Forest Service
U.S. DEPARTMENT OF AGRICULTURE

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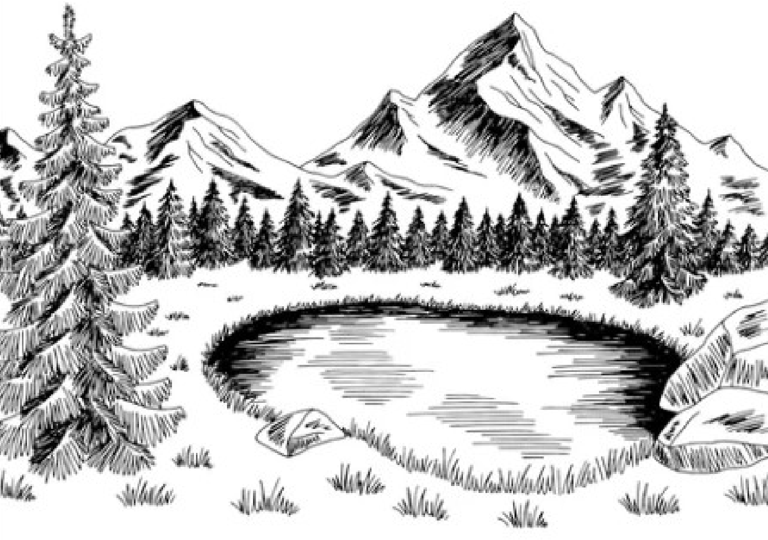
Groundwater-Dependent Ecosystems Level I Inventory Field Guide

Inventory Methods for Assessment and Planning



Contributors

This field guide was developed under the direction of the Groundwater-Dependent Ecosystems (GDE) Protocol Development Core Team with primary contributions from Marc Coles-Ritchie of Management & Engineering Technologies International, Inc. (METI, Inc.) and Joe Gurrieri (U.S. Department of Agriculture [USDA], Forest Service). Chris Carlson (Forest Service) and Steve Solem (METI, Inc.) provided essential edits and guidance in the field guide development process. Other members of the Core Team, who provided detailed edits and recommendations at multiple stages of the field guide development, were (of the Forest Service unless otherwise noted): Allison Aldous (The Nature Conservancy), Devendra Amatya, Trish Carroll, Kate Dwire, Mark Gonzalez (Bureau of Land Management, U.S. Department of the Interior), and Barry Johnston.

The GDE Protocol Development Steering Team provided valuable guidance at multiple stages of the process. That team was made up the following individuals (of the Forest Service unless otherwise noted): Leslie Bach (The Nature Conservancy), Chris Carlson (team leader), Tony Crump, Tony Erba, Russ Lafayette, Bill LeVere, Dan Neary, Mike Nevill, Andy Rorick, Linda Spencer, Cynthia Tait, and Richard Ullrich. Luke Boehnke created the figures, including invertebrate illustrations in appendix 7.

Reviews and comments were also provided by members of Technical Advisory Teams for the GDE Protocol Development project.

Pilot testing of this field guide involved dedicated individuals from the following units: Black Hills and Nebraska National Forests (Rocky Mountain Region); the Spring Mountains National Recreation Area on the Humboldt-Toiyabe National Forest (Intermountain Region); Inyo National Forest (Pacific Southwest Region); the Malheur, Wallowa-Whitman, and Umatilla National Forests (Pacific Northwest Region); Francis Marion and Sumter National Forest (Southern Region), White Mountain National Forest (Eastern Region); and the Fraser Experimental Forest (Rocky Mountain Research Station).

This updated 2022 version was revised by Joe Gurrieri and Tim Stroope (Forest Service) and Jeri Ledbetter and Larry Stevens (Spring Stewardship Institute).

