators is satisfied. All of these indicators are applicable throughout the Hawaii and Pacific Islands Region.

Indicators of hydrophytic vegetation involve looking up the wetland indicator status of plant species on the wetland plant list (Reed [1988] or current list). For the purposes of this supplement, only the five basic levels of wetland indicator status (i.e., OBL, FACW, FAC, FACU, and UPL) are used in hydrophytic vegetation indicators. Plus (+) and minus (–) modifiers are not used (e.g., FAC–, FAC, and FAC+ plants are all considered to be FAC). In general, species that are not listed on the wetland plant list are assumed to be upland (UPL) species. However, recent changes in plant nomenclature have resulted in a number of species that are not listed by Reed (1988) but are not necessarily UPL plants. Procedures described in Chapter 5, section on Problematic Hydrophytic Vegetation, can be used if it is believed that individual FACU, NI, NO, or unlisted plant species are functioning as hydrophytes on a particular site. For Clean Water Act purposes, wetland delineators should use the latest plant lists approved by Headquarters, U.S. Army Corps of Engineers (http://www.usace.army.mil/CECW/Pages/reg_supp.aspx).

The evaluation of the vegetation can begin with a rapid field test for hydrophytic vegetation to determine if there is a need to collect more detailed vegetation data. The rapid test for hydrophytic vegetation (Indicator 1) is met if all dominant species across all strata are OBL or FACW, or a combination of the two, based on a visual assessment. If the site is not dominated solely by OBL and FACW species, proceed to the standard dominance test (Indicator 2), which is the basic hydrophytic vegetation indicator. Either Indicator 1 or 2 should be applied in every wetland determination. Most wetlands in the Hawaii and Pacific Islands Region have plant communities that will meet one or both of these indicators. These are the only indicators that need to be considered in most situations. However, some wetland plant communities may fail a test based only on dominant species. Therefore, in those cases where indicators of hydric soil and wetland hydrology are present, the vegetation should be re-evaluated with the prevalence index (Indicator 3), which takes non-dominant plant species into consideration. Finally, certain disturbed or problematic wetland situations may lack any of these indicators and are described in Chapter 5.

## Procedure

The procedure for using hydrophytic vegetation indicators is as follows:

1. Apply Indicator 1 (Rapid Test for Hydrophytic Vegetation).
    a. If the plant community passes the rapid test for hydrophytic vegetation, then the vegetation is hydrophytic and no further vegetation analysis is required.
    b. If the rapid test for hydrophytic vegetation is not met, then proceed to step 2.

2. Apply Indicator 2 (Dominance Test).
    a. If the plant community passes the dominance test, then the vegetation is hydrophytic and no further vegetation analysis is required.
    b. If the plant community fails the dominance test, and indicators of hydric soil and/or wetland hydrology are absent, then hydrophytic vegetation is absent unless the site meets requirements for a problematic wetland situation (see Chapter 5).
    c. If the plant community fails the dominance test, but indicators of hydric soil and wetland hydrology are both present, proceed to step 3.

3. Apply Indicator 3 (Prevalence Index). This step assumes that at least one indicator of hydric soil and one primary or two secondary indicators of wetland hydrology are present.

    a. If the plant community satisfies the prevalence index, then the vegetation is hydrophytic. No further vegetation analysis is required.
    b. If the plant community fails the prevalence index, then hydrophytic vegetation is absent unless indicators of hydric soil and wetland hydrology are present and the site meets the requirements for a problematic wetland situation (Chapter 5).

## Indicator 1: Rapid test for hydrophytic vegetation

**Description:** All dominant species across all strata are rated OBL or FACW, or a combination of these two categories, based on a visual assessment.

**User Notes:** This test is intended as a quick confirmation in obvious cases that a site has hydrophytic vegetation, without the need for more intensive sampling. Dominant species are selected visually from each stratum of the community using the “50/20 rule” (see Indicator 2 – Dominance Test below) as a general guide but without the need to gather quantitative data. Only the dominant species in each stratum must be recorded on the data form.

## Indicator 2: Dominance test

**Description:** More than 50 percent of the dominant plant species across all strata are rated OBL, FACW, or FAC.

**User Notes:** Use the “50/20 rule” described below to select dominant species from each stratum of the community. Combine dominant species across strata and apply the dominance test to the combined list. Once a species is selected as a dominant, its cover value is not used in the dominance test; each dominant species is treated equally. Thus, a plant community with seven dominant species across all strata would need at least four dominant species that are OBL, FACW, or FAC to be considered hydrophytic by this indicator. Species that are dominant in two or more strata should be counted two or more times in the dominance test.

**Procedure for Selecting Dominant Species by the 50/20 Rule:** Dominant plant species are the most abundant species in the community; they contribute more to the character of the community than do the other non-dominant species present. The 50/20 rule is a repeatable and objective procedure for selecting dominant plant species and is recommended when data are available for all species in the community. The rule can also be used to guide visual sampling of plant communities in rapid wetland determinations.

Dominant species are chosen independently from each stratum of the community. In general, dominants are the most abundant species that individually or collectively account for more than 50 percent of the total coverage of vegetation in the stratum, plus any other species that, by itself, accounts for at least 20 percent of the total. For the purposes of this regional supplement, absolute percent cover is the recommended abundance measure for plants in all vegetation strata. See Table 3 for an example application of the 50/20 rule in evaluating a plant community. Steps in selecting dominant species by the 50/20 rule are as follows:

1. Estimate the absolute percent cover of each species in the first stratum. Since the same data may be used later to calculate the prevalence index, the data should be recorded as absolute cover and not converted to relative cover.

2. Rank all species in the stratum from most to least abundant.

3. Calculate the total coverage of all species in the stratum (i.e., sum their individual percent cover values). Absolute cover estimates do not necessarily sum to 100 percent.

4. Select plant species from the ranked list, in decreasing order of coverage, until the cumulative coverage of selected species *exceeds* 50 percent of the total absolute coverage for the stratum. If two or more species are equal in coverage (i.e., they are tied in rank), they should all be selected. The selected plant species are all considered to be dominants. All dominants must be identified to species.

5. In addition, select any other species that, by itself, is at least 20 percent of the total absolute percent cover in the stratum. Any such species is also considered to be a dominant and must be accurately identified.

6. Repeat steps 1-5 for any other stratum present. Combine the lists of dominant species across all strata. Note that a species may be dominant in more than one stratum (e.g., a woody species may be dominant in both the tree and sapling/shrub strata).

**Table 3**
**Example of the selection of dominant species by the 50/20 rule and determination of hydrophytic vegetation by the dominance test.**

| Stratum | Species Name | Wetland Indicator Status | Absolute Percent Cover | Dominant? |
|---|---|---|---|---|
| Herb | *Carex alligata* | FACW | 15 | Yes |
| | *Cyperus haspan* | FACW | 25 | Yes |
| | *Dicranopteris linearis* | FACU | 10 | No |
| | *Ludwigia palustris* | OBL | 5 | No |
| | *Peperomia membranacea* | FAC | 10 | No |
| | *Uncinia uncinata* | FAC | 5 | No |
| | | Total cover | 70 | |
| | | 50/20 Thresholds:<br>50% of total cover = 35.0%<br>20% of total cover = 14.0% | | |
| Sapling/shrub | *Cibotium chamissoi* | FAC | 15 | Yes |
| | *Metrosideros polymorpha* | FAC | 20 | Yes |
| | *Sadleria cyatheoides* | FACU | 5 | No |
| | | Total cover | 40 | |
| | | 50/20 Thresholds:<br>50% of total cover = 20.0%<br>20% of total cover = 8.0% | | |
| Tree | *Cheirodendron trigynum* | FAC | 20 | Yes |
| | *Metrosideros polymorpha* | FAC | 55 | Yes |
| | | Total cover | 75 | |
| | | 50/20 Thresholds:<br>50% of total cover = 37.5%<br>20% of total cover = 15% | | |
| Woody vine | *Freycinetia arborea* | FACU | 15 | Yes |
| | | Total cover | 15 | |
| | | 50/20 Thresholds:<br>50% of total cover = 7.5%<br>20% of total cover = 3.0% | | |
| Hydrophytic Vegetation Determination | Total number of dominant species across all strata = 7.<br>Percent of dominant species that are OBL, FACW, or FAC = 6/7 = 86%.<br>Therefore, this community is hydrophytic by Indicator 2 (Dominance Test). | | | |

## Indicator 3: Prevalence index

**Description:** The prevalence index is 3.0 or less.

**User Notes:** The prevalence index ranges from 1 to 5. A prevalence index of 3.0 or less indicates that hydrophytic vegetation is present. To calculate the prevalence index, at least 80 percent of the total vegetation cover on the plot (summed across all strata) must be of species that have been correctly identified and have assigned wetland indicator statuses (Reed [1988] or current list) or are upland (UPL) species.

**Procedure for Calculating a Plot-Based Prevalence Index:** The prevalence index is a weighted-average wetland indicator status of all plant species in the sampling plot, where each indicator status category is given a numeric code (OBL = 1, FACW = 2, FAC = 3, FACU = 4, and UPL = 5) and weighting is by abundance (absolute percent cover). It is a more comprehensive analysis of the hydrophytic status of the community than one based on just a few dominant species. It is particularly useful in (1) communities with only one or two dominants, (2) highly diverse communities where many species may be present at roughly equal coverage, and (3) cases where strata differ greatly in total plant cover (e.g., total herb cover is 80 percent but sapling/shrub cover is only 10 percent). The prevalence index is used in this supplement to determine whether hydrophytic vegetation is present on sites where indicators of hydric soil and wetland hydrology are present but the vegetation initially fails the dominance test.

The following procedure is used to calculate a plot-based prevalence index. The method was described by Wentworth et al. (1988) and modified by Wakeley and Lichvar (1997). It uses the same field data (i.e., percent cover estimates for each plant species) that were used to select dominant species by the 50/20 rule, with the added constraint that at least 80 percent of the total vegetation cover on the plot must be of species that have been correctly identified and have an assigned indicator status (including UPL). For any species that occurs in more than one stratum, cover estimates are summed across strata. Steps for determining the prevalence index are as follows:

1. Identify and estimate the absolute percent cover of each species in each stratum of the community. Sum the cover estimates for any species that is present in more than one stratum.

2. Organize all species (across all strata) into groups according to their wetland indicator status (i.e., OBL, FACW, FAC, FACU, or UPL) and sum their cover values within groups. Do not include species that were not identified.

3. Calculate the prevalence index using the following formula:

$$PI = \frac{A_{OBL} + 2A_{FACW} + 3A_{FAC} + 4A_{FACU} + 5A_{UPL}}{A_{OBL} + A_{FACW} + A_{FAC} + A_{FACU} + A_{UPL}}$$

where:
$PI$ = Prevalence index
$A_{OBL}$ = Summed percent cover values of obligate (OBL) plant species;
$A_{FACW}$ = Summed percent cover values of facultative wetland (FACW) plant species;
$A_{FAC}$ = Summed percent cover values of facultative (FAC) plant species;
$A_{FACU}$ = Summed percent cover values of facultative upland (FACU) plant species;
$A_{UPL}$ = Summed percent cover values of upland (UPL) plant species.

See Table 4 for an example calculation of the prevalence index using the same data set as in Table 3. The following web link provides free public-domain software for simultaneous calculation of the 50/20 rule, dominance test, and prevalence index: http://www.crrel.usace.army.mil/rsgisc/wetshed/wetdatashed.htm.

**Table 4**
**Example of the prevalence index using the same data as in Table 3.**

| Indicator Status Group | Species name | Absolute Percent Cover by Species | Total Cover by Group | Multiply by:[1] | Product |
|---|---|---|---|---|---|
| OBL species | *Ludwigia palustris* | 5 | 5 | 1 | 5 |
| FACW species | *Carex alligata*<br>*Cyperus haspan* | 15<br>25 | 40 | 2 | 80 |
| FAC species | *Cheirodendron trigynum*<br>*Cibotium chamissoi*<br>*Metrosideros polymorpha*[2]<br>*Peperomia membranacea*<br>*Uncinia uncinata* | 20<br>15<br>75<br>10<br>5 | 125 | 3 | 375 |
| FACU species | *Dicranopteris linearis*<br>*Freycinetia arborea*<br>*Sadleria cyatheoides* | 10<br>15<br>5 | 30 | 4 | 120 |
| UPL species | None | 0 | 0 | 5 | 0 |
| Sum | | | 200 (A) | | 580 (B) |
| Hydrophytic Vegetation Determination | | Prevalence Index = B/A = 580/200 = 2.90 Therefore, this community is hydrophytic by Indicator 3 (Prevalence Index). | | | |

[1] Where OBL = 1, FACW = 2, FAC = 3, FACU = 4, and UPL = 5.

[2] *Metrosideros polymorpha* was recorded in two or more strata (see Table 3), so the cover estimates were summed across strata.

# 3 Hydric Soil Indicators

## Introduction

The National Technical Committee for Hydric Soils (NTCHS) defines a hydric soil as a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (USDA Soil Conservation Service 1994). Most hydric soils exhibit characteristic morphologies that result from repeated periods of saturation or inundation that last more than a few days. Saturation or inundation, when combined with microbial activity in the soil, causes the depletion of oxygen. This anaerobiosis promotes certain biogeochemical processes, such as the accumulation of organic matter and the reduction, translocation, or accumulation of iron and other reducible elements. These processes result in distinctive characteristics that persist in the soil during both wet and dry periods, making them particularly useful for identifying hydric soils in the field (USDA Natural Resources Conservation Service 2006b).

This chapter presents indicators that are designed to help identify hydric soils in the Hawaii and Pacific Islands Region. Indicators are not intended to replace or relieve the requirements contained in the definition of a hydric soil. Therefore, a soil that meets the definition of a hydric soil is hydric whether or not it exhibits indicators. Guidance for identifying hydric soils that lack indicators can be found later in this chapter (see the sections on documenting the site and its soils) and in Chapter 5 (Difficult Wetland Situations in the Hawaii and Pacific Islands Region).

This list of indicators is dynamic; changes and additions are anticipated with new research and field testing. The indicators presented in this supplement are a subset of the NTCHS *Field Indicators of Hydric Soils in the United States* (USDA Natural Resources Conservation Service [2006b] or current version) that are commonly found in the region. Any change to the NTCHS *Field Indicators of Hydric Soils in the United States* represents a change to this subset of indicators for the Hawaii and Pacific Islands Region. The current version of the indicators can be found on the NRCS hydric soils web site (http://soils.usda.gov/use/hydric). To use the indicators properly, a basic knowledge of soil/landscape relationships is necessary. All of the hydric soil indicators presented in this supplement are applicable throughout the region.

## Concepts

Hydric soil indicators are formed predominantly by the accumulation or loss of iron, manganese, sulfur, or carbon compounds in a saturated and anaerobic environment. These processes and the features that develop are described in the following paragraphs.

### Iron and Manganese Reduction, Translocation, and Accumulation

In an anaerobic environment, soil microbes reduce iron from the ferric ($Fe^{3+}$) to the ferrous ($Fe^{2+}$) form, and manganese from the manganic ($Mn^{4+}$) to the manganous ($Mn^{2+}$) form. Of the two, evidence of iron reduction is more commonly observed in soils. Areas in the soil where iron is reduced often develop characteristic bluish-gray or greenish-gray colors known as *gley*. Ferric iron is insoluble but ferrous iron easily enters the soil solution and may be moved or translocated to other areas of the soil. Areas that have lost iron typically develop characteristic gray or reddish-gray colors and are known as *redox depletions.* If a soil reverts to an aerobic state, iron that is in solution will oxidize and become concentrated in patches and along root channels and other pores. These areas of oxidized iron are called *redox concentrations.* Since water movement in these saturated or inundated soils can be multi-directional, redox depletions and concentrations can occur anywhere in the soil and have irregular shapes and sizes. Soils that are saturated and contain ferrous iron at the time of sampling may change color upon exposure to the air, as ferrous iron is rapidly converted to ferric iron in the presence of oxygen. Such soils are said to have a *reduced matrix* (Vepraskas 1992).

While indicators related to iron or manganese depletion or concentration are the most common in hydric soils, they cannot form in soils whose parent materials are low in Fe or Mn. Soils formed in such materials may have low-chroma colors that are not related to saturation and reduction. For such soils, morphological features formed through accumulation of organic matter may be present.

## Sulfate Reduction

Sulfur is one of the last elements to be reduced by microbes in an anaerobic environment. The microbes convert $SO_4^{2-}$ to $H_2S$, or hydrogen sulfide gas. This results in a very pronounced “rotten egg” odor in some soils that are inundated or saturated for very long periods. In non-saturated or non-inundated soils, sulfate is not reduced and there is no rotten egg odor. The presence of hydrogen sulfide is a strong indicator of a hydric soil, but this indicator is found only in the wettest sites in soils that contain sulfur-bearing compounds.

## Organic Matter Accumulation

Soil microbes use carbon compounds found in organic matter as an energy source. However, the rate at which organic carbon is utilized by soil microbes is considerably lower in a saturated and anaerobic environment than under aerobic conditions. Therefore, in saturated soils, partially decomposed organic matter may accumulate. The result in wetlands is often the development of thick organic surfaces, such as peat or muck, or dark organic-rich mineral surface layers.

**Non-saturated or non-inundated organic soils.** Abundant rainfall and/or acid conditions can also slow the decomposition of organic matter. In these situations, even some well-drained soils, under predominantly aerobic conditions, can develop organic surface layers called folistic layers. These layers are not necessarily related to wetness. Most folistic layers consist of poorly decomposed organic material (i.e., fibric or hemic material; see the following section) although some consist of highly decomposed (i.e., sapric) material. Folistic surface layers may overlie rock, a mineral layer, or saturated organic layers. They typically have moderate to strong, subangular blocky structure; that is, they break naturally into aggregates that are angular to rounded in shape (Figure 5). Saturated muck layers, in contrast, are more homogeneous, without obvious aggregates or structural units. It may be necessary to involve a soil scientist with local knowledge to help distinguish folistic surface layers from saturated organic layers.

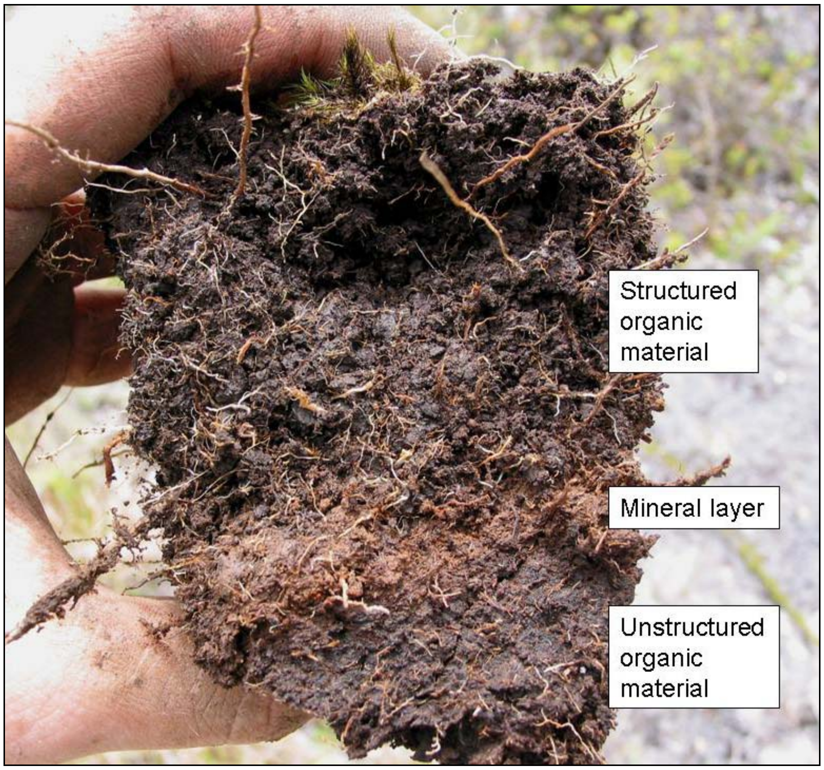

**Figure 5.** A soil sample from the island of Hawai‘i containing structured (subangular blocky) sapric material at the surface and unstructured (homogeneous) sapric material below. Only the unstructured sapric material (muck) indicates soil saturation.

**Determining the Texture of Soil Materials High in Organic Carbon.** Material high in organic carbon could fall into three categories: organic, mucky mineral, or mineral. In lieu of laboratory data, the following estimation method can be used for soil material that is wet or nearly saturated with water. This method may be inconclusive with loamy or clayey textured mineral soils. Gently rub the wet soil material between forefinger and thumb. If upon the first or second rub the material feels gritty, it is mineral soil material. If after the second rub the material feels greasy, it is either mucky mineral or organic soil material. Gently rub the material two or three more times. If after these additional rubs it feels gritty or plastic, it is mucky mineral soil material; if it still feels greasy, it is organic soil material. If the material is organic soil material, a further division should be made, as follows.

Organic soil materials are classified as sapric, hemic, or fibric based on the percentage of visible fibers observable with a hand lens in an undisturbed state and after rubbing between thumb and fingers 10 times (Table 5). If there is a conflict between unrubbed and rubbed fiber content, rubbed content is used. *Live roots are not considered*. In saturated organic materials, the terms sapric, hemic, and fibric correspond to the textures muck, mucky peat, and peat, respectively (Table 5). The terms muck, mucky peat, and peat should only be used for organic accumulations associated with wetness.

Table 5. Proportion of fibers visible with a hand lens.

| Unrubbed | Rubbed | Horizon Descriptor | Soil Texture (Saturated Organic Soils) |
|---|---|---|---|
| <33% | <17% | Sapric | Muck |
| 33-67% | 17-40% | Hemic | Mucky peat |
| >67% | >40% | Fibric | Peat |
| Adapted from USDA Natural Resources Conservation Service (1999). | | | |

Another field method for determining the degree of decomposition for organic materials is a system modified from a method originally developed by L. von Post and described in detail in ASTM standard D 5715-00 (http://www.astm.org/). This method is based on a visual examination of the color of the water that is expelled and the soil material remaining in the hand after a saturated sample is squeezed (Table 6). If a conflict occurs between results for sapric, hemic, or fibric material using percent visible fiber (Table 5) and degree of humification (Table 6), then percent visible fiber should be used.

Table 6. Determination of degree of decomposition of organic materials.

| Degree of Humification | Nature of Material Extruded on Squeezing | Nature of Plant Structure in Residue | Horizon Descriptor |
|---|---|---|---|
| H1 | Clear, colorless water; no organic solids squeezed out | Unaltered, fibrous, undecomposed | Fibric (Peat) |
| H2 | Yellowish water; no organic solids squeezed out | Almost unaltered, fibrous | |
| H3 | Brown, turbid water; no organic solids squeezed out | Easily identifiable | |
| H4 | Dark brown, turbid water; no organic solids squeezed out | Visibly altered but identifiable | Hemic (Mucky peat) |
| H5 | Turbid water and some organic solids squeezed out | Recognizable but vague, difficult to identify | |
| H6 | Turbid water; 1/3 of sample squeezed out | Indistinct, pasty | |
| H7 | Very turbid water; 1/2 of sample squeezed out | Faintly recognizable; few remains identifiable, mostly amorphous | Sapric (Muck) |
| H8 | Thick and pasty; 2/3 of sample squeezed out | Very indistinct | |
| H9 | No free water; nearly all of sample squeezed out | No identifiable remains | |
| H10 | No free water; all of sample squeezed out | Completely amorphous | |

# Cautions

A soil that is artificially drained or protected (for instance, by dikes or levees) is still hydric if the soil in its undisturbed state would meet the definition of a hydric soil. To be identified as hydric, these soils should generally have one or more of the indicators. However, not all areas that have hydric soils will qualify as wetlands, if they no longer have wetland hydrology or support hydrophytic vegetation.

Morphological features that do not reflect contemporary or recent conditions of saturation and anaerobiosis are called relict features. Often, contemporary and recent hydric soil features have diffuse boundaries, whereas relict hydric soil features have sharp boundaries (Vepraskas 1992). Additional guidance for some of the most common problem hydric soils can be found in Chapter 5. When soil morphology seems inconsistent with the landscape, vegetation, or observable hydrology, it may be necessary to obtain the assistance of an experienced soil or wetland scientist to determine whether the soil is hydric.

# Procedures for Sampling Soils

## Observe and Document the Site

Before making any decision about the presence or absence of hydric soils, the overall site and how it interacts with the soil should be considered. The questions below, while not required to identify a hydric soil, can help to explain why one is or is not present. Always look at the landscape features of the immediate site and compare them to the surrounding areas. Try to contrast the features of wet and dry sites that are in close proximity. When observing slope features, look first at the area immediately around the sampling point. For example, a nearly level bench or depression at the sampling point may be more important to site wetness than the overall landform on which it occurs. By understanding how water moves across the site, the reasons for the presence or absence of hydric soil indicators should be clear.

If one or more of the hydric soil indicators given later in this chapter is present, then the soil is hydric. If no hydric soil indicator is present, the additional site information below may be useful in documenting whether the soil is indeed non-hydric or if it might represent a "problem" hydric soil that meets the hydric soil definition despite the absence of indicators.

- *Hydrology*–Is standing water observed on the site or is water observed in the soil pit? What is the depth of the water table in the area? Is there indirect evidence of ponding or flooding?

- *Slope*–Is the site level or nearly level so that surface water does not run off readily, or is it steeper where surface water would run off from the soil?

- *Slope shape*–Is the surface concave (e.g., in a depression), where water would tend to collect and possibly pond on the soil surface? On hillsides, are there convergent slopes (Figure 6), where surface or groundwater may be directed toward a central stream or swale? Or is the surface or slope shape convex, causing water to run off or disperse?

- *Landform*–Is the soil in a floodplain, flat, or drainageway that may be subject to seasonal high water tables or flooding? Is it at the toe of a slope (Figure 7) where runoff may tend to collect or groundwater emerge at or near the surface? Has the microtopography been altered by cultivation or other disturbances?

- *Soil materials*–Is there a restrictive layer in the soil that would slow or prevent the infiltration of water? This could include consolidated bedrock, cemented layers such as duripans and petrocalcic horizons, layers of silt or substantial clay content, or strongly contrasting soil textures (e.g., silt over sand). Or is there relatively loose soil material (sand, gravel, or rocks) or fractured bedrock that would allow the water to flow laterally down slope?

- *Vegetation*–Does the vegetation at the site indicate wetter conditions than at other nearby sites, or is it similar to what is found at nearby upland sites?

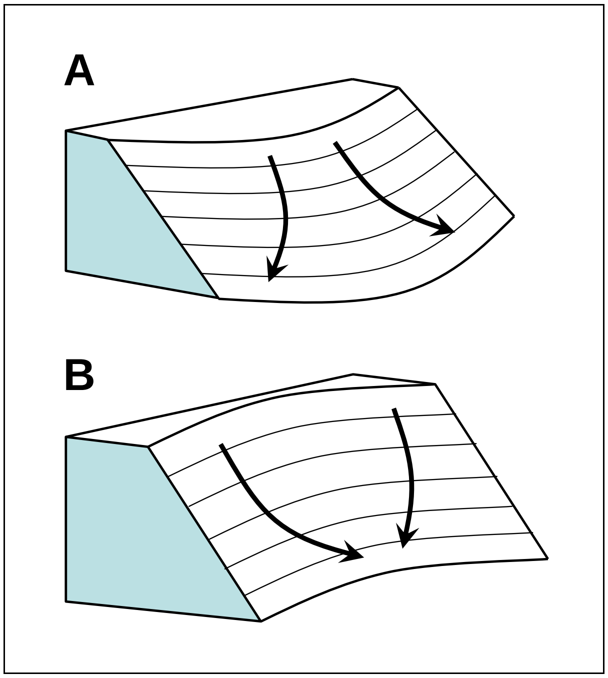

**Figure 6.** Divergent slopes (A) disperse surface water, whereas convergent slopes (B) concentrate water. Surface flow paths are indicated by the arrows.

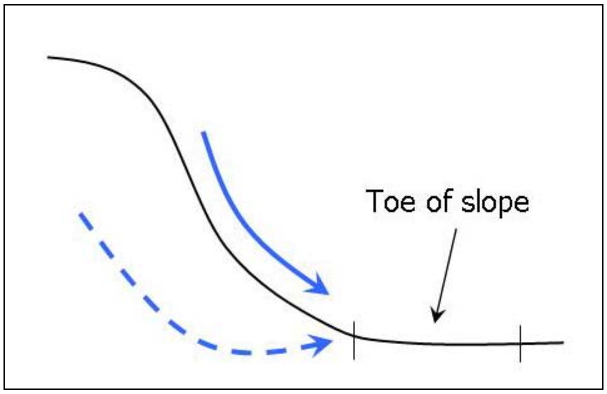

**Figure 7.** At the toe of a hill slope, the gradient is only slightly inclined or nearly level. Blue arrows represent flow paths of surface water (solid arrow) and groundwater (dashed arrow).

## Observe and Document the Soil

To observe and document a hydric soil, first remove any loose leaves, needles, or bark from the soil surface. Do not remove the organic surface layers of the soil, which usually consist of plant remains in varying stages of decomposition. Dig a hole and describe the soil profile. In general, the hole should be dug to the depth needed to document an indicator or to confirm the absence of indicators. For most soils, the recommended excavation depth is approximately 20 in. (50 cm) from the soil surface, although a shallower soil pit may suffice for some indicators (e.g., A2 – Histic Epipedon). Digging may be difficult in some areas due to rocks and hardpans, and shallow bedrock may limit excavation depths in many areas. Use the completed profile description to determine which hydric soil indicators have been met (USDA Natural Resources Conservation Service 2006b).

For soils with deep, dark surface layers, deeper examination may be required when field indicators are not easily seen within 20 in. (50 cm) of the surface. The accumulation of organic matter in these soils may mask redoximorphic features in the surface layers. Examination to 40 in. (1 m) or more may be needed to determine whether they meet the requirements of indicator A12 (Thick Dark Surface). A soil auger or probe may be useful for sampling soil materials below 20 in.

Whenever possible, excavate the soil deep enough to determine if there are layers or materials present that might restrict soil drainage. This will help to understand why the soil may or may not be hydric. After a sufficient number of exploratory excavations have been made to understand the soil-hydrologic relationships at the site, subsequent excavations can be limited to the depth needed to identify hydric soil indicators. Consider taking photographs of both the soil and the overall site, including a clearly marked measurement scale in soil pictures.

Depths used in the indicators are measured from the muck surface, or from the mineral soil surface if a muck surface is absent. For indicators A1 (Histosol), A2 (Histic Epipedon), and A3 (Black Histic), depths are measured from the top of the organic material (peat, mucky peat, or muck). This protocol for making soil-depth measurements as part of a hydric soil determination may differ from standard procedures used to describe soils for other purposes.

All colors noted in this supplement refer to moist Munsell® colors (Gretag/Macbeth 2000). Dry soils should be moistened until the color no longer changes and wet soils should be allowed to dry until they no longer glisten. Care should be taken to avoid over-moistening dry soil. Soil colors specified in the indicators do not have decimal points (except for indicator A12); however, intermediate colors do occur between Munsell chips. Soil colors should not be rounded to qualify as meeting an indicator. For example, a soil matrix with a chroma between 2 and 3 should be recorded as having a chroma of 2+. This soil material does not have a chroma of 2 and would not meet any indicator that requires a chroma of 2 or less.

Always examine soil matrix colors in the field immediately after sampling. Ferrous iron, if present, can oxidize rapidly and create colors of higher chroma or redder hue. In soils that are saturated at the time of sampling, redox concentrations may be absent or difficult to see, particularly in dark-colored soils. It may be necessary to let the soil dry to a moist state (5 to 30 minutes or more) for the iron or manganese to oxidize and redox features to become visible.

Particular attention should be paid to changes in microtopography over short distances. Small changes in elevation may result in repetitive sequences of hydric/non-hydric soils, making the delineation of individual areas of hydric and non-hydric soils difficult. Often the dominant condition (hydric or non-hydric) is the only reliable interpretation (also see the section on Wetland/Non-Wetland Mosaics in Chapter 5). The shape of the local landform can greatly affect the movement of water through the landscape. Significant changes in parent material or lithologic discontinuities in the soil can also affect the hydrologic properties of the soil.

# Use of Existing Soil Data

## Soil surveys

Soil surveys are available for most of the region and can provide useful information regarding soil properties and soil moisture conditions for an area. A list of available soil surveys is located at http://soils.usda.gov/survey/online_surveys/ and soil maps and data are available online from the Web Soil Survey at http://websoilsurvey.nrcs.usda.gov/. Soil survey maps divide the landscape into areas called map units. Map units usually contain more than one soil type or component. They often contain several minor components or inclusions of soils with properties that may be similar to or quite different from the major component. Those soils that are hydric are noted in the *Hydric Soils List* published separately from the soil survey report. Soil survey information can be valuable for planning purposes, but it is not site-specific and is generally less detailed for areas at higher elevations in the islands than at lower elevations, due to differences in topography and access. Soil survey information does not preclude the need for an on-site investigation.

## Hydric soils lists

Hydric Soils Lists are developed for each detailed soil survey. Using criteria approved by the NTCHS, these lists rate each soil component as either hydric or non-hydric based on soil property data. If the soil is rated as hydric, information is provided regarding which hydric criteria are met and on what landform the soil typically occurs. Hydric Soils Lists are useful as general background information for an on-site delineation. However, not all areas within a mapping unit or polygon identified as having hydric soils may be hydric. Conversely, inclusions of hydric soils may be found within soil mapping units where no hydric soils have been identified. Hydric soils lists in the region may identify only a limited number of hydric soil mapping units; however, hydric soils exist throughout the region. The Hydric Soils List should be used as a tool, indicating that hydric soil will likely be found within a given area, but should never be used as a substitute for onsite investigation and field indicators of hydric soils.

Hydric Soils Lists developed for individual detailed soil surveys are known as Local Hydric Soils Lists. They are available from state or county NRCS offices and over the internet from the Soil Data Mart (http://soildatamart.nrcs.usda.gov/). Local Hydric Soils Lists have been compiled into a National Hydric Soils List available at http://soils.usda.gov/use/hydric/. However, use of Local Hydric Soils Lists is preferred since they are more current and reflect local variations in soil properties.

# Hydric Soil Indicators

Many of the hydric soil indicators were developed specifically for wetland-delineation purposes. During the development of these indicators, soils in the interior of wetlands were not always examined; therefore, there are wetlands that lack any of the approved hydric soil indicators in the wettest interior portions. Wetland delineators and other users of the hydric soil indicators should concentrate their sampling efforts near the wetland edge and, if these soils are hydric, assume that soils in the wetter, interior portions of the wetland are also hydric even if they lack an indicator.

Hydric soil indicators are presented in three groups. Indicators for “All Soils” are used in any soil regardless of texture. Indicators for “Sandy Soils” are used in soil layers with USDA textures of loamy fine sand or coarser. Indicators for “Loamy and Clayey Soils” are used with soil layers of loamy very fine sand and finer. Both sandy and loamy/clayey layers may be present in the same soil profile. Therefore, a soil that contains a loamy surface layer over sand is hydric if it meets all of the requirements of matrix color, amount and contrast of redox concentrations, depth, and thickness for a specific A (All Soils), F (Loamy and Clayey Soils), or S (Sandy Soils) indicator.

It is permissible to combine certain hydric soil indicators if all requirements of the indicators are met except thickness (see Hydric Soil Technical Note 4, http://soils.usda.gov/use/hydric/ntchs/tech_notes/index.html). The most restrictive requirements for thickness of layers in any indicators used must be met. Not all indicators are possible candidates for combination. For example, indicator F2 (Loamy Gleyed Matrix) has no thickness requirement, so a site would either meet the requirements of this indicator or it would not. Table 7 lists the indicators that are the most likely candidates for combining in the region.

Table 7. Minimum thickness requirements for commonly combined indicators in the Hawaii and Pacific Islands Region.

| Indicator | Thickness Requirement |
|---|---|
| S5 – Sandy Redox | 4 in. (10 cm) thick starting within 6 in. (15 cm) of the soil surface |
| S7 – Dark Surface | 4 in. (10 cm) thick starting within 6 in. (15 cm) of the soil surface |
| F3 – Depleted Matrix | 6 in. (15 cm) thick starting within 10 in. (25 cm) of the soil surface |
| F6 – Redox Dark Surface | 4 in. (10 cm) thick entirely within the upper 12 in. (30 cm) |
| F7 – Depleted Dark Surface | 4 in. (10 cm) thick entirely within the upper 12 in. (30 cm) |

Table 8 presents an example of a soil in which a combination of layers meets the requirements for indicators F6 (Redox Dark Surface) and F3 (Depleted Matrix). The second layer meets the morphological characteristics of F6 and the third layer meets the morphological characteristics of F3, but neither meets the thickness requirements for its respective indicator. However, the combined thickness of the second and third layers meets the more restrictive conditions of thickness for F3 (i.e., 6 in. (15 cm) starting within 10 in. (25 cm) of the soil surface). Therefore, the soil is considered to be hydric based on the combination of indicators.

Table 8. Example of a soil that is hydric based on a combination of indicators F6 and F3.

| Depth (inches) | Matrix Color | Redox Concentrations | | | Texture |
|---|---|---|---|---|---|
| | | Color | Abundance | Contrast | |
| 0 – 3 | 10YR 2/1 | -- | -- | -- | Loamy |
| 3 – 6 | 10YR 3/1 | 7.5YR 5/6 | 3 percent | Prominent | Loamy |
| 6 – 10 | 10YR 5/2 | 7.5YR 5/6 | 5 percent | Prominent | Loamy |
| 10 – 14 | 2.5Y 4/2 | -- | -- | -- | Loamy |

Another situation in which it is appropriate to combine the characteristics of hydric soil indicators is when stratified textures of sandy (i.e., loamy fine sand and coarser) and loamy (i.e., loamy very fine sand and finer) material occur in the upper 12 in. of the soil. For example, the soil shown in Table 9 is hydric based on a combination of indicators F6 (Redox Dark Surface) and S5 (Sandy Redox). This soil meets the morphological characteristics of F6 in the first layer and S5 in the second layer, but neither layer by itself meets the thickness requirements for its respective indicator. However, the combined thickness of the two layers (6 in.) meets the more restrictive thickness requirement of either indicator (4 in.).

Table 9. Example of a soil that is hydric based on a combination of indicators F6 and S5.

| Depth (inches) | Matrix Color | Redox Concentrations | | | Texture |
|---|---|---|---|---|---|
| | | Color | Abundance | Contrast | |
| 0 – 3 | 10YR 3/1 | 10YR 5/6 | 3 percent | Prominent | Loamy |
| 3 – 6 | 10YR 4/1 | 10YR 5/6 | 3 percent | Prominent | Sandy |
| 6 – 16 | 10YR 4/1 | -- | -- | -- | Loamy |

## All Soils

"All soils" refers to soils with any USDA soil texture. Use the following indicators regardless of soil texture.

Unless otherwise indicated all mineral layers above any of the indicators must have a dominant chroma of 2 or less, or the layer(s) with dominant chroma of more than 2 must be less than 6 in. (15 cm) thick to meet any hydric soil indicator. Nodules and concretions are not considered to be redox concentrations unless otherwise noted.

## Indicator A1: Histosol

**Technical Description:** Classifies as a Histosol (except Folists)

**User Notes:** In most Histosols, 16 in. (40 cm) or more of the upper 32 in. (80 cm) is organic soil material (Figure 8). Histosols also include soils that have organic soil material of any thickness over rock or fragmental soil material that has interstices filled with organic soil material. Organic soil material has an organic carbon content (by weight) of 12 to 18 percent or more, depending on the clay content of the soil. The material includes muck (sapric soil material), mucky peat (hemic soil material), or peat (fibric soil material); muck and mucky peat are the most common across the region. See the glossary of *Field Indicators of Hydric Soils in the United States* (USDA Natural Resources Conservation Service 2006b) for definitions of muck, mucky peat, peat, and organic soil material. Use caution in areas that may have folistic surface layers; folistic layers do not meet the requirements of this indicator. See the Concepts section of this chapter for field methods to identify organic soil materials.

Histosols are not known to occur on Molokaʻi or Lānaʻi and are of limited extent on Oʻahu. Wet Histosols rarely occur on slopes greater than 20 percent in this region and are most likely found in tidal areas that are saturated most of the year. Shallow Histosols over lava bedrock are widespread on the island of Hawaiʻi (Figure 9). Those in scattered depressions on pāhoehoe flows may be saturated for long periods each year. Saturated organic layers can be identified by their massive (homogeneous) structure, whereas unsaturated (folistic) layers typically have moderate to strong subangular blocky structure.

**Figure 8.** Example of a Histosol in which muck (sapric soil material) is greater than 3 ft (0.9 m) thick.

**Figure 9.** Thin organic soils (primarily Folists) are common over lava bedrock on the island of Hawai‘i. However, saturated Histosols can be found on pāhoehoe flows in scattered depressions that trap and hold water.

## Indicator A2: Histic Epipedon

**Technical Description:** A histic epipedon underlain by mineral soil material with chroma of 2 or less.

**User Notes:** Most histic epipedons are surface horizons 8 in. (20 cm) or more thick of organic soil material (Figure 10). Aquic conditions or artificial drainage are required (see *Soil Taxonomy*, USDA Natural Resources Conservation Service 1999); however, aquic conditions can be assumed if indicators of hydrophytic vegetation and wetland hydrology are present. See the glossary of *Field Indicators of Hydric Soils in the United States* (USDA Natural Resources Conservation Service 2006b) for definitions. See the Concepts section of this chapter for field methods to identify organic soil materials. See indicator A1 for organic carbon requirements. Slightly lower organic carbon contents are allowed in plowed soils. Use caution in areas that may have folistic surface layers.

Histic epipedons are not known to occur on Molokaʻi or Lānaʻi and are of limited extent on Oʻahu. Histic epipedons rarely occur on slopes greater than 20 percent in this region and are most likely found in tidal areas that are saturated most of the year. Saturated organic layers generally have massive (homogeneous) structure, whereas unsaturated (folistic) layers typically have moderate to strong subangular blocky structure.

**Figure 10.** Example of an organic surface layer approximately 8 in. (20 cm) thick.

## Indicator A3: Black Histic

**Technical Description:** A layer of peat, mucky peat, or muck 8 in. (20 cm) or more thick that starts within 6 in. (15 cm) of the soil surface; has hue of 10YR or yellower, value of 3 or less, and chroma of 1 or less; and is underlain by mineral soil material with chroma of 2 or less (Figure 11).

**User Notes:** This indicator does not require proof of aquic conditions or artificial drainage. See the glossary of *Field Indicators of Hydric Soils in the United States* (USDA Natural Resources Conservation Service 2006b) for definitions of peat, mucky peat, and muck. See the Concepts section of this chapter for field methods to identify organic soil materials. See indicator A1 for organic carbon requirements.

This indicator is most likely to be associated with depressional wetlands that are ponded or saturated nearly all year, and flats in tidewater areas. The Black Histic indicator is generally not found at the boundary between wetlands and non-wetlands. These soils typically lack a moderate to strong subangular blocky structure.

**Figure 11.** In this soil, the organic surface layer is about 9 in. (23 cm) thick.

## Indicator A4: Hydrogen Sulfide

**Technical Description:** A hydrogen sulfide (rotten egg) odor within 12 in. (30 cm) of the soil surface.

**User Notes:** Any time the soil smells of hydrogen sulfide (rotten egg odor), sulfur is currently being reduced and the soil is definitely in an anaerobic state. In some soils, the odor is pronounced; in others it is very fleeting as the gas dissipates rapidly. If in doubt, quickly open several small holes in the area of concern to determine if a hydrogen sulfide odor is really present. This indicator is common throughout the region in permanently saturated or inundated tidal areas and rare in other environmental settings. Hydrogen sulfide odor is generally not found at the boundary between wetlands and non-wetlands.