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Foundations

Much of this field guide has been influenced by the foundational work of others in the fields of spring and wetland science as represented in the following protocols:

- "Field and Laboratory Operations Report for the Oregon Wetlands Study" (Magee et al. 1995).
- "Terrestrial Springs Ecosystems Inventory Protocols" (Stevens et al. 2006).
- "National Park Service Mojave Inventory and Monitoring Network Spring Survey Protocols: Level I and Level II" (Sada and Pohlmann 2006 draft).
- "Groundwater and Biodiversity Conservation: A Methods Guide for Integrating Groundwater Needs of Ecosystems and Species Into Conservation Plans in the Pacific Northwest" (Brown et al. 2007).
- "Interim Protocol, Ground-Water Resource Inventory and Monitoring Protocol, Level I Spring Ecosystem Inventory" (Gurrieri 2007 draft).
- "Assessing Proper Functioning Condition for Fen Areas in the Sierra Nevada and Southern Cascade Ranges in California: A User Guide" (Weixelman and Cooper 2009).
- "Study Plan: Sampling of the Polygons Photo Interpreted for Possible Fens on the Grand Mesa-Uncompahgre-Gunnison National Forest, Colorado" (Johnston et al. 2009 draft).

List of Acronyms

Note: some acronyms are found on the forms shown in appendix 1.

BLM	Bureau of Land Management
DD	decimal degree
DO	dissolved oxygen
EDW	Enterprise Data Warehouse
FSH	Forest Service Handbook
FSM	Forest Service Manual
FWS	U.S. Fish and Wildlife Service
GDE	groundwater-dependent ecosystems
GIS	geographic information system
GPS	Global Positioning System
HCL	hydrochloric acid
HUC	hydrologic unit code
ID	identification
NAD	North American Datum
NFS	National Forest System
NHD	National Hydrography Database
NRCS	Natural Resources Conservation Service
ORP	oxidation-reduction potential
SOC	species of concern
SOI	species of interest
SSI	Springs Stewardship Institute
TES	threatened and endangered species
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System

Contents

Introduction

This level I inventory field guide describes a national protocol to supply data used in project identification and planning. Data collected through this field guide serve as the basis for the assessment of project and activity effects on, and the identification of project-level design and mitigation measures for, a specific set of groundwater-dependent ecosystem (GDE) types.

This level I field guide includes procedures for collecting a narrower array of data attributes and less detail for some data attributes than the companion level II field guide (GTR-WO-86b). This level I field guide is intended to document the location, size, and basic characteristics of a site during a relatively short 2-hour site visit by a trained field crew. The level II field guide is intended to more comprehensively characterize the vegetation, hydrology, geology, and soils of GDE sites and typically would require 4 to 8 hours at the field site by a crew of specialists.

If inventory or monitoring of specific species or communities is the goal, then a more detailed and/or targeted set of methods should be used.

Specific examples of what this field guide is designed to be used for include the following:

- Determining the location and extent of GDEs within an area (as long as appropriate site selection process is used).
- Qualitatively characterizing GDEs within an area (as long as appropriate site selection process is used).
- Determining if GDEs may be affected by proposed actions or activities.

If the objective is to monitor certain conditions of a GDE, then it will be necessary to develop and use a more detailed and site-specific level III protocol. This level I field guide, however, can be used as a starting point for the development of a site-specific level III protocol that will meet the management needs of a particular situation. Assistance with the development of level III protocols is available from the National Groundwater Technical Team.

Business Requirements Addressed by This Field Guide

Pressure on National Forest System (NFS) lands to supply the water, minerals, and energy needed to meet societal needs is intensifying. In addition, wildland fire management, hazardous fuels reduction, invasive species control, livestock grazing, mineral extraction, road and trail management, and ecological restoration activities also affect GDEs. Accurate and consistent information regarding GDEs and their condition is critical to making decisions about and implementing a wide variety of mission responsibilities of the Forest Service, an agency of the U.S. Department of Agriculture (USDA). This level I field guide is designed to collect accurate and consistent information regarding the location of GDEs and their condition. Data collected are essential to informed decision making associated with the agency's mission responsibilities supported by broad- and mid-scale assessments and land and resource management planning. The level II GDE field guide should be used to collect data needed to inform project-level decisions and activity administration affecting GDEs.

Effective resource management requires a clear understanding of the underlying business requirements for practicing conservation. In some instances, policy and direction limit management's ability to respond to identified needs; in others, they create an affirmative obligation for the agency to take action to conserve or protect resources and public safety. Business requirements stem from two primary sources: (1) regulatory and policy requirements, and (2) management questions and concerns associated with land and resource management plans and ongoing or proposed projects/activities (box 1).

Across the NFS, legal requirements and management issues are highly variable, so it is difficult to define a discrete set of business requirements applicable to all NFS lands. In several instances, laws and regulations provide the opportunity for States and Tribes to establish additional requirements (these could be statutory or rule based) for the protection of resources associated with GDEs. This situation creates an even more complex set of management requirements. This level I field guide, therefore, is designed to allow for local additions within an established national framework.