## Indicator A8: Muck Presence

**Technical Description:** A layer of muck with a value of 3 or less and chroma of 1 or less within 6 in. (15 cm) of the soil surface.

**User Notes:** The presence of muck of any thickness within 6 in. (15 cm) of the surface is the only requirement for this indicator. Normally, the layer is at the soil surface; however, it may occur at any depth within 6 in. (15 cm). Muck is sapric soil material with a minimum content of organic carbon that ranges from 12 to18 percent, depending on the content of clay. Organic soil material is called muck if virtually all of the material has undergone sufficient decomposition to prevent the identification of plant parts. Hemic (mucky peat) and fibric (peat) soil materials do not qualify. Generally, muck is black and has a greasy feel; sand grains should not be evident. Use caution in areas where a thin layer of highly decomposed (sapric) material may be present below a coarser (fibric or hemic), dry, folistic surface layer. These soils do not become saturated or anaerobic and do not meet the definition of a hydric soil. Folistic layers that are highly decomposed typically have moderate to strong subangular blocky structure. See the Concepts section of this chapter for field methods to identify organic soil materials.

## Indicator A11: Depleted Below Dark Surface

**Technical Description:** A layer with a depleted or gleyed matrix that has 60 percent or more chroma of 2 or less, starting within 12 in. (30 cm) of the soil surface, and having a minimum thickness of either:

- 6 in. (15 cm), or
- 2 in. (5 cm) if the 2 in. (5 cm) consists of fragmental soil material.

Loamy/clayey layer(s) above the depleted or gleyed matrix must have a value of 3 or less and chroma of 2 or less. Any sandy material above the depleted or gleyed matrix must have a value of 3 or less and chroma of 1 or less, and at least 70 percent of the visible soil particles must be covered, coated, or similarly masked with organic material.

**User Notes:** This indicator often occurs in wet soils with dark-colored surface layers (Figure 12). For soils that have dark surface layers greater than 12 in. (30 cm) thick, use indicator A12. Two percent or more distinct or prominent redox concentrations, including iron/manganese soft masses, pore linings, or both, are required in soils that have matrix values/chromas of 4/1, 4/2, and 5/2 (Figure A1). If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible. Redox concentrations are not required for soils with matrix values of 5 or more and chroma of 1, or values of 6 or more and chromas of 2 or 1. The low-chroma matrix must be caused by wetness and not be a relict or parent material feature. See the Glossary (Appendix A) for definitions of depleted matrix, gleyed matrix, distinct and prominent features, and fragmental soil material.

In some places, the gleyed matrix may change color upon exposure to air (reduced matrix). This phenomenon is included in the concept of a gleyed matrix (USDA Natural Resources Conservation Service 2002).

This indicator is common at the boundaries between wetlands and non-wetlands in dark-colored soils.

**Figure 12.** In this soil, a depleted matrix starts immediately below the black surface layer at approximately 11 in. (28 cm).

## Indicator A12: Thick Dark Surface

**Technical Description:** A layer at least 6 in. (15 cm) thick with a depleted or gleyed matrix that has 60 percent or more chroma of 2 or less starting below 12 in. (30 cm) of the surface. The layer(s) above the depleted or gleyed matrix must have a value of 2.5 or less and chroma of 1 or less to a depth of at least 12 in. (30 cm) and a value of 3 or less and chroma of 1 or less in any remaining layers above the depleted or gleyed matrix. Any sandy material above the depleted or gleyed matrix must have at least 70 percent of the visible soil particles covered, coated, or similarly masked with organic material.

**User Notes:** This soil has a depleted matrix or gleyed matrix below a black or very dark gray surface layer 12 in. (30 cm) or more thick (Figure 13). This indicator is most often associated with overthickened soils in concave landscape positions. Two percent or more distinct or prominent redox concentrations (Table A1), including iron/manganese soft masses, pore linings, or both, are required in soils that have matrix values/chromas of 4/1, 4/2, and 5/2 (Figure A1). If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible. Redox concentrations are not required in soils with matrix values of 5 or more and chroma of 1, or values of 6 or more and chromas of 2 or 1. The low-chroma matrix must be caused by wetness and not be a relict or parent material feature. See the Glossary (Appendix A) for the definitions of depleted and gleyed matrix.

In some places, the gleyed matrix may change color upon exposure to air (reduced matrix). This phenomenon is included in the concept of a gleyed matrix (USDA Natural Resources Conservation Service 2002).

This indicator is almost never found at the boundary between wetlands and non-wetlands and is much less common than indicators A11 (Depleted Below Dark Surface), F3 (Depleted Matrix), and F6 (Redox Dark Surface).

**Figure 13.** Deep observations may be necessary to identify the depleted or gleyed matrix below a thick, dark surface layer. In this example, the depleted matrix starts at 20 in. (50 cm).

## Sandy Soils

"Sandy soils" refers to soil materials with a USDA soil texture of loamy fine sand and coarser. Use the following indicators in soil layers consisting of sandy soil materials.

Unless otherwise indicated, all mineral layers above any of the indicators must have a dominant chroma of 2 or less, or the layer(s) with dominant chroma of more than 2 must be less than 6 in. (15 cm) thick to meet any hydric soil indicator. Nodules and concretions are not considered to be redox concentrations unless otherwise noted.

## Indicator S4: Sandy Gleyed Matrix

**Technical Description:** A gleyed matrix that occupies 60 percent or more of a layer starting within 6 in. (15 cm) of the soil surface (Figure 14).

**User Notes:** There is no thickness requirement for the gleyed layer in this indicator. Gley colors are not synonymous with gray colors. Gley colors are those colors that are on the gley pages (Gretag/Macbeth 2000). They have hue N, 10Y, 5GY, 10GY, 5G, 10G, 5BG, 10BG, 5B, 10B, or 5PB, with a value of 4 or more. Soils with dark gley colors (value less than 4) do not meet the definition of a gleyed matrix and this indicator would not apply. If dark gley soil colors are present, users should consider indicators involving high organic-matter content (e.g., A1, A2, A3) or dark-surface indicators (e.g., A11, A12, F6). The gleyed matrix only has to start within 6 in. (15 cm) of the surface. See the Glossary (Appendix A) for the definition of a gleyed matrix.

This indicator is found in areas that are saturated for significant periods. Therefore, it is generally not found at the boundaries between wetlands and non-wetlands.

**Figure 14.** In this example, the gleyed matrix begins at the soil surface.

## Indicator S5: Sandy Redox

**Technical Description:** A layer starting within 6 in. (15 cm) of the soil surface that is at least 4 in. (10 cm) thick and has a matrix with 60 percent or more chroma of 2 or less with 2 percent or more distinct or prominent redox concentrations occurring as soft masses and/or pore linings (Figure 15).

**User Notes:** Distinct and prominent are defined in the Glossary (Appendix A). Redox concentrations include iron and manganese masses (reddish mottles) and pore linings (Vepraskas 1992). Common (2 to less than 20 percent) to many (20 percent or more) redox concentrations (USDA Natural Resources Conservation Service 2002) are required. If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible.

**Figure 15.** Redox concentrations (orange areas) in loamy fine sand on the island of O‘ahu.

## Indicator S7: Dark Surface

**Technical Description:** A layer 4 in. (10 cm) thick starting within 6 in. (15 cm) of the soil surface with a matrix value of 3 or less and chroma of 1 or less. At least 70 percent of the visible soil particles must be covered, coated, or similarly masked with organic material. The matrix color of the layer immediately below the dark layer must have the same colors as those described above or any color that has a chroma of 2 or less.

**User Notes:** If the dark layer is greater than 4 in. (10 cm) thick, then the indicator is met, because any dark soil material in excess of 4 in. (10 cm) meets the requirement that "the layer immediately below the dark layer must have the same colors as those described above… ." If the dark layer is exactly 4 in. (10 cm) thick, then the material immediately below must have a matrix chroma of 2 or less. The organic carbon content of this indicator is slightly less than that required for "mucky." An undisturbed sample must be observed (Figure 16). Many moderately wet soils have a ratio of about 50 percent of soil particles covered or coated with organic matter to about 50 percent uncoated or uncovered soil particles, giving the soil a salt-and-pepper appearance. Where the percent coverage by organic matter is less than 70 percent, a Dark Surface indicator is not present. A 10- or 15-power hand lens is an excellent tool to aid in this decision. Do not confuse this indicator with dark sands derived from black parent materials.

**Figure 16.** This sandy soil has a dark surface approximately 6 in. (15 cm) thick. Scale is in inches on the right.

## Loamy and Clayey Soils

"Loamy and clayey soils" refers to soil materials with USDA textures of loamy very fine sand and finer. Use the following indicators in soil layers consisting of loamy or clayey soil materials.

Unless otherwise indicated (e.g., see indicator F8 – Redox Depressions), all mineral layers above any of the indicators must have a dominant chroma of 2 or less, or the layer(s) with dominant chroma of more than 2 must be less than 6 in. (15 cm) thick to meet any hydric soil indicator. Nodules and concretions are not considered to be redox concentrations unless otherwise noted.

## Indicator F2: Loamy Gleyed Matrix

**Technical Description:** A gleyed matrix that occupies 60 percent or more of a layer starting within 12 in. (30 cm) of the soil surface (Figure 17).

**User Notes:** There is no thickness requirement for this indicator. Gley colors are not synonymous with gray colors. Gley colors are those colors that are on the gley pages (Gretag/Macbeth 2000). They have hue N, 10Y, 5GY, 10GY, 5G, 10G, 5BG, 10BG, 5B, 10B, or 5PB, with a value of 4 or more. Soils with dark gley colors (value less than 4) do not meet the definition of a gleyed matrix and this indicator would not apply. If dark gley soil colors are present, users should consider indicators for soils with high organic-matter content (e.g., A1, A2, A3) or those involving dark surface layers (e.g., A11, A12, F6). The gleyed matrix only has to start within 12 in. (30 cm) of the surface. Soils with gleyed matrices are saturated for significant periods; therefore, no minimum thickness of gleyed layer is required. See the Glossary (Appendix A) for the definition of a gleyed matrix.

This indicator is found in soils that are inundated or saturated for nearly all of the growing season in most years and is not usually found at the boundaries between wetlands and non-wetlands**.**

**Figure 17.** In this soil, a gleyed matrix begins immediately below the dark surface layer.

## Indicator F3: Depleted Matrix

**Technical Description:** A layer with a depleted matrix that has 60 percent or more chroma of 2 or less and that has a minimum thickness of either:

- 2 in. (5 cm) if the 2 in. (5 cm) is entirely within the upper 6 in. (15 cm) of the soil, or
- 6 in. (15 cm) starting within 10 in. (25 cm) of the soil surface.

**User Notes:** This is one of the most commonly observed hydric soil indicators at wetland boundaries. Redox concentrations including iron/manganese soft masses or pore linings, or both, are required in soils with matrix values/chromas of 4/1, 4/2, and 5/2 (Figures 18 and 19). If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible. Redox concentrations are not required in soils with matrix values of 5 or more and chroma of 1, or values of 6 or more and chromas of 2 or 1. The low-chroma matrix must be caused by wetness and not be a relict or parent material feature. See the Glossary (Appendix A) for the definition of a depleted matrix.

**Figure 18.** Example of indicator F3 (Depleted Matrix), in which redox concentrations extend nearly to the surface.

**Figure 19**. This soil has a depleted matrix with redox concentrations in a low-chroma matrix.

## Indicator F6: Redox Dark Surface

**Technical Description:** A layer that is at least 4 in. (10 cm) thick, is entirely within the upper 12 in. (30 cm) of the mineral soil, and has a:

- Matrix value of 3 or less and chroma of 1 or less and 2 percent or more distinct or prominent redox concentrations occurring as soft masses or pore linings, or
- Matrix value of 3 or less and chroma of 2 or less and 5 percent or more distinct or prominent redox concentrations occurring as soft masses or pore linings.

**User Notes:** This is a very common indicator used to delineate wetlands in soils with dark-colored surface layers. Redox concentrations are often small and difficult to see in mineral soils that have dark (value of 3 or less) surface layers due to high organic-matter content (Figure 20). The organic matter masks some or all of the concentrations that may be present; it also masks the diffuse boundaries of the concentrations and makes them appear to be more sharp. Careful examination is required to see what are often brownish redox concentrations in the darkened materials. If the soil is saturated at the time of sampling, it may be necessary to let it dry at least to a moist condition for redox features to become visible. In some cases, further drying of the samples makes the concentrations (if present) easier to see. A hand lens may be helpful in seeing and describing small redox concentrations. Care should be taken to examine the interior of soil peds for redox concentrations. Dry colors, if used, also must have matrix chromas of 1 or 2, and the redox concentrations must be distinct or prominent (see Glossary, Appendix A).

In soils that are wet because of subsurface saturation, the layer immediately below the dark epipedon will likely have a depleted or gleyed matrix (see the Glossary for definitions). Soils that are wet because of ponding or have a shallow, perched layer of saturation may not always have a depleted/gleyed matrix below the dark surface. It is recommended that delineators evaluate the hydrologic source and examine and describe the layer below the dark-colored epipedon when applying this indicator.

**Figure 20.** Redox features can be small and difficult to see within a dark soil layer.

## Indicator F7: Depleted Dark Surface

**Technical Description:** Redox depletions with a value of 5 or more and chroma of 2 or less in a layer that is at least 4 in. (10 cm) thick, is entirely within the upper 12 in. (30 cm) of the mineral soil (Figure 21), and has a:

- Matrix value of 3 or less and chroma of 1 or less and 10 percent or more redox depletions, or
- Matrix value of 3 or less and chroma of 2 or less and 20 percent or more redox depletions.

**User Notes:** Knowledge of local conditions is required in areas where light-colored, highly leached layers and/or layers high in carbonates may be present. Mixing of layers can be caused by burrowing animals or cultivation. Pieces of deeper layers that become incorporated into the surface layer are not redox depletions. Redox depletions will usually have associated microsites with redox concentrations that occur as pore linings or masses within the depletion(s) or surrounding the depletion(s). In soils that are wet because of subsurface saturation, the layer immediately below the dark surface is likely to have a depleted or gleyed matrix.

**Figure 21.** Redox depletions (lighter colored areas) are scattered within the darker matrix. Scale is in centimeters.

## Indicator F8: Redox Depressions

**Technical Description:** In closed depressions subject to ponding, 5 percent or more distinct or prominent redox concentrations occurring as soft masses or pore linings in a layer that is 2 in. (5 cm) or more thick and is entirely within the upper 6 in. (15 cm) of the soil.

**User Notes:** This indicator occurs on depressional landforms, such as forested depressions and ephemeral pools (Figure 22); but not in microdepressions on convex landscapes. Closed depressions often occur within flats or floodplain landscapes. *Note that there is no color requirement for the soil matrix.* The layer containing redox concentrations may extend below 6 in. (15 cm) as long as at least 2 in. (5 cm) occurs within 6 in. (15 cm) of the surface. If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible. See the Glossary for definitions of distinct and prominent.

This is a common but often overlooked indicator at the wetland/non-wetland boundary of depressional sites.

**Figure 22.** In this example, the layer of redox concentrations begins at the soil surface and is slightly more than 2 in. (5 cm) thick.

# Hydric Soil Indicators for Problem Soils

The following indicators are not currently recognized for general application by the NTCHS, or they are not recognized in this region. However, these indicators may be used in problem wetland situations in the Hawaii and Pacific Islands Region where there is evidence of wetland hydrology and hydrophytic vegetation, and the soil is believed to meet the definition of a hydric soil despite the lack of other indicators of a hydric soil. To use these indicators, follow the procedure described in the section on Problematic Hydric Soils in Chapter 5. If either of the following indicators is observed, it is recommended that the NTCHS be notified by following the protocol described in the "Comment on the Indicators" section of *Field Indicators of Hydric Soils in the United States* (USDA Natural Resources Conservation Service 2006b).

## Indicator A5: Stratified Layers

**Technical Description:** Several stratified layers starting within 6 in. (15 cm) of the soil surface. At least one of the layers has a value of 3 or less with chroma of 1 or less or it is muck, mucky peat, peat, or mucky modified mineral texture. Any sandy material that constitutes the layer with value of 3 or less and chroma of 1 or less must have at least 70 percent of the visible soil particles covered, coated, or similarly masked with organic material. The remaining layers have a chroma of 2 or less (Figures 23 and 24).

**User Notes:** Use of this indicator may require assistance from a soil scientist with local experience. An undisturbed sample must be observed. Individual strata are dominantly less than 1 in. (2.5 cm) thick. At least one layer must have at least 70 percent of the soil material covered, coated, or similarly masked with organic matter. A hand lens is an excellent tool to aid in the identification of this indicator. Many alluvial soils have stratified layers at greater depths; these are not hydric soils. Many alluvial soils have stratified layers at the required depths, but lack a chroma of 2 or less; these do not fit this indicator. Stratified layers occur in any type of soil material, generally in floodplains and other areas where wet soils are subject to rapid and repeated burial with thin deposits of sediment.

**Figure 23.** Stratified layers in loamy material. Scale is in inches on the right.

**Figure 24.** Stratified layers in sandy material. Scale is in inches.

## Indicator S1: Sandy Mucky Mineral

**Technical Description:** A layer of mucky modified sandy soil material 2 in. (5 cm) or more thick starting within 6 in. (15 cm) of the soil surface (Figure 25).

**User Notes:** This indicator is rare in the region and is most likely found on coastal flats and depressions. *Mucky* is a USDA texture modifier for mineral soils. The organic carbon content is at least 5 percent and ranges to as high as 14 percent for sandy soils. The percentage requirement is dependent upon the clay content of the soil; the higher the clay content, the higher the organic carbon requirement. See the glossary of *Field Indicators of Hydric Soils in the United States* (USDA Natural Resources Conservation Service 2006b) for the definition of mucky modified mineral texture. A field procedure for identifying mucky mineral soil material is presented in the Concepts section of this chapter.

**Figure 25.** The mucky modified sandy layer is approximately 3 in. (7.5 cm) thick. Scale in inches on the right side of ruler.

## Indicator TF2: Red Parent Material

**Technical Description:** In parent material with a hue of 7.5YR or redder, a layer at least 4 in. (10 cm) thick with a matrix value and chroma of 4 or less and 2 percent or more redox depletions and/or redox concentrations occurring as soft masses and/or pore linings. The layer is entirely within 12 in. (30 cm) of the soil surface. The minimum thickness requirement is 2 in. (5 cm) if the layer is the mineral surface layer.

**User Notes:** Red soils in the region are not necessarily due to red parent materials but are derived from highly weathered lava. However, this indicator is applicable in these situations. Redox features most noticeable in red materials include redox depletions and soft manganese masses that are black or dark reddish black. If the soil is saturated at the time of sampling, it may be necessary to let it dry to a moist condition for redox features to become visible. This indicator is most commonly found on older islands. Users of this indicator should document the probable source of red soil materials found on the site.

## Indicator TF12: Very Shallow Dark Surface

**Technical Description:** In depressions and other concave landforms, one of the following:

a. If bedrock occurs between 6 in. (15 cm) and 10 in. (25 cm), a layer at least 6 in. (15 cm) thick starting within 4 in. (10 cm) of the soil surface with a value of 3 or less and chroma of 1 or less, and the remaining soil to bedrock must have the same colors as above or any other color that has a chroma of 2 or less.

b. If bedrock occurs within 6 in. (15 cm), more than half of the soil thickness must have a value of 3 or less and chroma of 1 or less, and the remaining soil to bedrock must have the same colors as above or any other color that has a chroma of 2 or less.

# 4 Wetland Hydrology Indicators

## Introduction

Wetland hydrology indicators are used in combination with indicators of hydric soil and hydrophytic vegetation to determine whether an area is a wetland under the Corps Manual. Indicators of hydrophytic vegetation and hydric soil generally reflect a site's medium- to long-term wetness history. They provide readily observable evidence that episodes of inundation or soil saturation lasting more than a few days during the growing season have occurred repeatedly over a period of years and that the timing, duration, and frequency of wet conditions have been sufficient to produce a characteristic wetland plant community and hydric soil morphology. If hydrology has not been altered, vegetation and soils provide strong evidence that wetland hydrology is present (National Research Council 1995). Wetland hydrology indicators provide evidence that the site has a *continuing* wetland hydrologic regime and that hydric soils and hydrophytic vegetation are not relicts of a past hydrologic regime. Wetland hydrology indicators confirm that an episode of inundation or soil saturation occurred recently, but may provide little additional information about the timing, duration, or frequency of such events (National Research Council 1995).

Hydrology indicators are often the most transitory of wetland indicators. Some hydrology indicators are naturally temporary or seasonal, and many are affected by recent or long-term meteorological conditions. For example, indicators involving direct observation of surface water or saturated soils often are present only during the normal wet season and may be absent during the dry season or during drier-than-normal years. Hydrology indicators also may be subject to disturbance or destruction by natural processes or human activities. Most wetlands in the region will exhibit one or more of the hydrology indicators presented in this chapter. However, some wetlands may lack any of these indicators due to dry conditions, disturbance, or other factors. Therefore, *the lack of an indicator is not evidence for the absence of wetland hydrology*. See Chapter 5 (Difficult Wetland Situations in the Hawaii and Pacific Islands Region) for help in identifying wetlands that may lack wetland hydrology indicators at certain times.

The various islands in the region have subtropical and tropical climates, with annual precipitation ranging from approximately 10 to more than 400 in. (255 to more than 10,160 mm) depending upon location, aspect, and topography. In the Hawaiian Islands, for example, annual rainfall is greater on northeastern, windward slopes, while areas in the rain shadow of prominent mountain ranges and peaks may be semiarid. The region is also affected by tropical weather systems and occasional hurricanes and typhoons that can produce very heavy downpours. Some wetland hydrology indicators may be present on non-wetland sites immediately after a heavy rain or during periods of unusually high precipitation, river stages, tides, or runoff. Therefore, it is important to consider weather and climatic conditions prior to the site visit to minimize both false-positive and false-negative wetland hydrology decisions. An understanding of normal seasonal, annual, and spatial variations in rainfall, temperature, and other climatic conditions is important in interpreting hydrology indicators in the region. Some useful sources of climatic data are described in Chapter 5.

Areas that have hydrophytic vegetation and hydric soils generally also have wetland hydrology unless the hydrologic regime has changed due to natural events or human activities (National Research Council 1995). Therefore, when wetland hydrology indicators are absent from an area that has indicators of hydric soil and hydrophytic vegetation, further information may be needed to determine whether or not wetland hydrology is present. If possible, one or more site visits should be scheduled to coincide with the normal wet season, the period of the year when the presence or absence of wetland hydrology indicators is most likely to reflect the true wetland/non-wetland status of the site. In addition, aerial photography or other remote-sensing data, stream gauge data, runoff estimates, scope-and-effect equations for ditches and subsurface drainage systems, or groundwater modeling are tools that may help to determine whether wetland hydrology is present when indicators are equivocal or lacking (e.g., USDA Natural Resources Conservation Service 1997). Finally, on highly disturbed or problematic sites, direct hydrologic monitoring may be undertaken to determine whether wetland hydrology is present. The U. S. Army Corps of Engineers (2005) provides a technical standard for monitoring hydrology on such sites. This standard requires 14 or more consecutive days of flooding or ponding, or a water table 12 in. (30 cm) or less below the soil surface, during the growing season at a minimum frequency of 5 years in 10 (50 percent or higher probability) (National Research Council 1995) unless an alternative standard has been established for a particular region or wetland type. See Chapter 5 for further information on these techniques.

## Growing Season

In the Hawaii and Pacific Islands Region, the growing season for wetland delineation purposes is year-round or 365 days long. The growing season is the period of the year when biological activity in plant roots and soil microbial populations is sufficient to bring about the depletion of oxygen and the chemical reduction of nitrogen, iron, and other elements in soils that become saturated for more than a few days. In this region, soil temperatures are consistently above “biological zero” or 41 °F (5 °C) and significant biological activity occurs year-round, even at the highest elevations. Therefore, wetland hydrology indicators are applicable throughout the year. In the event that recorded hydrologic data, such as stream gauge or water-table monitoring data, must be analyzed to determine whether wetland hydrology is present on highly disturbed or problematic sites, extended periods of flooding, ponding, or high water tables are relevant at any time of year. See Chapter 5, section on Wetlands that Periodically Lack Indicators of Wetland Hydrology, for more information.

## Wetland Hydrology Indicators

In this chapter, wetland hydrology indicators are presented in four groups. Indicators in Group A are based on the direct observation of surface water or groundwater during a site visit. Group B consists of evidence that the site is subject to flooding or ponding, although it may not be inundated currently. These indicators include water marks, drift deposits, sediment deposits, and similar features. Group C consists of other evidence that the soil is saturated currently or was saturated recently. Some of these indicators, such as oxidized rhizospheres surrounding living roots and the presence of reduced iron or sulfur in the soil profile, indicate that the soil has been saturated for an extended period. Group D consists of landscape, vegetation, and soil features that indicate contemporary rather than historical wet conditions. Wetland hydrology indicators are intended as one-time observations of site conditions that are sufficient evidence of wetland hydrology in areas where hydric soils and hydrophytic vegetation are present. Unless otherwise noted, all of the indicators presented in this supplement are applicable throughout the Hawaii and Pacific Islands Region.

Within each group, indicators are divided into two categories – *primary* and *secondary* – based on their estimated reliability in this region. One primary indicator from any group is sufficient to conclude that wetland hydrology is present; the area is a wetland if indicators of hydric soil and hydrophytic vegetation are also present. In the absence of a primary indicator, two or more secondary indicators from any group are required to conclude that wetland hydrology is present. Indicators of wetland hydrology include, but are not necessarily limited to, those listed in Table 10 and described on the following pages. Other evidence of wetland hydrology may also be used with appropriate documentation.

**Table 10. Wetland hydrology indicators for the Hawaii and Pacific Islands Region**

| Indicator | Category | |
|---|---|---|
| | Primary | Secondary |
| **Group A – Observation of Surface Water or Saturated Soils** | | |
| A1 – Surface water | X | |
| A2 – High water table | X | |
| A3 – Saturation | X | |
| **Group B – Evidence of Recent Inundation** | | |
| B1 – Water marks | X | |
| B2 – Sediment deposits | X | |
| B3 – Drift deposits | X | |
| B4 – Algal mat or crust | X | |
| B5 – Iron deposits | X | |
| B7 – Inundation visible on aerial imagery | X | |
| B9 – Water-stained leaves | X | |
| B13 – Aquatic fauna | X | |
| B17 – Tilapia nests | X | |
| B6 – Surface soil cracks | | X |
| B8 – Sparsely vegetated concave surface | | X |
| B10 – Drainage patterns | | X |
| **Group C – Evidence of Current or Recent Soil Saturation** | | |
| C1 – Hydrogen sulfide odor | X | |
| C3 – Oxidized rhizospheres along living roots | X | |
| C4 – Presence of reduced iron | X | |
| C6 – Recent iron reduction in tilled soils | X | |
| C7 – Thin muck surface | X | |
| C10 – Fiddler crab burrows | X[1] | |
| C2 – Dry-season water table | | X |
| C5 – Salt deposits | | X |
| **Group D – Evidence from Other Site Conditions or Data** | | |
| D1 – Stunted or stressed plants | | X |
| D2 – Geomorphic position | | X |
| D3 – Shallow aquitard | | X |
| D5 – FAC-neutral test | | X |

[1] Applicable to Guam, the Northern Mariana Islands, and American Samoa.

## Group A – Observation of Surface Water or Saturated Soils

### Indicator A1: Surface water

**Category:** Primary

**General Description:** This indicator consists of the direct, visual observation of surface water (flooding or ponding) during a site visit (Figure 26).

**Cautions and User Notes:** Care must be used in applying this indicator because surface water may be present in non-wetland areas immediately after a rainfall event or during periods of unusually high precipitation, runoff, tides, or stream flow. Furthermore, some non-wetlands flood frequently for brief periods. Note that surface water may be absent from a wetland during the normal dry season or during extended periods of drought. Even under normal rainfall conditions, some wetlands do not become inundated or saturated every year (i.e., wetlands are inundated or saturated at least 5 out of 10 years, or 50 percent or higher probability). In addition, groundwater-dominated wetland systems may never or rarely contain surface water.

**Figure 26.** A wetland with surface water present, Waipi‘o Valley, Hawai‘i.

## Indicator A2: High water table

**Category:** Primary

**General Description:** This indicator consists of the direct, visual observation of the water table 12 in. (30 cm) or less below the surface in a soil pit, auger hole, or shallow monitoring well (Figure 27). This indicator includes water tables influenced by tides or derived from perched water, throughflow, or discharging groundwater (e.g., in seeps) that may be moving laterally near the soil surface.

**Cautions and User Notes:** Sufficient time must be allowed for water to infiltrate into a newly dug hole and to stabilize at the water-table level. The required time will vary depending upon soil texture. In some cases, the water table can be determined by examining the wall of the soil pit and identifying the upper level at which water is seeping into the pit. Care must be used in interpreting this indicator because water-table levels normally vary seasonally and are a function of both recent and long-term precipitation and, in coastal areas, may be influenced by tides. Even under normal rainfall conditions, some wetlands do not become inundated or saturated every year (i.e., wetlands are inundated or saturated at least 5 out of 10 years, or 50 percent or higher probability). For an accurate determination of the water-table level, the soil pit, auger hole, or well should not penetrate any restrictive soil layer capable of perching water near the surface.

**Figure 27.** High water table observed in a soil pit.

## Indicator A3: Saturation

**Category:** Primary

**General Description:** Visual observation of saturated soil conditions 12 in. (30 cm) or less from the soil surface as indicated by water glistening on the surfaces and broken interior faces of soil samples removed from the pit or auger hole (Figure 28). This indicator must be associated with an existing water table located immediately below the saturated zone; however, this requirement is waived under episaturated conditions if there is a restrictive soil layer or bedrock within 12 in. (30 cm) of the surface.

**Cautions and User Notes:** Glistening is evidence that the soil sample was taken either below the water table or within the saturated capillary fringe above the water table. Recent rainfall events and the proximity of the water table at the time of sampling must be considered in applying and interpreting this indicator. Water observed in soil cracks or on the faces of soil aggregates (peds) does not meet this indicator unless ped interiors are also saturated. Depth to the water table must be recorded on the data form or in field notes. A water table is not required below the saturated zone under episaturated conditions if the restrictive layer or bedrock is present within 12 in. (30 cm) of the surface. Note the restrictive layer in the soils section of the data form. The restrictive layer may be at the surface.

**Figure 28.** Water glistens on the surface of a saturated soil sample.

## Group B – Evidence of Recent Inundation

### Indicator B1: Water marks

**Category:** Primary

**General Description:** Water marks are discolorations or stains on the bark of woody vegetation, rocks, bridge supports, buildings, fences, or other fixed objects as a result of inundation (Figure 29).

**Cautions and User Notes:** When several water marks are present, the highest reflects the maximum extent of inundation. Water marks indicate a water-level elevation and can be extrapolated from nearby objects across lower elevation areas. Use caution with water marks that may have been caused by extreme, infrequent, or very brief flooding events. Along streams subject to severe downcutting in recent years, water marks may reflect historic rather than contemporary flooding levels.

**Figure 29.** Water marks on rocks in a seasonally ponded depression.

### Indicator B2: Sediment deposits

**Category:** Primary

**General Description:** Sediment deposits are thin layers or coatings of fine-grained mineral material (e.g., silt or clay) or organic matter (e.g., pollen), sometimes mixed with other detritus, remaining on tree bark (Figure 30), plant stems or leaves, rocks, and other objects after surface water recedes.

**Cautions and User Notes:** Sediment deposits most often occur in ponded situations where water has stood for sufficient time to allow suspended sediment to settle. Sediment deposits may remain for a considerable period before being removed by precipitation or subsequent inundation. Sediment deposits on vegetation or other objects indicate the minimum inundation level. This level can be extrapolated across lower elevation areas. Use caution with sediment left after infrequent high flows or very brief flooding events. This indicator does not include thick accumulations of sand or gravel in fluvial channels that may reflect historic flow conditions or recent extreme events.

**Figure 30.** Silt deposit left after a recent high-water event forms a tan coating on these tree trunks (upper edge indicated by the arrow).

## Indicator B3: Drift deposits

**Category:** Primary

**General Description:** Drift deposits consist of rafted debris that has been deposited on the ground surface or entangled in vegetation or other fixed objects (Figure 31). Debris consists of vegetation (e.g., branches, stems, leaves, seeds, and propagules), man-made litter, or other waterborne materials. Drift material may be deposited at or near the high water line in ponded or flooded areas, piled against the upstream side of trees, rocks, and other fixed objects, or widely distributed within the dewatered area.

**Cautions and User Notes:** Deposits of drift material are often found adjacent to streams or other sources of flowing water in wetlands. They also occur in tidal wetlands, along lake shores, and in other ponded areas. The elevation of a drift line can be extrapolated across lower elevation areas. Use caution with drift lines that may have been caused by extreme, infrequent, or very brief flooding events, and in areas with functioning drainage systems capable of removing excess water quickly.

**Figure 31.** Drift material caught on a fence and in low vegetation in a coastal wetland.

### Indicator B4: Algal mat or crust

**Category:** Primary

**General Description:** This indicator consists of a mat or dried crust of algae, perhaps mixed with other detritus, left on or near the soil surface after dewatering.

**Cautions and User Notes:** Algal deposits include those produced by green algae (Chlorophyta) and blue-green algae (cyanobacteria). They may be attached to low vegetation or other fixed objects, or may cover the soil surface (Figures 32 and 33). Dried crusts of blue-green algae may crack and curl at plate margins (Figure 34). Algal deposits are usually seen in coastal flats, swales, and depressions; seasonally ponded areas; lake fringes; and low-gradient stream margins. They reflect prolonged wet conditions sufficient for algal growth and development.

**Figure 32.** Algal mat in a recently ponded depression, Kawainui Marsh, O‘ahu.

**Figure 33.** Drying algal mat surrounding a ponded depression near the Saddle Road, Hawai‘i.

**Figure 34.** Dried crust of blue-green algae that has cracked and curled.

## Indicator B5: Iron deposits

**Category:** Primary

**General Description:** This indicator consists of a thin orange or yellow crust or gel of oxidized iron on the soil surface or on objects near the surface.

**Cautions and User Notes:** Iron deposits form in localized areas where reduced iron discharges with groundwater and oxidizes upon exposure to air. The oxidized iron forms a film or sheen on standing water (Figure 35) and an orange or yellow deposit (Figure 36) on the ground surface after dewatering. Iron sheen on water can be distinguished from an oily film by touching with a stick or finger; iron films are crystalline and will crack into angular pieces.

**Figure 35.** Iron sheen on the water surface may be deposited as an orange or yellow crust after dewatering.

**Figure 36**. Iron deposit (reddish area) in a taro patch.

## Indicator B7: Inundation visible on aerial imagery

**Category:** Primary

**General Description:** One or more recent aerial photographs or satellite images show the site to be inundated (Figure 37).

**Cautions and User Notes:** Care must be used in applying this indicator because surface water may be present on a non-wetland site immediately after a heavy rain or during periods of unusually high precipitation, runoff, tides, or stream flows. See Chapter 5 for procedures to evaluate the normality of precipitation prior to the photo date. Surface water may be absent from a wetland during the normal dry season or during extended periods of drought. Even under normal rainfall conditions, some wetlands do not become inundated or saturated every year (i.e., wetlands are inundated or saturated at least 5 out of 10 years, or 50 percent or higher probability). If available, it is recommended that multiple years of photography be evaluated. If 5 or more years of aerial photos are available, the procedure described in the Hydrology Tools for Wetland Determination (USDA Natural Resources Conservation Service 1997, section 650.1903) is recommended (see Chapter 5, section on Wetlands that Periodically Lack Indicators of Wetland Hydrology, for additional information).

**Figure 37.** Aerial photograph showing inundation within an emergent wetland in the Ko‘olau Mountains on O‘ahu.

## Indicator B9: Water-stained leaves

**Category:** Primary

**General Description:** Water-stained leaves are fallen or recumbent dead leaves that have turned grayish or blackish in color due to inundation for long periods.

**Cautions and User Notes:** In this region, water-stained leaves are often found in coastal wetlands, depressional wetlands, and along streams in shrub-dominated or forested habitats; however, they also occur in herbaceous communities. Staining generally occurs in leaves that are in contact with the soil surface while inundated for long periods. Water-stained leaves maintain their blackish or grayish colors when dry (Figures 38 and 39). They should contrast strongly with fallen leaves in nearby non-wetland landscape positions. Use caution on windward slopes where frequent rainfall and wet surface conditions may produce water-stained leaves in areas that normally do not pond or flood. In these areas, check for additional evidence of wetland hydrology, such as indicators of soil saturation.

**Figure 38.** Water-stained leaves in a coastal wetland.

**Figure 39.** Water-stained hau (*Hibiscus tiliaceus*) leaves at Kawainui Marsh, O‘ahu.

## Indicator B13: Aquatic fauna

**Category:** Primary

**General Description:** Presence of live individuals, diapausing insect eggs or crustacean cysts, or dead remains of aquatic fauna, such as sponges, bivalves, aquatic snails, aquatic insects, ostracods, shrimp, other crustaceans, tadpoles, or fish, either on the soil surface or clinging to plants or other emergent objects.

**Cautions and User Notes:** Examples of dead remains include clam shells, chitinous exoskeletons (e.g., dragonfly nymphs), insect head capsules, aquatic snail shells, and skins or skeletons of aquatic amphibians or fish (Figures 40, 41, and 42). Aquatic fauna or their remains should be reasonably abundant; one or two individuals are not sufficient. Use caution in areas where faunal remains may have been transported by high winds, unusually high water, or other animals into non-wetland areas. Shells and exoskeletons are resistant to tillage but may be moved by equipment beyond the boundaries of the wetland. They may also persist in the soil for years after dewatering. Be careful not to mistake land snails for aquatic species.

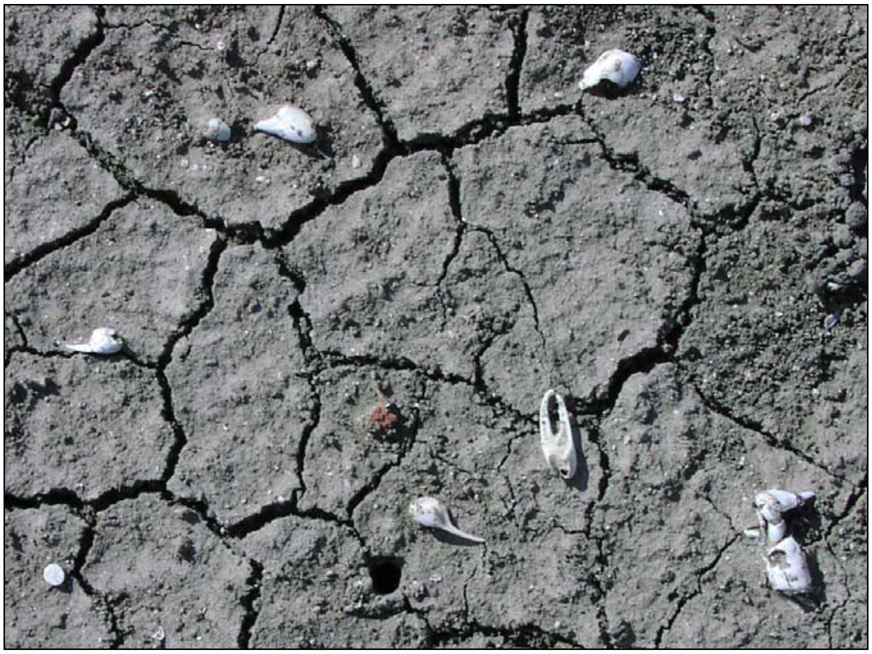

**Figure 40.** Remains of fiddler crabs (*Uca* spp.) in a coastal wetland.

**Figure 41.** Aquatic snails in a coastal wetland.

**Figure 42.** Dead fish in a dried pool near Wai‘anae, O‘ahu.

### Indicator B17: Tilapia nests

**Category:** Primary

**General Description:** Presence of shallow, bowl-like depressions formed in shallow water by nesting tilapia.

**Cautions and User Notes:** The name tilapia is applied to a number of different fish species in the family Cichlidae that were introduced to the Hawaiian Islands and other Pacific islands from Africa and Asia. They inhabit a wide range of freshwater, brackish, and saltwater habitats, including streams, reservoirs, coastal lagoons, and sheltered bays, and are raised for aquaculture. Male tilapia excavate shallow, bowl-like nests in soft sediments to which they entice females for breeding (Neil 1966, Popma and Masser 1999). The nests are typically 8 to 20 in. (20 to 50 cm) or more in diameter (Figures 43 and 44) and often occur in clusters along shorelines. They persist and are visible after the surface water recedes. Tilapia are known to occur throughout the region except in the northwestern Hawaiian Islands. Their range in American Samoa is limited to a few locations, including the Aunu‘u Crater wetland.

**Figure 43.** Cluster of tilapia nests in a shallow pond.

**Figure 44.** Tilapia nest along the fringe of a drying pool near Wai‘anae, O‘ahu.

## Indicator B6: Surface soil cracks

**Category:** Secondary

**General Description:** Surface soil cracks consist of shallow cracks that form when fine-grained mineral or organic sediments dry and shrink, often creating a network of cracks or small polygons (Figure 45).

**Cautions and User Notes:** Surface soil cracks are often seen in recently deposited, fine sediments and in concave landscape positions where water has ponded long enough to destroy surface soil structure, such as in coastal flats, depressions, lake fringes, and floodplains. Use caution, however, as they may also occur in temporary ponds and puddles in non-wetlands and in areas that have been effectively drained; these areas are easily distinguished by the absence of indicators of hydric soil and/or hydrophytic vegetation. This indicator does not include deep cracks due to shrink-swell action in clay soils (e.g., Vertisols).

**Figure 45.** Surface soil cracks (and drift material) in a coastal wetland.

### Indicator B8: Sparsely vegetated concave surface

**Category:** Secondary

**General Description:** On concave land surfaces (e.g., depressions and swales) and associated fringe areas, the ground surface is either unvegetated or sparsely vegetated (less than 5 percent ground cover) due to long-duration ponding (Figure 46).

**Cautions and User Notes:** Ponding of water for long periods can limit the establishment and growth of ground-layer vegetation. Sparsely vegetated concave surfaces should contrast with vegetated slopes and convex surfaces in the same area. A woody overstory of trees or shrubs may or may not be present. Examples in the region include, but are not limited to, depressional areas behind beach berms and roads in coastal areas, concave positions on floodplains, and seasonally ponded depressions in flat landscapes. They also may be associated with saline conditions in shallow depressions on coastal flats.

**Figure 46.** A sparsely vegetated depression in *Batis*-dominated coastal flats, northern O‘ahu.

### Indicator B10: Drainage patterns

**Category:** Secondary

**General Description:** This indicator consists of flow patterns visible on the soil surface or eroded into the soil, low vegetation bent over in the direction of flow, absence of leaf litter or small woody debris due to flowing water, and similar evidence that water flowed across the ground surface.

**Cautions and User Notes:** Drainage patterns are usually seen in areas where water flows broadly over the surface and is not confined to a channel, such as in areas adjacent to streams, in seeps, slope wetlands, vegetated swales, and tidal flats (Figure 47). Use caution in areas subject to high winds or affected by recent extreme or unusual flooding events.