Information used to identify management requirements was gleaned from the Forest Service Directives System. Forest Service Manual (FSM) 2880 and the “zero chapters” of FSMs 1900, 1940, and 2500 were the primary sources consulted.

Box 1

Business Requirements for Effective Resource Management

Management requirements

- **Laws—**Establish Forest Service authority and procedural requirements for managing GDEs.
- **Regulations—**Establish the processes and policy for conducting land and resource management activities affecting GDEs.
- **Executive Orders—**Specify procedures and requirements applicable to all Government agencies for the management and protection of GDEs and associated resources.
- **Policy—**Establishes procedures and policies for USDA agencies responsible for or potentially affecting GDE resources. Establishes agency-specific procedures for regulatory requirements if not addressed directly through other means.

Management questions

- **Land management plans—**Establish desired outcomes (goals and objectives), standards and guidelines, and monitoring requirements. Plans include:
  - **Ecological context—**Are ecological systems functioning and disturbance processes operating within the natural or desired range of variation? Are human pressures or changes in ecological systems inducing changes to the ecological context in which species reside?
  - **Species context—**Are habitat relationships or ecological factors affected by management creating risk to species persistence?
- **Resource or area plans—**Refine interpretations and requirements for specific resources or areas.
- **Monitoring—**Includes:
  - **Implementation—**Are projects and activities being implemented as designed?
  - **Effectiveness—**Are mitigation measures, best practices, and design features effective in mitigating anticipated impacts?
  - **Validation—**Are conservation actions achieving desired outcomes?

Management requirements applicable to inventory and monitoring of GDEs fall into three groups:

1. **GDE resource management**—The importance of GDEs, and their ability to sustain both ecological systems and species dependent on groundwater resources, is evident in most national forests and grasslands. The collection of requirements related to the management of water and water uses, and the conservation of threatened, endangered, and sensitive species that rely upon these areas, is further evidence of their importance. Protection, conservation, and restoration of GDEs are often key aspects of decision making on NFS lands and a foundation for many land management plans. Inventory and monitoring of GDEs are described in FSM 2880.

   Because of the State-by-State variability associated with water rights and uses within the NFS, no attempt has been made to summarize such requirements that apply below the national level as part of this effort. Readers are encouraged to consult FSM 2540 and appropriate regional and forest supplements to that chapter to review those requirements.
2. **Planning and environmental compliance**—Policy and procedures for land management planning and environmental compliance activities are outlined in FSM 1920 and 1950, respectively. The land management planning handbook (FSH 1909.12) and the 2012 Planning Rule (36 CFR Part 219) provide guidance on how and where groundwater resources including GDEs should fit into the planning process. Depending on the "vintage" of the land and resource management plan for an NFS administrative unit, different requirements apply. Field users are encouraged to consult their appropriate land management plans and the National Environmental Policy Act (NEPA) decision documents associated with individual uses, activities, and authorizations to determine specific design and monitoring requirements.
3. **Resource information management**—GDE data collected under this level I field guide is stored in Springs Online, an application maintained by the Springs Stewardship Institute (SSI), a nonprofit 501(c)(3) organization. The Forest Service has a memorandum of understanding (MOU) and master agreement with SSI to manage Forest Service data. Springs

Online also provides standard analysis and evaluation tools supported by the data collection methods described in this field guide. Forest Service data in the Springs Online database are periodically uploaded to the Forest Service Enterprise Data Warehouse and stored here: T:\FS\Reference\EDW\Hydrology_SpringEcosystem_SSI_EDW_SpringType.

Management requirements applicable to GDE inventory and monitoring can be summarized into the following general points:

- Support an affirmative agency obligation to **protect, conserve, and restore** waters, watersheds, and listed wildlife and plant species and their habitats, and to conserve biological diversity.
- **Assess and disclose environmental effects** associated with ongoing and proposed actions and activities, including using monitoring data to identify needed adjustments to management practices.
- **Use the best available information and science** to support agency decision making. Collect and maintain resource data with known data standards and data quality for use in agency decision-making processes. Provide for information security.