**Figure 47.** Vegetation bent over in the direction of water flow across a stream terrace.

## Group C – Evidence of Current or Recent Soil Saturation

### Indicator C1: Hydrogen sulfide odor

**Category:** Primary

**General Description:** A hydrogen sulfide (rotten egg) odor within 12 in. (30 cm) of the soil surface.

**Cautions and User Notes:** Hydrogen sulfide is a gas produced by soil microbes in response to prolonged saturation in soils where oxygen, nitrogen, manganese, and iron have been largely reduced and there is a source of sulfur. For hydrogen sulfide to be detectable, the soil must be saturated at the time of sampling and must have been saturated long enough to become highly reduced. These soils are often permanently saturated and anaerobic at or near the surface. To apply this indicator, dig the soil pit no deeper than 12 in. to avoid release of hydrogen sulfide from deeper in the profile. Hydrogen sulfide odor serves as both an indicator of hydric soil and wetland hydrology. This one observation proves that the soil meets the definition of a hydric soil (i.e., anaerobic in the upper part), plus has an ongoing wetland hydrologic regime. Often these soils have a high water table (wetland hydrology indicator A2), but the hydrogen sulfide odor provides further proof that the soil has been saturated for a long period of time. This indicator is common throughout the region in permanently saturated or inundated tidal areas and rare in other environmental settings.

## Indicator C3: Oxidized rhizospheres along living roots

**Category:** Primary

**General Description:** Presence of a layer containing 2 percent or more iron-oxide coatings or plaques on the surfaces of living roots and/or iron-oxide coatings or linings on soil pores immediately surrounding living roots within 12 in. (30 cm) of the soil surface (Figures 48 and 49).

**Cautions and User Notes:** Oxidized rhizospheres are the result of oxygen leakage from living roots into the surrounding anoxic soil, causing oxidation of ferrous iron present in the soil solution. They are evidence of saturated and reduced soil conditions during the plant's lifetime. Iron concentrations or plaques may form on the immediate root surface or may coat the soil pore adjacent to the root. In either case, the oxidized iron must be associated with living roots to indicate contemporary wet conditions and to distinguish these features from other pore linings. Care must be taken to distinguish iron-oxide coatings from organic matter associated with plant roots. Viewing with a hand lens may help to distinguish mineral from organic material and to identify oxidized rhizospheres along fine roots and root hairs. Iron coatings sometimes show concentric layers in cross section and may transfer iron stains to the fingers when rubbed. Note the location and abundance of oxidized rhizospheres in the soil profile description or remarks section of the data form. There is no minimum thickness requirement for the layer containing oxidized rhizospheres. Oxidized rhizospheres must occupy at least 2 percent of the volume of the layer.

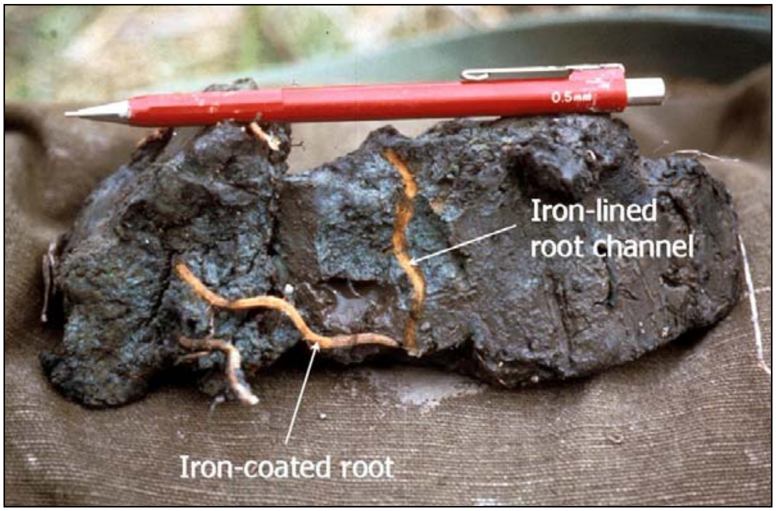

**Figure 48.** Iron-oxide plaque (orange coating) on a living root. Iron also coats the channel or pore from which the root was removed.

**Figure 49.** Soil with oxidized rhizospheres surrounding many fine roots.

## Indicator C4: Presence of reduced iron

**Category:** Primary

**General Description:** Presence of a layer containing reduced (ferrous) iron in the upper 12 in. (30 cm) of the soil profile, as indicated by a ferrous iron test or by the presence of a soil that changes color upon exposure to the air.

**Cautions and User Notes:** The reduction of iron occurs in soils that have been saturated long enough to become anaerobic and chemically reduced. Ferrous iron is converted to oxidized forms when saturation ends and the soil reverts to an aerobic state. Thus, the presence of ferrous iron indicates that the soil is saturated and anaerobic at the time of sampling, and has been saturated for an extended period. The presence of ferrous iron can be verified with alpha, alpha-dipyridyl dye (Figure 50) or by observing a soil that changes color upon exposure to air (i.e., reduced matrix). A positive reaction to alpha, alpha-dipyridyl dye should occur over more than 50 percent of the soil layer in question. The dye does not react when wetlands are dry; therefore, a negative test result is not evidence that the soil is not reduced at other times of year. Soil samples should be tested or examined immediately after opening the soil pit because ferrous iron may oxidize and colors change soon after the sample is exposed to the air. Avoid areas of the soil that may have been in contact with iron digging tools. Soils that contain little weatherable iron may not react even when saturated and reduced. There are no minimum thickness requirements or initial color requirements for the soil layer in question.

**Figure 50.** When alpha, alpha-dipyridyl dye is applied to a soil containing reduced iron, a positive reaction is indicated by a pink or red coloration to the treated area.

## Indicator C6:  Recent iron reduction in tilled soils

**Category:** Primary

**General Description:** Presence of a layer containing 2 percent or more redox concentrations as pore linings or soft masses in the tilled surface layer of soils cultivated within the last two years. The layer containing redox concentrations must be within the tilled zone or within 12 in. (30 cm) of the soil surface, whichever is shallower.

**Cautions and User Notes:** Cultivation breaks up or destroys redox features in the plow zone. The presence of continuous and unbroken redox features indicates that the soil was saturated and reduced since the last episode of cultivation (Figure 51). Redox features often form around organic material, such as crop residue, incorporated into the tilled soil. Use caution with older features that may be broken up but not destroyed by tillage. The indicator is most reliable in areas that are cultivated regularly, so that soil aggregates and older redox features are more likely to be broken up. If not obvious, information about the timing of last cultivation may be available from the land owner. A plow zone of 6 to 8 in. (15-20 cm) depth is typical but may extend deeper. There is no minimum thickness requirement for the layer containing redox concentrations.

**Figure 51.** Redox concentrations in the tilled surface layer of a recently cultivated soil.

## Indicator C7: Thin muck surface

**Category:** Primary

**General Description:** This indicator consists of a layer of muck 1 in. (2.5 cm) or less thick on the soil surface.

**Cautions and User Notes:** Muck is highly decomposed organic material that has accumulated due to wetness (see the Concepts section of Chapter 3 for guidance on identifying muck). In this region, muck accumulates only where soils are saturated to the surface for long periods each year. Thick muck layers can persist for years after wetland hydrology is effectively removed; therefore, a muck layer greater than 1 in. (2.5 cm) thick does not qualify for this indicator. However, thin muck surfaces disappear quickly or become incorporated into mineral horizons when wetland hydrology is withdrawn. Therefore, the presence of a thin muck layer on the soil surface indicates an active wetland hydrologic regime. This indicator does not include folistic surface layers, which are not caused by wetness. Folistic material that is highly decomposed generally exhibits moderate to strong subangular blocky structure (i.e., it breaks into natural aggregates that are angular to rounded in shape). In muck, the organic material is more homogeneous, without obvious aggregates or structural units.

### Indicator C10: Fiddler crab burrows

**Category:** Primary

**General Description:** On coastal flats and shorelines, the presence of fiddler crab (*Uca* spp.) burrows, as indicated by openings in soft soil or sand approximately 0.5 to 1 in. (1 to 2 cm) in diameter, often associated with excavated balls of mud or sand (Figure 52).

**Applicable Subregion:** Territory of Guam, Commonwealth of the Northern Mariana Islands, and Territory of American Samoa

**Cautions and User Notes:** *Uca* is a burrowing crab of the intertidal zone in saltmarshes, tidal flats, mangrove swamps, and their fringes. Two species, *U. crassipes* and *U. vocans*, are known to inhabit Guam and the Mariana island chain; *U. crassipes* and other species also inhabit American Samoa. Fiddler crabs are not known to occur in the Hawaiian Islands. Fiddler crabs dig their burrows in intertidal wetlands and in adjacent areas where the water table is generally within 12 in. (30 cm) of the surface (Shinn 1968, Warner 1969, Thurman 1984, Grimes et al. 1989). They forage in the intertidal zone at low tide and seldom move far from their protective burrows.

**Figure 52.** Fiddler crab burrows and excavated soil.

## Indicator C2: Dry-season water table

**Category:** Secondary

**General Description:** Visual observation of the water table between 12 and 24 in. (30 and 60 cm) below the surface during the normal dry season or during a drier-than-normal year.

**Cautions and User Notes:** Due to normal seasonal fluctuations, water tables in wetlands often drop below 12 in. during the summer dry season. A water table between 12 and 24 in. during the dry season, or during an unusually dry year, indicates a normal wet-season water table within 12 in. of the surface. Sufficient time must be allowed for water to infiltrate into a newly dug hole and to stabilize at the water-table level. The required time will vary depending upon soil texture. In some cases, the water table can be determined by examining the wall of the soil pit and identifying the upper level at which water is seeping into the pit. For an accurate determination of the water-table level, the soil pit, auger hole, or well should not penetrate any restrictive soil layer capable of perching water near the surface. Water tables in wetlands often drop well below 24 in. during dry periods. Therefore, a dry-season water table below 24 in. does not necessarily indicate a lack of wetland hydrology. Water tables are a function of both recent and long-term precipitation; use caution in interpreting this indicator immediately following an unusually heavy rainfall event. See Chapter 5 (section on Wetlands that Periodically Lack Indicators of Wetland Hydrology) to determine typical dry-season dates and for procedures to evaluate normal rainfall.

## Indicator C5: Salt deposits

**Category:** Secondary

**General Description:** Salt deposits are whitish or brownish deposits of salts that accumulate on the ground surface through the evaporation of saline surface water or the capillary action of saline groundwater.

**Cautions and User Notes:** Salt deposits are often seen on coastal flats and in depressions where saline surface water has evaporated or capillary rise has brought salts to the surface from a shallow water table (Figures 53 and 54). Use caution in disturbed areas where salt water or brine may have been deposited on the surface through human activities.

**Figure 53.** Salt deposits (light-colored areas) on coastal flats near Wai‘anae, O‘ahu.

**Figure 54.** Salt deposit at Kanaha Ponds, Maui.

## Group D – Evidence from Other Site Conditions or Data

### Indicator D1: Stunted or stressed plants

**Category:** Secondary

**General Description:** This indicator is present if individuals of the same species growing in the potential wetland are clearly of smaller stature, less vigorous, or stressed compared with individuals growing in nearby non-wetland situations.

**Cautions and User Notes:** Some plant species can become established and grow in both wetlands and non-wetlands but may exhibit obvious stunting, yellowing, or stress in wet situations. This indicator is applicable to natural plant communities as well as agricultural crops and other introduced or planted vegetation. For this indicator to be present, a majority of individuals in the stand must be stunted or stressed. The comparison with individuals in non-wetland situations may be accomplished over a broad area and is not limited to the project site. Use caution in areas where stunting of plants on non-wetland sites may be caused by low soil fertility, excessively drained soils, shallow bedrock, persistent high winds, uneven application of agricultural chemicals, salinity, or other factors. This indicator is often seen in wet ʻōhiʻa forests and montane bogs (Figure 55), and in agricultural crops and other introduced or planted species.

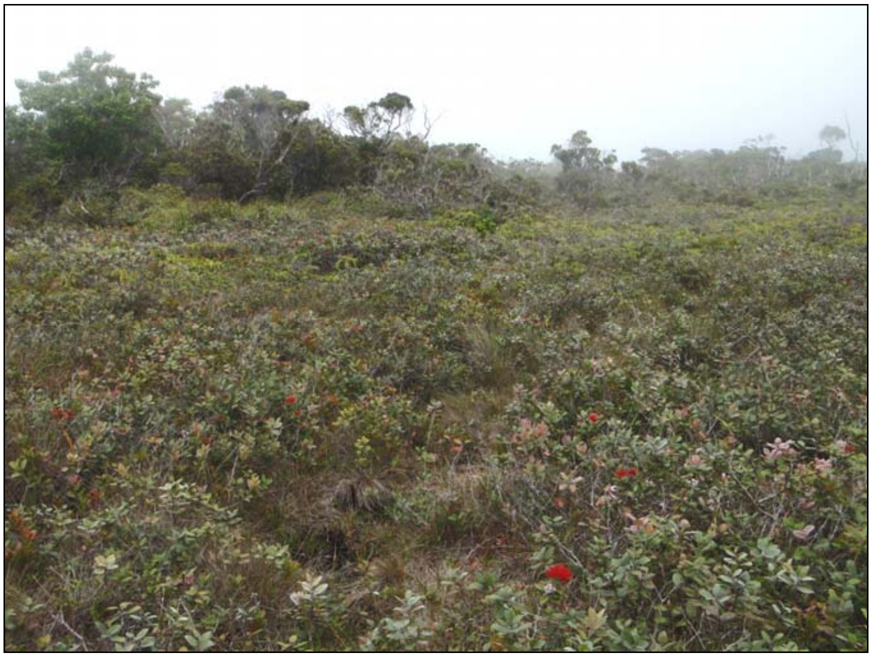

**Figure 55.** Stunted ʻōhiʻa in Lehua Bog, Kauaʻi.

## Indicator D2: Geomorphic position

**Category:** Secondary

**General Description:** This indicator is present if the area in question is located on a tidal flat, in a localized depression, in the low area behind a beach berm (Figure 56), within a floodplain or drainageway, at the toe of a slope, on the low-elevation fringe of a pond or other water body, or in an area where groundwater discharges.

**Cautions and User Notes:** Excess water from precipitation naturally accumulates in certain geomorphic positions in the landscape, particularly in low-lying areas such as depressions, drainages, toe slopes, and fringes of estuaries, oceans, lakes, and other water bodies. In regions with abundant rainfall, these geomorphic positions often, but not always, exhibit wetland hydrology. This indicator does not include concave positions on rapidly permeable soils (e.g., floodplains with sand and gravel substrates, coastal sand dunes) unless the water table is periodically near the surface.

**Figure 56.** Low areas behind coastal beach berms often exhibit wetland hydrology.

## Indicator D3: Shallow aquitard

**Category:** Secondary

**General Description:** This indicator occurs in and around the margins of depressions, in flat landscapes, and on mountain slopes with ironstone or cemented ash layers, and consists of the presence of an aquitard within the soil profile that is potentially capable of perching water within 12 in. (30 cm) of the surface.

**Cautions and User Notes:** An aquitard is a relatively impermeable soil layer or bedrock that slows the downward infiltration of water and can produce a perched water table, generally in flat or depressional landforms but occasionally on slopes. In some cases, the aquitard may be at the surface (e.g., in clay soils) and cause water to pond on the surface. Potential aquitards in the region include shallow bedrock, cemented layers (e.g., beach rock, iron stone), spodic horizons, clay layers, and saprolite (i.e., weathered bedrock) (Figure 57). An aquitard can often be identified by the limited root penetration through the layer and/or the presence of redoximorphic features in the layer(s) above the aquitard. Use caution in areas with functioning drainage systems that are capable of removing perched water quickly.

**Figure 57.** Contact between surface soil and underlying saprolite for a soil on Guam. Saprolite can be a physical barrier to roots and often acts as an aquitard, perching water above it.

## Indicator D5: FAC-neutral test

**Category:** Secondary

**General Description:** The plant community passes the FAC-neutral test.

**Cautions and User Notes:** The FAC-neutral test is performed by compiling a list of dominant plant species across all strata in the community, and dropping from the list any species with a Facultative (FAC+, FAC, or FAC–) indicator status. The FAC-neutral test is met if more than 50 percent of the remaining dominant species are rated FACW and/or OBL. This indicator may also be used in communities that contain no FAC dominants. If there are an equal number of dominants that are OBL and FACW versus FACU and UPL, or if all dominants are FAC, non-dominant species should be considered.

# 5 Difficult Wetland Situations in the Hawaii and Pacific Islands Region

## Introduction

Some wetlands can be difficult to identify because wetland indicators may be missing due to natural processes or recent disturbances. This chapter provides guidance for making wetland determinations in difficult-to-identify wetland situations in the Hawaii and Pacific Islands Region. It includes regional examples of problem area wetlands and atypical situations as defined in the Corps Manual, as well as other situations that can make wetland delineation more challenging. Problem area wetlands are naturally occurring wetland types that lack indicators of hydrophytic vegetation, hydric soil, or wetland hydrology periodically due to normal seasonal or annual variability, or permanently due to the nature of the soils or plant species on the site. Atypical situations are wetlands in which vegetation, soil, or hydrology indicators are absent due to recent human activities or natural events. In addition, this chapter addresses certain procedural problems (e.g., wetland/non-wetland mosaics) that can make wetland determinations in the region difficult or confusing. The chapter is organized into the following sections:

- Lands Used for Agriculture
- Problematic Hydrophytic Vegetation
- Problematic Hydric Soils
- Wetlands that Periodically Lack Indicators of Wetland Hydrology
- Wetland/Non-Wetland Mosaics

The list of difficult wetland situations presented in this chapter is not intended to be exhaustive and other problematic situations may exist in the region. See the Corps Manual for general guidance. Furthermore, more than one wetland factor (i.e., vegetation, soil, and/or hydrology) may be disturbed or problematic on a given site. In general, *wetland determinations on difficult or problematic sites must be based on the best information available to the field inspector, interpreted in light of his or her professional experience and knowledge of the ecology of wetlands in the region*.

## Lands Used for Agriculture

Agriculture is an important land use in the region and can present challenges to wetland identification and delineation. Wetlands used for agriculture often lack a natural plant community and may be planted to crops, pasture species, or desirable tree species and may be altered by mowing, grazing, herbicide use, or other management practices. Soils may be disturbed by cultivation, land clearing, grading, or bedding, at least in the surface layers, and hydrology may or may not be manipulated. Some areas that are used for agriculture still retain their natural wetland hydrology. In other areas, historic wetlands have been effectively drained and no longer meet wetland hydrology standards. Wetland indicators may still be present in these areas, making it difficult to distinguish current wetlands from those that have been effectively drained.

Agricultural drainage systems use ditches, subsurface drainage lines or “tiles,” and water-control structures to manipulate the water table and improve conditions for crops or other desired species. A freely flowing ditch or drainage line depresses the water table within a certain lateral distance or zone of influence (Figure 58). The effectiveness of drainage in an area depends in part on soil characteristics, the timing and amount of rainfall, and the depth and spacing of ditches or drains. Wetland determinations on current and former agricultural lands must consider whether a drainage system is present, how it is designed to function, and whether it is effective in removing wetland hydrology from the area.

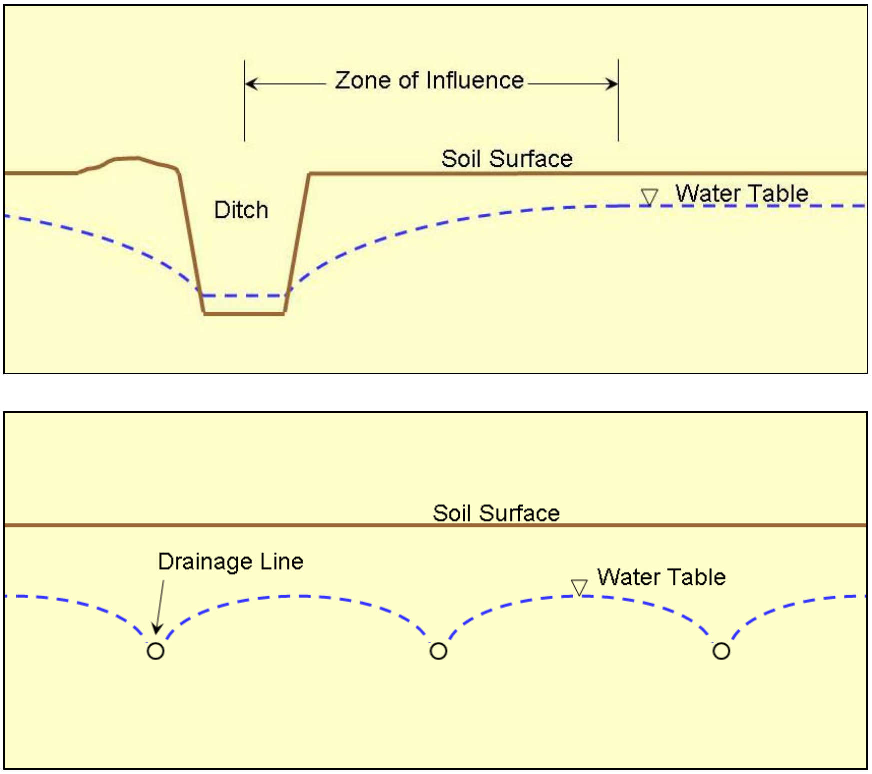

**Figure 58.** Effects of ditches (upper) and parallel subsurface drainage lines (lower) on the water table.

In the Hawaiian Islands, agricultural drainage systems in many areas have been abandoned and wetland hydrology has returned to some of these areas. On the coastal plain of Kaua‘i, for example, some wetlands have become reestablished after having been drained in the past for sugar cane production.

A number of information sources and tools are listed below to help determine whether wetlands are present on lands where vegetation, soils, hydrology, or a combination of these factors have been manipulated. Some of these options are discussed in more detail later in this chapter under the appropriate section headings.

1. **Vegetation** – The goal is to determine the plant community that would occupy the site under normal circumstances, if the vegetation were not cleared or manipulated.

    a. Examine the vegetation on an undisturbed reference area with soils, hydrology, landscape position, and other conditions similar to those on the site.

   b. In recently cleared areas, examine the site for piles of cleared vegetation and for buried vegetation that may be identifiable.
   c. Examine the site for volunteer vegetation that emerges between cultivations, plantings, mowings, or other treatments.
   d. If the conversion to agriculture was recent and the hydrology of the site was not manipulated, examine pre-disturbance aerial photography, NWI maps, land cover maps for the Hawaiian Islands available at the National Oceanic and Atmospheric Administration's Coastal Services Center (http://www.csc.noaa.gov/crs/lca/hawaii.html), botanical surveys, environmental assessments, and other sources for information concerning the previous vegetation on the site.
   e. Cease the clearing, cultivation, or manipulation of the site for at least one wet season and examine the plant community that develops.

2. **Soils** – Tilling of agricultural land mixes the surface layer(s) of the soil and may cause compaction below the tilled zone (i.e., a "plow pan") due to the weight and repeated passage of farm machinery. Nevertheless, a standard soil profile description and examination for hydric soil indicators are often sufficient to determine whether hydric soils are present. In areas where soils have been deeply tilled or otherwise disturbed, options and information sources for making hydric soil determinations include the following:

   a. Examine NRCS soil survey maps and the local hydric soils list for the likely presence of hydric soils on the site.
   b. Examine the soils on an undisturbed reference area with landscape position, parent materials, and hydrology similar to those on the site.
   c. Use alpha, alpha-dipyridyl dye to check for the presence of reduced iron during the normal wet portion of the year, or note whether the soil changes color upon exposure to the air.
   d. Monitor the hydrology of the site in relation to the appropriate wetland hydrology or hydric soils technical standard.

3. **Hydrology** – The goal is to determine whether wetland hydrology is present on agricultural lands under normal circumstances, as defined in the Corps Manual and subsequent guidance. These sites may or may not have been hydrologically manipulated.

   a. Examine the site for existing indicators of wetland hydrology. If the natural hydrology of the site has been permanently altered, discount any indicators known to have been produced before the alteration (e.g., relict water marks or drift lines).
   b. Examine five or more years of aerial photographs for wetness signatures listed in Part 513.30 of the National Food Security Act Manual (USDA Natural Resources Conservation Service 1994). Use the procedure given by the USDA Natural Resources Conservation Service (1997) to determine whether wetland hydrology is present.
   c. Estimate the effects of ditches and subsurface drainage systems using scope-and-effect equations (USDA Natural Resources Conservation Service 1997). A web application to analyze data using various models is available at http://www.wli.nrcs.usda.gov/technical/web_tool/tools_java.html. Scope-and-effect equations are approximations only and may not reflect actual field conditions. Their results should be verified by comparison with other techniques for evaluating drainage and should not overrule onsite evidence of wetland hydrology.

  d. Use hydrologic models (e.g., runoff, surface water, and groundwater models) to determine whether wetland hydrology is present (USDA Natural Resources Conservation Service 1997).
  e. Monitor the hydrology of the site in relation to the appropriate wetland hydrology technical standard (U. S. Army Corps of Engineers 2005).

# Problematic Hydrophytic Vegetation

## Description of the Problem

Many factors affect the structure and composition of plant communities in the Hawaii and Pacific Islands Region, including climatic variability, tropical storms, agricultural use, and other human land-use practices. As a result, some wetlands may exhibit indicators of hydric soil and wetland hydrology but lack any of the hydrophytic vegetation indicators presented in Chapter 2, at least at certain times. To identify and delineate these wetlands may require special sampling procedures or additional analysis of factors affecting the site. To the extent possible, the hydrophytic vegetation decision should be based on the plant community that is normally present during the wet season in a normal rainfall year. The following procedure addresses several examples of problematic vegetation situations in the region.

## Procedure

Problematic hydrophytic vegetation can be identified using a combination of observations made in the field and/or supplemental information from the scientific literature and other sources. These procedures should be applied only where indicators of hydric soil and wetland hydrology are present, unless one or both of these factors is also problematic, but no indicators of hydrophytic vegetation are evident. The following procedures are recommended:

1. Verify that at least one indicator of hydric soil and one primary or two secondary indicators of wetland hydrology are present. If indicators of either hydric soil or wetland hydrology are absent, the area is likely non-wetland unless soil and/or hydrology are also disturbed or problematic. If indicators of hydric soil and wetland hydrology are present (or are absent due to disturbance or other problem situations), proceed to step 2.

2. Verify that the area is in a landscape position that is likely to collect or concentrate water. Appropriate settings include the following. If the landscape setting is appropriate, proceed to step 3.

   a. Concave surface (e.g., depression or swale)
   b. Floodplain
   c. Level or nearly level area (e.g., 0- to 3-percent slope)
   d. Toe slope (Figure 7) or an area of convergent slopes (Figure 6)
   e. Fringe of another wetland or water body
   f. Area with a restrictive soil layer or aquitard within 24 in. (60 cm) of the surface
   g. Area where groundwater discharges (e.g., a seep)
   h. Other (explain in field notes why this area is likely to be inundated or saturated for long periods)

3. Use one or more of the approaches described in step 4 (Specific Problematic Vegetation Situations below) or step 5 (General Approaches to Problematic Hydrophytic Vegetation on page 98) to determine whether the vegetation is hydrophytic. In the remarks section of the data form or in the delineation report, explain the rationale for concluding that the plant community is hydrophytic even though indicators of hydrophytic vegetation described in Chapter 2 were not observed.

4. Specific Problematic Vegetation Situations

   a. *Seasonal shifts in vegetation.* As mentioned in Chapter 2, the species composition of some wetland plant communities in the region can change from the wet season to the dry season. Wetland types in the region that are influenced by these shifts include ephemeral pools, other depressional wetlands, salt pans, seeps, and springs. During the dry season, when surface water dries up and water tables drop, these wetlands may be invaded and dominated by FACU and UPL grasses or annual plant species, such as rough cocklebur (*Xanthium strumarium*) or golden crownbeard (*Verbesina encelioides*). Also, marshes that are dominated by Chinese water chestnut (*Eleocharis dulcis*) or spikerush (*E. ochrostachys*) can lose above-ground vegetative parts during the dry season and the marsh can appear barren or devoid of vegetation. Therefore, the lack of hydrophytic vegetation during the dry season should not immediately eliminate a site from consideration as a wetland, because the site may have been dominated by wetland species at other times of year. A site qualifies for further consideration if the plant community at the time of sampling does not exhibit hydrophytic vegetation indicators, but indicators of hydric soil and wetland hydrology are present or known to be disturbed or problematic. The following options are recommended in these situations:

      1) If possible, return to the site during the normal wet season and re-examine the site for indicators of hydrophytic vegetation.

      2) Examine the site for identifiable plant remains, either alive or dead, or other evidence that the plant community that was present during the normal wet season was hydrophytic.

   b. *Managed plant communities.* Plant communities throughout the region have been altered and are managed to meet human goals. Examples include clearing of woody vegetation in pastures and croplands, periodic disking or plowing, planting of native and non-native species (including cultivars or planted species that have escaped and become established on other sites), applying silvicultural treatments, and using herbicides. These actions can result in elimination of certain species and their replacement by other species, changes in abundance of certain plants, and shifts in dominant species, possibly influencing a hydrophytic vegetation determination. The following options are recommended if the natural vegetation has been altered through management to such an extent that a hydrophytic vegetation determination is not possible or would be unreliable:

      (1) Examine the vegetation on a nearby, unmanaged reference site having similar soils and hydrologic conditions. Assume that the same plant community would exist on the managed site in the absence of human alteration.

(2) To determine whether managed plant communities would support hydrophytic vegetation, omit planted species when evaluating hydrophytic vegetation indicators.

(3) For recently cleared or tilled areas (not planted or seeded), leave representative areas unmanaged for at least one year with normal rainfall and reevaluate the vegetation.

(4) Use offsite data sources such as aerial photography, NWI maps, and interviews with the land owner and other persons familiar with the site or area to determine what plant community was present on the site before the management occurred.

(5) If the unmanaged vegetation condition cannot be determined, make the wetland determination based on indicators of hydric soil and wetland hydrology.

5. General Approaches to Problematic Hydrophytic Vegetation. The following general procedures are provided to identify hydrophytic vegetation in difficult situations not necessarily associated with specific vegetation types or management practices, including wetlands dominated by FACU, NI, NO, or unlisted species that are functioning as hydrophytes. Examples of FACU or unlisted species that sometimes dominate wetlands in the region include, but are not limited to, wedelia (*Sphagneticola trilobata = Wedelia trilobata*) and albizia (*Albizia lebbeck*). The following recommended procedures should be applied only where indicators of hydric soil and wetland hydrology are present (or are absent due to disturbance or other problem situations) but indicators of hydrophytic vegetation are not evident.

a. *Sites dominated by certain FACU trees.* Certain FACU tree species are known to occur in and dominate wetlands in the region, particularly on disturbed sites, and may cause the plant community to fail to meet any of the hydrophytic vegetation indicators described in Chapter 2. These long-lived plant species become established during the dry season or in drier-than-normal years and, once established, are able to persist indefinitely despite seasonal soil saturation. The introduced kiawe (*Prosopis pallida*), ironwood (*Casuarina equisetifolia*), and coconut palm (*Cocos nucifera*) are the species most likely to cause problems with wetland identification. If the potential wetland area appears to lack hydrophytic vegetation due to the presence of one or more of these FACU species, use the following procedure to make the hydrophytic vegetation determination:

(1) At each sampling point in the potential wetland, drop any FACU species listed above from the vegetation data, and compile the species list and coverage data for the remaining species in the community.

(2) Reevaluate the remaining vegetation using hydrophytic vegetation indicators 2 (Dominance Test) and/or 3 (Prevalence Index). If either indicator is met, then the vegetation is hydrophytic.

b. *Direct hydrologic observations.* Verify that the plant community occurs in an area subject to prolonged inundation or soil saturation. This can be done by visiting the site at 2- to 3-day intervals during the portion of the year when surface water is most likely to be present or water tables are normally high. Hydrophytic vegetation is considered to be present, and the site is a wetland, if surface water is present and/or the water table is 12 in. (30 cm) or less from the surface for 14 or more consecutive days during a period when antecedent precipitation has been normal or drier than normal. If necessary, microtopographic highs and lows should be evaluated separately. The normality of the current year's rainfall must be considered in interpreting field results, as well as the likelihood that wet conditions will occur on the site at least every other year (for more information, see the section on "Wetlands that Periodically Lack Indicators of Wetland Hydrology" in this chapter).

c. *Reference sites.* If indicators of hydric soil and wetland hydrology are present, the site may be considered to be a wetland if the landscape setting, topography, soils, and vegetation are substantially the same as those on nearby wetland reference areas. Hydrologic characteristics of wetland reference areas should be documented through long-term monitoring or by application of the procedure described in item *5b* above. Reference sites should be minimally disturbed and provide long-term access. Soils, vegetation, and hydrologic conditions should be thoroughly documented and the data kept on file in the district or field office.

d. *Technical literature.* Published and unpublished scientific literature may be used to support a decision to treat specific FACU species or species with no assigned indicator status (e.g., NI, NO, or unlisted) as hydrophytes or certain plant communities as hydrophytic. Preferably, this literature should discuss the species' natural distribution along the moisture gradient, its capabilities and adaptations for life in wetlands, wetland types in which it is typically found, or other wetland species with which it is commonly associated.

# Problematic Hydric Soils

## Description of the Problem

### *Soils with faint or no indicators*

Some soils that meet the hydric soil definition may not exhibit any of the indicators presented in Chapter 3. These problematic hydric soils exist for a number of reasons and require additional information, such as landscape position, presence or absence of restrictive soil layers, or information about hydrology, to identify properly. This section describes several soil situations in the Hawaii and Pacific Islands Region that are considered to be hydric if additional requirements are met. In some cases, these hydric soils may appear to be non-hydric due to the color of the parent material from which the soils developed. In others, the lack of hydric soil indicators is due to conditions that inhibit the development of redoximorphic features despite prolonged soil saturation and anoxia. In addition, recently developed wetlands may lack hydric soil indicators because insufficient time has passed for their development. Examples of problematic hydric soils in the region include, but are not limited to, the following.

1. **Moderately to Very Strongly Alkaline Soils.** The formation of redox concentrations and depletions requires that soluble iron, manganese, and organic matter be present in the soil. In a neutral to acidic soil, iron and manganese readily enter into solution as reduction occurs and then precipitate in the form of redox concentrations as the soil becomes oxidized. Identifiable iron or manganese features do not form readily in

saturated soils with high pH. High pH (7.9 or higher) can be caused by many factors. In the Hawaii and Pacific Islands Region, salt content is a common cause of high soil pH. Carbonate sands, which are common in the region, also have high pH. If the pH is high, indicators of hydrophytic vegetation and wetland hydrology are present, and landscape position is consistent with wetlands in the area, then the soil may be hydric even in the absence of a recognized hydric soil indicator. In the absence of an approved indicator, thoroughly document soil conditions, including pH, in addition to the rationale for identifying the soil as hydric (e.g., landscape position, vegetation, evidence of hydrology, etc.). The concept of high pH includes the USDA terms Moderately Alkaline, Strongly Alkaline, and Very Strongly Alkaline (USDA Natural Resources Conservation Service 2002).

2. **Fluvial Sediments within Floodplains.** These soils commonly occur on vegetated bars within the active channel of rivers and streams, and often occur above the bankfull stage. In some cases, these soils lack hydric soil indicators due to yearly or seasonal deposition of new soil material, low iron or manganese content, and/or low organic-matter content. Redox concentrations can sometimes be found on the bottoms of coarse fragments or between stratifications where organic matter gets buried and should be examined closely to see if they satisfy an indicator.

3. **Recently Developed Wetlands.** Recently developed wetlands include mitigation sites, wetland management areas (e.g., for waterfowl), other wetlands intentionally or unintentionally produced by human activities, and naturally occurring wetlands that have not been in place long enough to develop hydric soil indicators.

4. **Seasonally Ponded Soils.** Seasonally ponded, depressional wetlands occur throughout the Hawaii and Pacific Islands Region. Most are perched systems, with water ponding above a restrictive soil layer, such as a hardpan, bedrock, or clay layer that is at or near the surface. Some of these wetlands lack hydric soil indicators due to the limited saturation depth, saline conditions, or other factors.

5. **Dark-Colored Mineral Soils Due to Organic-Matter Accumulation.** As little as 1.5 percent organic matter can color a soil black. The strong coloring properties of organic matter can mask redoximorphic features in hydric soils. It is important to examine dark soils closely for small redox features (e.g., see indicator F6 – Redox Dark Surface), let saturated soils dry to a moist condition before describing the soil, and look below the dark surface layer(s) for a depleted or gleyed matrix (see indicators A11 – Depleted Below Dark Surface and A12 – Thick Dark Surface). Assistance from a soil scientist with local experience may be necessary when working with dark-colored soils.

6. **Red Soils.** Red soils occur in the region and can be difficult to interpret. These soils formed under conditions of long-term weathering and oxidation, and are primarily found on older islands (e.g., Kaua‘i, O‘ahu, Moloka‘i, Lāna‘i, and Maui in the Hawaiian chain). Some red hydric soils will exhibit hydric soil indicators and others will not. Caution must be taken in evaluating soil indicators in these areas, due to the potential for red soils to enhance or mask certain redox features. Indicator TF2 (Red Parent Material) is applicable in problem situations in areas containing red soils. Indicator F8 (Redox Depressions) may also be useful in areas that are subject to ponding, such as riparian depressions containing red soils. Nodules and concretions can be relict soil features and do not count as redox concentrations when applying hydric soil indicators.

7. **Carbonate Sands.** The formation of redox features requires microbial activity and the presence of iron, manganese, and organic matter. Carbonate sands are common in the region and are derived from weathered shells, coral rubble, foraminifera, and coralline algae. Therefore, they may lack the components required for the development of redox features. This makes carbonate sands difficult to interpret. Care should be taken to examine the soil closely, as redox concentrations and depletions can be very small and have diffuse boundaries. Look for redox features along any visible roots or organic-matter sources. Organic-matter accumulations can be used to identify some hydric soils in carbonate sands; consider indicators S7 (Dark Surface) and S1 (Sandy Mucky Mineral).

8. **Very Shallow Mineral Soils.** In areas where bedrock is close to the surface, hydric mineral soils may meet the color requirements but not the thickness requirements of one or more hydric soil indicators. Some shallow hydric soils in depressions in pāhoehoe lava flows may meet all requirements for indicator TF12 (Very Shallow Dark Surface).

### *Soils with relict or induced hydric soil indicators*

Some soils in the Hawaii and Pacific Islands Region exhibit redoximorphic features and hydric soil indicators that formed in the recent or distant past when conditions may have been wetter than they are today. These features have persisted even though wetland hydrology may no longer be present. For example, wetlands drained long ago for agricultural purposes may contain persistent hydric soil features. Wetland soils drained during historic times are still considered to be hydric but they may no longer support wetlands. Relict hydric soil features may be difficult to distinguish from contemporary features. However, if indicators of hydrophytic vegetation and wetland hydrology are present, then hydric soil indicators can be assumed to be contemporary.

Relict redoximorphic features are no longer active due to geologic or other changes that have permanently altered the hydrologic regime. Only on close examination is it evident that hydric soil morphologies are not present. Several morphological characteristics that can help distinguish between contemporary and relict redoximorphic features (Vepraskas 1992) are described below.

1. Contemporary hydric soils may have nodules or concretions with diffuse boundaries or irregular surfaces. If surfaces are smooth and round, then red to yellow coronas should be present. Relict hydric soils may have nodules or concretions with abrupt boundaries and smooth surfaces without accompanying coronas.

2. Contemporary hydric soils may have Fe depletions along stable macropores in which roots repeatedly grow that are not overlain by iron-rich coatings (redox concentrations). Relict hydric soils may have Fe depletions along stable macropores in which roots repeatedly grow that are overlain by iron-rich coatings.

3. Contemporary hydric soils may have iron-enriched redox concentrations with Munsell colors of 5YR or yellower and with a value and chroma of 4 or more. Relict hydric soils may have iron-enriched redox concentrations with colors redder than 5YR and a value and chroma less than 4.

4. Contemporary pore linings may be continuous while relict pore linings may be broken or discontinuous (Hurt and Galbraith 2005).

There are also areas where hydric soil features have developed in former uplands due to human activities, such as the diversion of water for irrigation or other uses. The application of irrigation water to upland areas can create wetland hydrology and, given adequate time, induce the formation of hydric soil indicators. In some cases, a soil scientist can distinguish naturally occurring hydric soil features from those induced by irrigation. Characterizing the naturally occurring hydrology is often important to the determination, and the timing of field observations can be critical. Observations made during the normal wet season, when natural hydrology is often at its peak and irrigation has not yet begun, may help to differentiate naturally occurring and irrigation-induced hydric soil features.

## Procedure

Soils that are thought to meet the definition of a hydric soil but do not exhibit any of the indicators described in Chapter 3 can be identified by the following recommended procedure. This procedure should be used only where indicators of hydrophytic vegetation and wetland hydrology are present (or are absent due to disturbance or other problem situations), but indicators of hydric soil are not evident.

1. Verify that one or more indicators of hydrophytic vegetation are present, or that vegetation is problematic or has been altered (e.g., by tillage or other land alteration). If so, proceed to step 2.

2. Verify that at least one primary or two secondary indicators of wetland hydrology are present or that indicators are absent due to disturbance or other factors. If so, proceed to step 3. If indicators of hydrophytic vegetation and/or wetland hydrology are absent, then the area is probably non-wetland and no further analysis is required.

3. Thoroughly describe and document the soil profile and landscape setting. Verify that the area is in a landscape position that is likely to collect or concentrate water. Appropriate settings are listed below. If the landscape setting is appropriate, proceed to step 4.

    a. Concave surface (e.g., depression or swale)
    b. Floodplain
    c. Level or nearly level area (e.g., 0- to 3-percent slope)
    d. Toe slope (Figure 7) or an area of convergent slopes (Figure 6)
    e. Fringe of another wetland or water body
    f. Area with a restrictive soil layer or aquitard within 24 in. (60 cm) of the surface
    g. Area where groundwater discharges (e.g., a seep)
    h. Other (explain in field notes why this area is likely to be inundated or saturated for long periods)

4. Use one or more of the following approaches to determine whether the soil is hydric. In the remarks section of the data form or in the delineation report, explain why it is believed that the soil lacks any of the NTCHS hydric soil indicators described in Chapter 3 and why it is believed that the soil meets the definition of a hydric soil.

    a. Determine whether one or more of the following indicators of problematic hydric soils is present. See the descriptions of each indicator given in Chapter 3. If one or more indicators is present, then the soil is hydric.

        i. Stratified Layers (A5)

- ii. Sandy Mucky Mineral (S1)
- iii. Red Parent Material (TF2)
- iv. Very Shallow Dark Surface (TF12)

b. Determine whether one or more of the following problematic soil situations is present. If present, consider the soil to be hydric.

- i. Moderately to Very Strongly Alkaline Soils
- ii. Fluvial Sediments within Floodplains
- iii. Recently Developed Wetlands
- iv. Seasonally Ponded Soils
- v. Dark-Colored Mineral Soils Due to Organic-Matter Accumulation
- vi. Red Soils
- vii. Carbonate Sands
- viii. Very Shallow Mineral Soils
- ix. Other (in field notes, describe the problematic soil situation and explain why it is believed that the soil meets the hydric soil definition)

c. Soils that have been saturated for long periods and have become chemically reduced may change color when exposed to air due to the rapid oxidation of ferrous iron ($Fe^{2+}$) to $Fe^{3+}$ (i.e., a reduced matrix) (Figures 59 and 60). If the soil contains sufficient iron, this can result in an observable color change, especially in hue or chroma. The soil is hydric if a mineral layer 4 in. (10 cm) or more thick starting within 12 in. (30 cm) of the soil surface that has a matrix value of 4 or more and chroma of 2 or less becomes redder by one or more pages in hue and/or increases one or more in chroma when exposed to air within 30 minutes (Vepraskas 1992).