A detailed review of more than 100 statutes and policies that establish management requirements addressed by this effort is documented in "Groundwater Dependent Ecosystems Inventory and Monitoring Business Requirements Analysis" (v5.2, January 30, 2010).

Relationships Between Business Requirements and Field Guide Levels

Because of the variety of situations encountered on NFS lands, it is essential to develop a field guide "package" consisting of integrated modules or components that can be matched to a local unit's business requirements and needs. Using different inventory and monitoring "intensity levels," which herein correspond to field guide levels, supports this functionality.

A relationship exists between the types of management requirements and questions being addressed and the data needed to address those questions. The amount of effort or "intensity" of inventory and monitoring can be categorized into three levels. Table 1 describes the level of effort and focus of these levels.

Table 1.—Descriptions of GDE inventory and monitoring intensity levels.

Inventory and monitoring intensity level	Description
Level I	Conducted to characterize GDEs qualitatively within an administrative unit or management area. GDE location and extent are spatially referenced. Serves as the basis for determining when GDEs may be affected by proposed actions or activities or landscape scale change.
Level II	Serves as the foundation for assessment of project and activity effects and identification of design measures. Describes major attributes including the following: hydrogeologic setting, aquatic habitat, aquatic and wetland flora and fauna, and site-affecting disturbances. Can be used to determine ecological significance of the GDE and associated resources. Can also be used as a foundation for designing a long-term monitoring plan.
Level III	Usually conducted in relation to monitoring a major activity or set of activities affecting GDEs and their characteristics. Compiles highly quantitative information that describes spatial and temporal variation in physiochemical characteristics of GDEs. Often used in the administration of projects or activities and, therefore, is highly site specific.

To provide flexibility and ensure appropriate use of the GDE field guides, the relationship between business requirements (why data are collected) and inventory and monitoring field guides (how data are collected) must be clearly described and understood. The relationship between business requirements and GDE inventory and monitoring field guide (intensity) levels is illustrated in figure 1.

The number of management questions considered, and the level of detail needed to address these questions, increases with the inventory and monitoring intensity level. Each of the boxes in figure 1 represents a grouping of management requirements. The level of detail and resolution for data elements needed to support the business requirements increases from level I to level III. For example, the types of information collected in level I for

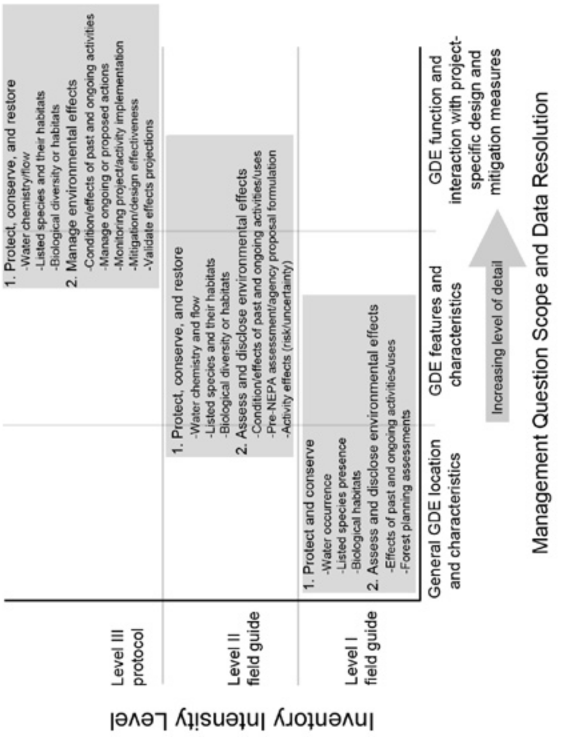

Figure 1.—General relationships between GDE business requirements and field guide levels.

vegetation would be more general than those collected in level II, which would likely be more general than those collected in level III, depending on the particular management requirements for which the level III protocol was developed. Specific management questions have been identified and associated with business requirements as part of the GDE Business Requirements Analysis.

Targeted GDEs

Although many different types of GDEs exist, not all are targeted for this field guide. GDEs are ecosystems that are supported by groundwater, which include springs and seeps, cave and karst systems, phreatophytic ecosystems, and, in many cases, rivers, wetlands, and lakes. This field guide was developed to focus on a subset of nonmarine GDEs, specifically springs and groundwater-dependent wetlands (such as fens) as illustrated in figure 2.