Care must be taken to obtain an accurate color of the soil sample immediately upon excavation. The colors should be observed closely and examined again after several minutes. Do not allow the sample to become dry. Dry soils will usually have a different color than wet or moist soils. As always, do not obtain colors while wearing sunglasses. Colors must be obtained in the field under natural light and not under artificial light.

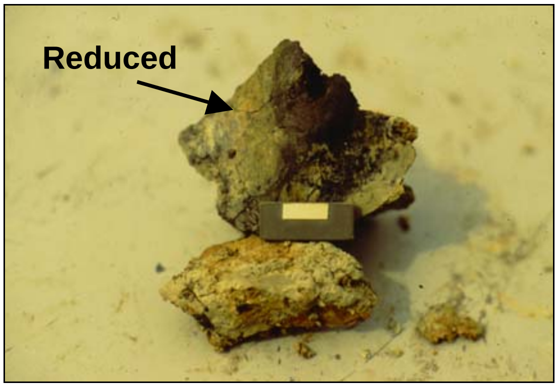

**Figure 59.** This soil exhibits colors associated with reducing conditions. Scale is 1 cm.

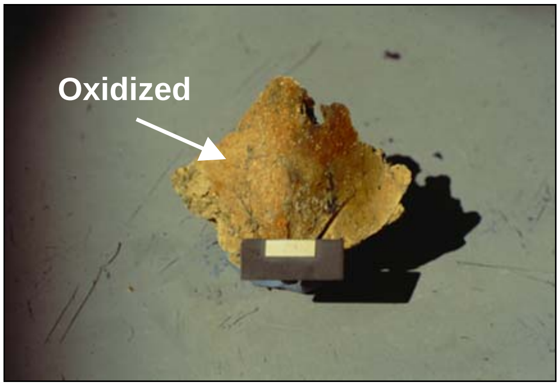

**Figure 60.** The same soil as in Figure 59 after exposure to the air and oxidation has occurred.

d. If the soil is saturated at the time of sampling, alpha, alpha-dipyridyl dye can be used in the following procedure to determine if reduced (ferrous) iron is present. If ferrous iron is present as described below, then the soil is hydric.

   Alpha, alpha-dipyridyl is a dye that reacts with reduced iron. In some cases, it can be used to provide evidence that a soil is hydric when it lacks other hydric soil indicators. The soil is likely to be hydric if application of alpha, alpha-dipyridyl dye to mineral soil material in at least 60 percent of a layer at least 4 in. (10 cm) thick within a depth of 12 in. (30 cm) of the soil surface results in a positive reaction within 30 seconds evidenced by a pink or red coloration to the dye during the growing season.

   Using a dropper, apply a small amount of dye to a freshly broken ped face to avoid any chance of a false positive test due to iron contamination from digging tools. Look closely at the treated soil for evidence of color change. If in doubt, apply the dye to a sample of known upland soil and compare the reaction to the sample of interest. A positive reaction will not occur in soils that lack iron and may not occur in soils with high pH. The lack of a positive reaction to the dye does not preclude the presence of a hydric soil. Specific information about the use of alpha, alpha-dipyridyl can be found in NRCS Hydric Soils Technical Note 8 (http://soils.usda.gov/use/hydric/ntchs/tech_notes/index.html).

e. Using gauge data, water-table monitoring data, or repeated direct hydrologic observations, determine whether the soil is ponded or flooded, or the water table is 12 in. (30 cm) or less from the surface, for 14 or more consecutive days during the growing season in most years (at least 5 years in 10, or 50 percent or higher probability) (U. S. Army Corps of Engineers 2005). If so, then the soil is hydric. Furthermore, any soil that meets the NTCHS hydric soil technical standard (NRCS Hydric Soils Technical Note 11, http://soils.usda.gov/use/hydric/ntchs/tech_notes/index.html) is hydric.

## Wetlands that Periodically Lack Indicators of Wetland Hydrology

## Description of the Problem

Wetlands are areas that are flooded or ponded, or have soils that are saturated with water, for long periods in most years. If the site is visited during a time of normal precipitation amounts and it is inundated or the water table is near the surface, then the wetland hydrology determination is straightforward. During the dry season, however, surface water recedes from wetland margins, water tables drop, and many wetlands dry out completely. Furthermore, not all wetlands become inundated or saturated every year. Wetlands in general are inundated or saturated at least 5 years in 10 (50 percent or higher probability) over a long-term record. Therefore, some wetlands in the region may not become inundated or saturated in some years.

Wetland hydrology determinations are based on indicators, many of which were designed to be used during dry periods when the direct observation of surface water or a shallow water table is not possible. However, some wetlands may lack any of the listed hydrology indicators, particularly during the dry season or in a dry year. The evaluation of wetland hydrology requires special care on any site where indicators of hydrophytic vegetation and hydric soil are present but hydrology indicators appear to be absent. Among other factors, this evaluation should consider the timing of the site visit in relation to normal seasonal and annual hydrologic variability, and whether the amount of rainfall prior to the site visit has been normal. This section describes a number of approaches that can be used to determine whether wetland hydrology is present on sites where indicators of hydrophytic vegetation and hydric soil are present but hydrology indicators may be lacking due to normal variations in rainfall or runoff, human activities that destroy hydrology indicators, and other factors.

## Procedure

1. Verify that indicators of hydrophytic vegetation and hydric soil are present, or are absent due to disturbance or other problem situations. If so, proceed to step 2.

2. Verify that the site is in a landscape position that is likely to collect or concentrate water. Appropriate settings are listed below. If the landscape setting is appropriate, proceed to step 3.

    a. Concave surface (e.g., depression or swale)
    b. Floodplain
    c. Level or nearly level area (e.g., 0- to 3-percent slope)
    d. Toe slope (Figure 7) or an area of convergent slopes (Figure 6)
    e. Fringe of another wetland or water body
    f. Area with a restrictive soil layer or aquitard within 24 in. (60 cm) of the surface
    g. Area where groundwater discharges (e.g., a seep)
    h. Other (explain in field notes why this area is likely to be inundated or saturated for long periods)

3. Use one or more of the following approaches to determine whether wetland hydrology is present and the site is a wetland. In the remarks section of the data form or in the delineation report, explain the rationale for concluding that wetland hydrology is present even though indicators of wetland hydrology described in Chapter 4 were not observed.

    a. *Site visits during the dry season*. Determine whether the site visit occurred during the normal annual "dry season." The dry season, as used in this supplement, is the period of the year when soil moisture is normally being depleted and water tables are falling to low levels in response to decreased precipitation and/or increased evapotranspiration. Typical dry-season months in the region are (USDA Natural Resources Conservation Service 2006a):

Hawaiian Islands – June through October
Guam and the Mariana Islands – January through May
American Samoa – June through September

In many wetlands, direct observation of flooding, ponding, or a shallow water table would be unexpected during the dry season. Wetland hydrology indicators, if present, would most likely be limited to indirect evidence, such as water marks, drift deposits, or surface cracks. In some situations, particularly in seasonally saturated wetland systems, hydrology indicators may be absent during the dry season. At such times, the wetland determination should be based on the preponderance of evidence that the site either is or is not wetland. If the site visit occurred during the dry season on a site that contains hydric soils and hydrophytic vegetation and no evidence of hydrologic manipulation (e.g., no dams, levees, water diversions, land grading, etc., and the site is not within the zone of influence of any ditches or subsurface drains), then consider the site to be a wetland. If necessary, revisit the site during the normal wet season and check again for the presence or absence of wetland hydrology indicators. If wetland hydrology indicators are absent during the wet season in a normal or wetter-than-normal rainfall year, the site is probably non-wetland.

b. *Periods with below normal rainfall.* Determine whether the amount of rainfall that occurred in the 2-3 months preceding the site visit was normal, above normal, or below normal based on the normal range reported in WETS tables. WETS tables are provided by the NRCS National Water and Climate Center (http://www.wcc.nrcs.usda.gov/climate/wetlands.html) and are calculated from long-term (30-year) weather records gathered at National Weather Service meteorological stations. To determine whether precipitation was normal prior to the site visit, actual rainfall in the current month and previous 2-3 months should be compared with the normal ranges for each month given in the WETS table (USDA Natural Resources Conservation Service 1997, Sprecher and Warne 2000). The lower and upper limits of the normal range are indicated by the columns labeled "30% chance will have less than" and "30% chance will have more than" in the WETS table. The USDA Natural Resources Conservation Service (1997, Section 650.1903) also gives a procedure that can be used to weight the information from each month and determine whether the entire period was normal, wet, or dry. Average precipitation can vary considerably over short distances, particularly on the higher islands with mountain ranges and peaks. Therefore, use caution in areas where elevation, aspect, rain-shadow effects, or other conditions differ between the site and the location of the nearest weather station. Sometimes a more distant station is more representative of the site in question.

When precipitation has been below normal, wetlands may not flood, pond, or develop shallow water tables even during the typical wet season and may not exhibit other indicators of wetland hydrology. Therefore, if precipitation was below normal prior to the site visit, and the site contains hydric soils and hydrophytic vegetation and no evidence of hydrologic manipulation (e.g., no dams, levees, water diversions, land grading, etc., and the site is not within the zone of influence of any ditches or subsurface drains), it should be identified as a wetland. If necessary, the site can be re-visited during a period of normal rainfall and checked again for hydrology indicators.

c. *Drought years*. Determine whether the area has been subject to drought. Drought periods can be identified by comparing annual rainfall totals with the normal range of annual rainfall given in WETS tables or by examining trends in drought indices. For the Hawaiian Islands, the U.S. Drought Monitor (http://drought.unl.edu/dm/monitor.html) provides maps of drought severity through time based on a multi-index approach. In addition, Sprecher and Warne (2000) give an overview of various methods for evaluating meteorological data as part of a wetland determination. If wetland hydrology indicators appear to be absent on a site that has hydrophytic vegetation and hydric soils, no significant hydrologic manipulation (e.g., no dams, levees, water diversions, land grading, etc., and the site is not within the zone of influence of any ditches or subsurface drains), and the region has been affected by drought, then the area should be identified as a wetland.

d. *Reference sites*. If indicators of hydric soil and hydrophytic vegetation are present on a site that lacks wetland hydrology indicators, the site may be considered to be a wetland if the landscape setting, topography, soils, and vegetation are substantially the same as those on nearby wetland reference areas. Hydrology of wetland reference areas should be documented through long-term monitoring (see item *g* below) or by application of the procedure described in item *5b* on page 98 (Direct Hydrologic Observations) of the procedure for Problematic Hydrophytic Vegetation in this chapter. Reference sites should be minimally disturbed and provide long-term access. Soils, vegetation, and hydrologic conditions should be thoroughly documented and the data kept on file in the District or field office.

e. *Hydrology tools*. The "Hydrology Tools for Wetland Determination" (USDA Natural Resources Conservation Service 1997) is a collection of methods that can be used to determine whether wetland hydrology is present on a potential wetland site that lacks indicators due to disturbance or other reasons, particularly on lands used for agriculture. Generally they require additional information, such as aerial photographs or stream-gauge data, or involve hydrologic modeling and approximation techniques. They should be used only when an indicator-based wetland hydrology determination is not possible or would give misleading results. A hydrologist may be needed to help select and carry out the proper analysis. The six hydrology tools that are applicable to the Hawaii and Pacific Islands Region are:

1. Analyze stream and lake gauge data
2. Estimate runoff volumes to determine duration and frequency of ponding in depressional areas
3. Evaluate the frequency of wetness signatures on aerial photography (see item *f* below for additional information)
4. Model water-table fluctuations in fields with parallel drainage systems using the DRAINMOD model

5. Estimate the "scope and effect" of ditches or subsurface drain lines
6. Analyze data from groundwater monitoring wells (see item *g* below for additional information)

f. *Evaluating multiple years of aerial photography*. NRCS has developed an offsite procedure that uses aerial photography to make wetland hydrology determinations (USDA Natural Resources Conservation Service 1997, Section 650.1903). The method is intended for use on agricultural lands where human activity has altered or destroyed other wetland indicators. However, the same approach may be useful in other environments.

The procedure uses five or more years of photography and evaluates each photo for wetness signatures that are listed in Part 513.30 of the National Food Security Act Manual (USDA Natural Resources Conservation Service 1994). Wetness signatures include surface water, saturated soils, flooded or drowned-out crops, stressed crops due to wetness, differences in vegetation patterns due to different planting dates, inclusion of wet areas into set-aside programs, unharvested crops, isolated areas that are not farmed with the rest of the field, patches of greener vegetation during dry periods, and other evidence of wet conditions. For each photo, the procedure described in item *b* above is used to determine whether the amount of rainfall in the 2-3 months prior to the date of the photo was normal, below normal, or above normal. Only photos taken in normal rainfall years, or an equal number of wetter-than-normal and drier-than-normal years, are used in the analysis. If wetness signatures are observed on photos in more than half of the years included in the analysis, then wetland hydrology is present. Data forms that may be used to document the wetland hydrology determination are given in section 650.1903 of USDA Natural Resources Conservation Service (1997).

g. *Long-term hydrologic monitoring.* On sites where the hydrology has been manipulated by man (e.g., with ditches, subsurface drains, dams, levees, water diversions, land grading or bedding) or where natural events (e.g., downcutting of streams) have altered conditions such that hydrology indicators may be missing or misleading, direct monitoring of surface and groundwater may be needed to determine the presence or absence of wetland hydrology. The U. S. Army Corps of Engineers (2005) provides minimum standards for the design, construction, and installation of water-table monitoring wells, and for the collection and interpretation of groundwater monitoring data, in cases where direct hydrologic measurements are needed to determine whether wetlands are present on highly disturbed or problematic sites. This standard calls for 14 or more consecutive days of flooding, ponding, or a water table 12 in. (30 cm) or less below the soil surface during the growing season at a minimum frequency of 5 years in 10 (50 percent or higher probability), unless a different standard has been established for a particular geographic area or wetland type. A disturbed or problematic site that meets this standard has wetland hydrology. If the site in question is naturally hummocky or has been graded to enhance microtopography (e.g., abandoned sugar cane plantations), then topographic highs and lows should be evaluated separately. This region has a year-round growing season. Therefore, wetland hydrology is present on a disturbed or problematic site if the minimum requirements for duration and frequency of flooding, ponding, or high water tables are met at any time of year. This standard is not intended (1) to overrule an indicator-based wetland determination on a site that is not disturbed or problematic, or (2) to test or validate existing or proposed wetland indicators.

# Wetland/Non-Wetland Mosaics

## Description of the Problem

In this supplement, “mosaic” refers to a landscape where wetland and non-wetland components are too closely associated to be easily delineated or mapped separately. These areas often have complex microtopography, with repeated small changes in elevation occurring over short distances. Tops of ridges or hummocks are often non-wetland but are interspersed with wetlands having clearly hydrophytic vegetation, hydric soils, and wetland hydrology. Potential examples of wetland/non-wetland mosaics in the Hawaii and Pacific Islands Region include scattered wetlands occupying microtopographic lows created by cracks, folds, and depressions in some undulating pāhoehoe lava flows (Wakeley et al. 1996); hummocky microtopography in floodplains caused by braided stream-flow patterns; and montane bog complexes.

Wetland components of a mosaic are often not difficult to identify. The problem for the wetland delineator is that microtopographic features are too small and intermingled, and there are too many such features on the site, to delineate and map them accurately. Instead, the following sampling approach can be used to estimate the percentage of wetland in the mosaic. From this, the number of acres of wetland on the site can be calculated, if needed.

## Procedure

First, identify and flag all contiguous areas of either wetland or non-wetland on the site that are large enough to be delineated and mapped separately. The remaining area should be mapped as “wetland/non-wetland mosaic” and the approximate percentage of wetland within the area determined by the following procedure.

1. Establish one or more continuous line transects across the mosaic area, as needed. Measure the total length of each transect. A convenient method is to stretch a measuring tape along the transect and leave it in place while sampling. If the site is shaped appropriately and multiple transects are used, they should be arranged in parallel with each transect starting from a random point along one edge of the site. However, other arrangements of transects may be needed for oddly shaped sites.

2. Use separate data forms for the swale or trough and for the ridges or hummocks. Sampling of vegetation, soil, and hydrology should follow the general procedures described in the Corps Manual and this supplement. Plot sizes and shapes for vegetation sampling must be adjusted to fit the microtopographic features on the site. Plots intended to sample the troughs should not overlap adjacent hummocks, and vice versa. Only one or two data forms are required for each microtopographic position, and do not need to be repeated for similar features or plant communities.

3. Identify every wetland boundary in every trough or swale encountered along each transect. Each boundary location may be marked with a pin flag or simply recorded as a distance along the stretched tape.

4. Determine the total distance along each transect that is occupied by wetlands and non-wetlands until the entire length of the line has been accounted for. Sum these distances across transects, if needed. Determine the percentage of wetland in the wetland/non-wetland mosaic by the following formula.

$$\%\ wetland = \frac{Total\ wetland\ distance\ along\ all\ transects}{Total\ length\ of\ all\ transects} \times 100$$

An alternative approach involves point-intercept sampling at fixed intervals along transects across the area designated as wetland/non-wetland mosaic. This method avoids the need to identify wetland boundaries in each swale, and can be carried out by pacing rather than stretching a measuring tape across the site. The investigator uses a compass or other means to follow the selected transect line. At a fixed number of paces (e.g., every two steps) the wetland status of that point is determined by observing indicators of hydrophytic vegetation, hydric soil, and wetland hydrology. Again, a completed data form is not required at every point but at least one representative swale and hummock should be documented with completed forms. After all transects have been sampled, the result is a number of wetland sampling points and a number of non-wetland points. Estimate the percentage of wetland in the wetland/non-wetland mosaic by the following formula:

$$\%\ wetland = \frac{Number\ of\ wetland\ points\ along\ all\ transects}{Total\ number\ of\ points\ sampled\ along\ all\ transects} \times 100$$

# References

Barbour, M. G., J. H. Burk, W. D. Pitts, F. S. Gilliam, and M. W. Schwartz. 1999. *Terrestrial plant ecology, third edition*. Toronto, Canada: Addison Wesley.

Carroll, D. and J. C. Hathaway. 1963. *Mineralogy of selected soils from Guam*. Professional Paper 403-F. Washington, DC: U.S. Department of the Interior, Geological Survey.

Central Intelligence Agency (CIA). 2008. *The 2008 world fact book*. Washington, DC. (https://www.cia.gov/library/index.html)

Cox, G. 1990. *Laboratory manual of general ecology, sixth edition.* Dubuque, IA: William C. Brown.

Deenik, J., and A. T. McClellan. 2007. *Soils of Hawaii*. Honolulu, HI: University of Hawaii at Manoa, Cooperative Extension Service.

Environmental Laboratory. 1987. *Corps of Engineers wetlands delineation manual*. Technical Report Y-87-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station. (http://el.erdc.usace.army.mil/wetlands/pdfs/wlman87.pdf)

Erickson, T. A., and C. F. Puttock. 2006. *Hawai'i wetland field guide*. Honolulu, HI: Bess Press.

Freeze, R. A., and J. A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall.

Gretag/Macbeth. 2000. *Munsell® color*. New Windsor, NY.

Grimes, B. H., M. T. Huish, J. H. Kerby, and D. Moran. 1989. Atlantic marsh fiddler. In *Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic)*. Biological Report 82(11.114). Washington, DC: U. S. Fish and Wildlife Service.

Hurt, G. W., and J. M. Galbraith. 2005. Using soil morphology and soil survey data for restoring and creating wetlands. *Soil Survey Horizons* 46(3): 109-119.

Juvik, S. P., and J. O. Juvik. 1998. *Atlas of Hawai'i, third edition*. Honolulu, HI: University of Hawai'i Press.

Kent, M., and P. Coker. 1992. *Vegetation description and analysis: A practical approach.* New York, NY: Wiley.

Mueller-Dombois, D., and H. Ellenberg. 1974. *Aims and methods of vegetation ecology*. New York, NY: Wiley.

Mueller-Dombois, D., and F. R. Fosberg. 1998. *Vegetation of the tropical Pacific islands*. New York, NY: Springer.

Nakamura, S. 1984. *Soil survey of American Samoa*. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. (http://soils.usda.gov/survey/online_surveys/pacific_basin/index.html)

National Research Council. 1995. *Wetlands: Characteristics and boundaries*. Washington, DC: National Academy Press.

Neil, E. H. 1966. Observations on the behavior of *Tilapia mossambica* (Pisces, Cichlidae) in Hawaiian ponds. *Copeia* 1966: 50-56.

Popma, T., and Masser, M. 1999. *Tilapia – life history and biology*. Publication No. 283. Stoneville, MS: Southern Regional Aquaculture Center. (http://www.aquanic.org/publicat/usda_rac/efs/srac/283fs.pdf, accessed 27 February 2009)

Ragone, D., and D. H. Lorence. 2006. *Botanical and ethnobotanical inventories of the National Park of American Samoa*. Draft Technical Report. Honolulu, HI: University of Hawai‘i at Manoa, Pacific Cooperative Studies Unit.

Reed, P. B., Jr. 1988. *National list of plant species that occur in wetlands: 1988 national summary*. Biological Report 88(24). Washington, DC: U.S. Fish and Wildlife Service. (http://www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list88.pdf)

Shinn, E. A. 1968. Burrowing in recent lime sediments of Florida and the Bahamas. *Journal of Paleontology* 42: 879-894.

Sprecher, S. W., and A. G. Warne. 2000. *Accessing and using meteorological data to evaluate wetland hydrology*. ERDC/EL TR-WRAP-00-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center. (http://el.erdc.usace.army.mil/elpubs/pdf/wrap00-1/wrap00-1.pdf)

Takhtajan, Armen. 1986. *Floristic regions of the world*. (Translated by T.J. Crovello, edited by A. Cronquist). Berkeley, CA: University of California Press.

Thurman, C. L., II. 1984. Ecological notes on fiddler crabs of south Texas, with special reference to *Uca subcylindrica*. *Journal of Crustacean Biology* 4: 665-681.

Tiner, R. W. 1999. *Wetland indicators: A guide to wetland identification, delineation, classification, and mapping*. Boca Raton, FL: Lewis Publishers.

Tracey, J. I., Jr., S. O. Schlanger, J. T. Stark, D. B. Doan, and H. G. May. 1964. *General geology of Guam*. Professional Paper 403-A. Washington, DC: U.S. Department of the Interior, Geological Survey.

U. S. Army Corps of Engineers. 2005. *Technical standard for water-table monitoring of potential wetland sites*. ERDC TN-WRAP-05-02. Vicksburg, MS: U.S. Army Engineer Research and Development Center. (http://el.erdc.usace.army.mil/wrap/pdf/tnwrap05-2.pdf)

U.S. Army Corps of Engineers. 2009. *National wetland plant list*. (https://rsgis.crrel.usace.army.mil/apex/f?p=393)

USDA Natural Resources Conservation Service. 1994. *National food security act manual, third edition* (as amended). Washington, DC. (http://www.nrcs.usda.gov/programs/compliance/index.html)

USDA Natural Resources Conservation Service. 1997. *Hydrology tools for wetland determination*. Chapter 19, Engineering Field Handbook. Fort Worth, TX: U.S. Department of Agriculture. (http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17556.wba)

USDA Natural Resources Conservation Service. 1999. *Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys*. Agricultural Handbook 436. Washington, DC: U.S. Department of Agriculture. (http://soils.usda.gov/technical/classification/taxonomy/)

USDA Natural Resources Conservation Service. 2002. *Field book for describing and sampling soils, version 2.0*. ed. P. J. Schoeneberger, D. A. Wysocki, E. C. Benham, and W. D. Broderson. Lincoln, NE: National Soil Survey Center. (http://soils.usda.gov/technical/fieldbook/)

USDA Natural Resources Conservation Service. 2005. *National soil survey handbook, part 629, glossary*. Washington, DC: U.S. Department of Agriculture. (ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Survey_Handbook/629_glossary.pdf)

USDA Natural Resources Conservation Service. 2006a. *Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin*. Agriculture Handbook 296. Washington, DC: U.S. Department of Agriculture. (http://soils.usda.gov/survey/geography/mlra/index.html)

USDA Natural Resources Conservation Service. 2006b. *Field indicators of hydric soils in the United States, version 6.0*. ed. G. W. Hurt and L. M. Vasilas. Fort Worth, TX: USDA NRCS in cooperation with the National Technical Committee for Hydric Soils. (http://soils.usda.gov/use/hydric/)

USDA Soil Conservation Service. 1994. *Changes in hydric soils of the United States*. Federal Register 59(133): 35680-35681, July 13, 1994.

USDI Bureau of Land Management. 1996. *Sampling vegetation attributes.* BLM/RS/ST-96/002+1730. Denver, CO.

USDI Bureau of Land Management. 1998. *Measuring and monitoring plant populations.* BLM/RS/ST-98/005+1730. Denver, CO.

Vepraskas, M. J. 1992. *Redoximorphic features for identifying aquic conditions*. Technical Bulletin 301. Raleigh, NC: North Carolina Agricultural Research Service, North Carolina State Univ.

Vepraskas, M. J., and S. W. Sprecher. 1997. *Aquic conditions and hydric soils: The problem soils*. Special Publication Number 50. Madison, WI: Soil Science Society of America.

Wakeley, J. S., and R. W. Lichvar. 1997. Disagreement between plot-based prevalence indices and dominance ratios in evaluations of wetland vegetation. *Wetlands* 17: 301-309.

Wakeley, J. S., S. W. Sprecher, and R. W. Lichvar. 1996. Relationships among wetland indicators in Hawaiian rain forest. *Wetlands* 16: 173-184.

Warner, G. F. 1969. The occurrence and distribution of crabs in a Jamaican mangrove swamp. *Journal of Animal Ecology* 38: 379-389.

Wentworth, T. R., G. P. Johnson, and R. L. Kologiski. 1988. Designation of wetlands by weighted averages of vegetation data: A preliminary evaluation. *Water Resources Bulletin* 24: 389-396.

Young, F. J. 1988. *Soil survey of Territory of Guam.* Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. (http://soils.usda.gov/survey/online_surveys/pacific_basin/index.html)

Young, F. J. 1989. *Soil survey of the islands of Aguijan, Rota, Saipan, and Tinian, Commonwealth of the Northern Mariana Islands*. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. (http://soils.usda.gov/survey/online_surveys/pacific_basin/index.html)

# Appendix A
# Glossary

This glossary is intended to supplement those given in the Corps Manual and other available sources. See the following publications for terms not listed here:

- Corps Manual (Environmental Laboratory 1987) (http://el.erdc.usace.army.mil/wetlands/pdfs/wlman87.pdf).
- Field Indicators of Hydric Soils in the United States (USDA Natural Resources Conservation Service 2006b) (http://soils.usda.gov/use/hydric/).
- National Soil Survey Handbook, Part 629 (USDA Natural Resources Conservation Service 2005) (ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Survey_Handbook/629_glossary.pdf).

**Absolute cover.** In vegetation sampling, the percentage of the ground surface that is covered by the aerial portions (leaves and stems) of a plant species when viewed from above. Due to overlapping plant canopies, the sum of absolute cover values for all species in a community or stratum may exceed 100 percent. In contrast, "relative cover" is the absolute cover of a species divided by the total coverage of all species in that stratum, expressed as a percent. Relative cover cannot be used to calculate the prevalence index.

**Aquitard.** A layer of soil or rock that retards the downward flow of water and is capable of perching water above it. For the purposes of this supplement, the term aquitard also includes the term aquiclude, which is a soil or rock layer that is incapable of transmitting significant quantities of water under ordinary hydraulic gradients.

**Contrast.** The color difference between a redox concentration and the dominant matrix color. Differences are classified as faint, distinct, or prominent and are defined in the glossary of USDA Natural Resources Conservation Service (2006b) and illustrated in Table A1.

**Depleted matrix.** The volume of a soil horizon or subhorizon from which iron has been removed or transformed by processes of reduction and translocation to create colors of low chroma and high value. A, E, and calcic horizons may have low chromas and high values and may therefore be mistaken for a depleted matrix. However, they are excluded from the concept of depleted matrix unless common or many, distinct or prominent redox concentrations as soft masses or pore linings are present. In some places the depleted matrix may change color upon exposure to air (reduced matrix); this phenomenon is included in the concept of depleted matrix. The following combinations of value and chroma identify a depleted matrix:

- Matrix value of 5 or more and chroma of 1, with or without redox concentrations occurring as soft masses and/or pore linings, or
- Matrix value of 6 or more and chroma of 2 or 1, with or without redox concentrations occurring as soft masses and/or pore linings, or
- Matrix value of 4 or 5 and chroma of 2, with 2 percent or more distinct or prominent redox concentrations occurring as soft masses and/or pore linings, or

- Matrix value of 4 and chroma of 1, with 2 percent or more distinct or prominent redox concentrations occurring as soft masses and/or pore linings (USDA Natural Resources Conservation Service 2006b).

Common (2 to less than 20 percent) to many (20 percent or more) redox concentrations (USDA Natural Resources Conservation Service 2002) are required in soils with matrix colors of 4/1, 4/2, and 5/2 (Figure A1). Redox concentrations include iron and manganese masses and pore linings (Vepraskas 1992). See “contrast” in this glossary for the definitions of “distinct” and “prominent.”

**Diapause.** A period during which growth or development is suspended and physiological activity is diminished, as in certain aquatic invertebrates in response to drying of temporary wetlands.

Table A1. Tabular key for contrast determinations using Munsell notation.

| Hues are the same (Δ h = 0) | | |
|---|---|---|
| Δ Value | Δ Chroma | Contrast |
| 0 | ≤1 | Faint |
| 0 | 2 | Distinct |
| 0 | 3 | Distinct |
| 0 | ≥4 | Prominent |
| 1 | ≤1 | Faint |
| 1 | 2 | Distinct |
| 1 | 3 | Distinct |
| 1 | ≥4 | Prominent |
| ≤2 | ≤1 | Faint |
| ≤2 | 2 | Distinct |
| ≤2 | 3 | Distinct |
| ≤2 | ≥4 | Prominent |
| 3 | ≤1 | Distinct |
| 3 | 2 | Distinct |
| 3 | 3 | Distinct |
| 3 | ≥4 | Prominent |
| ≥4 | --- | Prominent |

| Hues differ by 2 (Δ h = 2) | | |
|---|---|---|
| Δ Value | Δ Chroma | Contrast |
| 0 | 0 | Faint |
| 0 | 1 | Distinct |
| 0 | ≥2 | Prominent |
| 1 | ≤1 | Distinct |
| 1 | ≥2 | Prominent |
| ≥2 | --- | Prominent |

| Hues differ by 1 (Δ h = 1) | | |
|---|---|---|
| Δ Value | Δ Chroma | Contrast |
| 0 | ≤1 | Faint |
| 0 | 2 | Distinct |
| 0 | ≥3 | Prominent |
| 1 | ≤1 | Faint |
| 1 | 2 | Distinct |
| 1 | ≥3 | Prominent |
| 2 | ≤1 | Distinct |
| 2 | 2 | Distinct |
| 2 | ≥3 | Prominent |
| ≥3 | --- | Prominent |

| Hues differ by 3 or more (Δ h ≥ 3) | | |
|---|---|---|
| Δ Value | Δ Chroma | Contrast |
| Color contrast is prominent, except for low chroma and value. | | Prominent |

Note: If both colors have values of ≤3 and chromas of ≤2, the color contrast is Faint (regardless of the difference in hue).

Adapted from USDA Natural Resources Conservation Service (2002)

**Figure A1.** Illustration of values and chromas that require 2 percent or more distinct or prominent redox concentrations and those that do not, for hue 10YR, to meet the definition of a depleted matrix. *Due to inaccurate color reproduction, do not use this page to determine soil colors in the field.* Background image from the Munsell Soil Color Charts reprinted courtesy of Munsell Color Services Lab, a part of X-Rite, Inc.

**Distinct.** See Contrast.

**Episaturation.** Condition in which the soil is saturated with water at or near the surface, but also has one or more unsaturated layers below the saturated zone. The zone of saturation is perched on top of a relatively impermeable layer.

**Fragmental soil material.** Soil material that consists of 90 percent or more rock fragments; less than 10 percent of the soil consists of particles 2 mm or smaller (USDA Natural Resources Conservation Service 2006b).

**Gleyed matrix.** A gleyed matrix has one of the following combinations of hue, value, and chroma and the soil is not glauconitic (Figure A2):

- 10Y, 5GY, 10GY, 10G, 5BG, 10BG, 5B, 10B, or 5PB with value of 4 or more and chroma of 1; or
- 5G with value of 4 or more and chroma of 1 or 2; or
- N with value of 4 or more (USDA Natural Resources Conservation Service 2006b).

**Growing season.** The period of the year when plants and soils are biologically active, causing the depletion of oxygen and chemical reduction of nitrogen, iron, and other elements in soils that are saturated for more than a few days. In the Hawaii and Pacific Islands Region, the growing season is year-round or 365 days long.

**High pH.** pH of 7.9 or higher. Includes Slightly Alkaline, Moderately Alkaline, Strongly Alkaline, and Very Strongly Alkaline (USDA Natural Resources Conservation Service 2002).

**Nodules and concretions.** Irregularly shaped, firm to extremely firm accumulations of iron and manganese oxides. When broken open, nodules have uniform internal structure whereas concretions have concentric layers (Vepraskas 1992).

**Petrocalcic layer.** A soil horizon in which calcium carbonate has accumulated to the extent that the layer is cemented or indurated.

**Prominent.** See Contrast.

**Reduced matrix.** Soil matrix that has a low chroma *in situ* due to presence of reduced iron, but whose color changes in hue or chroma when exposed to air as $Fe^{2+}$ is oxidized to $Fe^{3+}$ (Vepraskas 1992).

**Saprolite.** Soft, friable, weathered bedrock.

**Saturation.** For wetland delineation purposes, a soil layer is saturated if virtually all pores between soil particles are filled with water (National Research Council 1995, Vepraskas and Sprecher 1997). This definition includes part of the capillary fringe above the water table (i.e., the tension-saturated zone) in which soil water content is approximately equal to that below the water table (Freeze and Cherry 1979).

**Figure A2.** For hydric soil determinations, a gleyed matrix has the hues and chroma identified in this illustration with a value of 4 or more. *Due to inaccurate color reproduction, do not use this page to determine soil colors in the field.* Background image from the Munsell Soil Color Charts reprinted courtesy of Munsell Color Services Lab, a part of X-Rite, Inc.

# Appendix B
# Point-Intercept Sampling Procedure for Determining Hydrophytic Vegetation

The following procedure for point-intercept sampling is an alternative to plot-based sampling methods to estimate the abundance of plant species in a community. The approach may be used with the approval of the appropriate Corps of Engineers District to evaluate vegetation as part of a wetland delineation. Advantages of point-intercept sampling include better quantification of plant species abundance and reduced bias compared with visual estimates of cover. The method is useful in communities with high species diversity, and in areas where vegetation is patchy or heterogeneous, making it difficult to identify representative locations for plot sampling. Disadvantages include the increased time required for sampling and the need for vegetation units large enough to permit the establishment of one or more transect lines within them. The approach also assumes that soil and hydrologic conditions are uniform across the area where transects are located. In particular, transects should not cross the wetland boundary. Point-intercept sampling is generally used with a transect-based prevalence index (see below) to determine whether vegetation is hydrophytic.

In point-intercept sampling, plant occurrence is determined at points located at fixed intervals along one or more transects established in random locations within the plant community or vegetation unit. If a transect is being used to sample the vegetation near a wetland boundary, the transect should be placed parallel to the boundary and should not cross either the wetland boundary or into other communities. Usually a measuring tape is laid on the ground and used for the transect line. Transect length depends upon the size and complexity of the plant community and may range from 100 to 300 ft (30 to 90 m) or more. Plant occurrence data are collected at fixed intervals along the line, for example every 2 ft (0.6 m). At each interval, a “hit” on a species is recorded if a vertical line at that point would intercept the stem or foliage of that species. Only one “hit” is recorded for a species at a point even if the same species would be intercepted more than once at that point. Vertical intercepts can be determined using a long pin or rod protruding into and through the various vegetation layers, a sighting device (e.g., for the canopy), or an imaginary vertical line. The total number of “hits” for each species along the transect is then determined. The result is a list of species and their frequencies of occurrence along the line (Mueller-Dombois and Ellenberg 1974, Tiner 1999). Species are then categorized by wetland indicator status (i.e., OBL, FACW, FAC, FACU, or UPL), the total number of hits determined within each category, and the data used to calculate a transect-based prevalence index. The formula is similar to that given in Chapter 2 for the plot-based prevalence index (see Indicator 3), except that frequencies are used in place of cover estimates. The community is hydrophytic if the prevalence index is 3.0 or less. To be valid, more than 80 percent of “hits” on the transect must be of species that have been identified correctly and placed in an indicator category.

The transect-based prevalence index is calculated using the following formula:

$$PI = \frac{F_{OBL} + 2F_{FACW} + 3F_{FAC} + 4F_{FACU} + 5F_{UPL}}{F_{OBL} + F_{FACW} + F_{FAC} + F_{FACU} + F_{UPL}}$$

where:
$PI$ = Prevalence index
$F_{OBL}$ = Frequency of obligate (OBL) plant species;
$F_{FACW}$ = Frequency of facultative wetland (FACW) plant species;
$F_{FAC}$ = Frequency of facultative (FAC) plant species;
$F_{FACU}$ = Frequency of facultative upland (FACU) plant species;
$F_{UPL}$ = Frequency of upland (UPL) plant species.

# Appendix C
# Data Form

# WETLAND DETERMINATION DATA FORM – Hawaii and Pacific Islands (DRAFT)

Project/Site: ______ City: ______ Sampling Date: ______ Time: ______

Applicant/Owner: ______ State/Terr.: ______ Island: ______ Sampling Point: ______

Investigator(s): ______ TMK/Parcel: ______

Landform (hillslope, coastal plain, etc.): ______ Local relief (concave, convex, none): ______

Lat: ______ Long: ______ Datum: ______ Slope (%): ______

Soil Map Unit Name: ______ NWI classification: ______

Are climatic / hydrologic conditions on the site typical for this time of year? Yes ______ No ______ (If no, explain in Remarks.)

Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes ______ No ______

Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

## SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

| | | | |
|---|---|---|---|
| Hydrophytic Vegetation Present? | Yes ______ | No ______ | **Is the Sampled Area within a Wetland?** **Yes ______ No ______** |
| Hydric Soil Present? | Yes ______ | No ______ | |
| Wetland Hydrology Present? | Yes ______ | No ______ | |

Remarks:

## VEGETATION – Use scientific names of plants.

| Tree Stratum (Plot size: ______ ) | Absolute % Cover | Dominant Species? | Indicator Status |
|---|---|---|---|
| 1. ______ | ______ | ______ | ______ |
| 2. ______ | ______ | ______ | ______ |
| 3. ______ | ______ | ______ | ______ |
| 4. ______ | ______ | ______ | ______ |
| 5. ______ | ______ | ______ | ______ |
| | ______ | = Total Cover | |
| Sapling/Shrub Stratum (Plot size: ______ ) | | | |
| 1. ______ | ______ | ______ | ______ |
| 2. ______ | ______ | ______ | ______ |
| 3. ______ | ______ | ______ | ______ |
| 4. ______ | ______ | ______ | ______ |
| 5. ______ | ______ | ______ | ______ |
| | ______ | = Total Cover | |
| Herb Stratum (Plot size: ______ ) | | | |
| 1. ______ | ______ | ______ | ______ |
| 2. ______ | ______ | ______ | ______ |
| 3. ______ | ______ | ______ | ______ |
| 4. ______ | ______ | ______ | ______ |
| 5. ______ | ______ | ______ | ______ |
| 6. ______ | ______ | ______ | ______ |
| 7. ______ | ______ | ______ | ______ |
| 8. ______ | ______ | ______ | ______ |
| | ______ | = Total Cover | |
| Woody Vine Stratum (Plot size: ______ ) | | | |
| 1. ______ | ______ | ______ | ______ |
| 2. ______ | ______ | ______ | ______ |
| | ______ | = Total Cover | |

**Dominance Test worksheet:**

| | | |
|---|---|---|
| Number of Dominant Species That Are OBL, FACW, or FAC: | ______ | (A) |
| Total Number of Dominant Species Across All Strata: | ______ | (B) |
| Percent of Dominant Species That Are OBL, FACW, or FAC: | ______ | (A/B) |

**Prevalence Index worksheet:**

| Total % Cover of: | | Multiply by: | |
|---|---|---|---|
| OBL species | ______ | x 1 = | ______ |
| FACW species | ______ | x 2 = | ______ |
| FAC species | ______ | x 3 = | ______ |
| FACU species | ______ | x 4 = | ______ |
| UPL species | ______ | x 5 = | ______ |
| Column Totals: | ______ (A) | | ______ (B) |

Prevalence Index = B/A = ______

**Hydrophytic Vegetation Indicators:**

___ Rapid Test for Hydrophytic Vegetation

___ Dominance Test is >50%

___ Prevalence Index is ≤3.0[1]

___ Problematic Hydrophytic Vegetation[1] (Explain in Remarks or in the delineation report)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

**Hydrophytic Vegetation Present?** **Yes ______ No ______**

Remarks:

## SOIL

Sampling Point: ___________

**Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)**

| Depth | Matrix | | Redox Features | | | | | |
|---|---|---|---|---|---|---|---|---|
| (inches) | Color (moist) | % | Color (moist) | % | Type[1] | Loc[2] | Texture | Remarks |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

[1] Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2] Location: PL=Pore Lining, M=Matrix.

**Hydric Soil Indicators:**

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Muck Presence (A8)
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Dark Surface (S7)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)

**Indicators for Problematic Hydric Soils[3]:**

___ Stratified Layers (A5)
___ Sandy Mucky Mineral (S1)
___ Red Parent Material (TF2)
___ Very Shallow Dark Surface (TF12)
___ Other (Explain in Remarks)

[3] Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

**Restrictive Layer (if observed):**

Type: ______________________________

Depth (inches): ______________________

**Hydric Soil Present? Yes ______ No ______**

Remarks:

## HYDROLOGY

**Wetland Hydrology Indicators:** (Explain observations in Remarks, if needed.)

Primary Indicators (minimum of one required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
___ Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Aquatic Fauna (B13)
___ Tilapia Nests (B17)
___ Hydrogen Sulfide Odor (C1)
___ Oxidized Rhizospheres on Living Roots (C3)
___ Presence of Reduced Iron (C4)
___ Recent Iron Reduction in Tilled Soils (C6)
___ Thin Muck Surface (C7)
___ Fiddler Crab Burrows (C10) (Guam, CNMI, and American Samoa)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
___ Drainage Patterns (B10)
___ Dry-Season Water Table (C2)
___ Salt Deposits (C5)
___ Stunted or Stressed Plants (D1)
___ Geomorphic Position (D2)
___ Shallow Aquitard (D3)
___ FAC-Neutral Test (D5)

**Field Observations:**

Surface Water Present? Yes _____ No _____ Depth (inches): ____________
Water Table Present? Yes _____ No _____ Depth (inches): ____________
Saturation Present? Yes _____ No _____ Depth (inches): ____________
(includes capillary fringe)

**Wetland Hydrology Present? Yes ______ No ______**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks: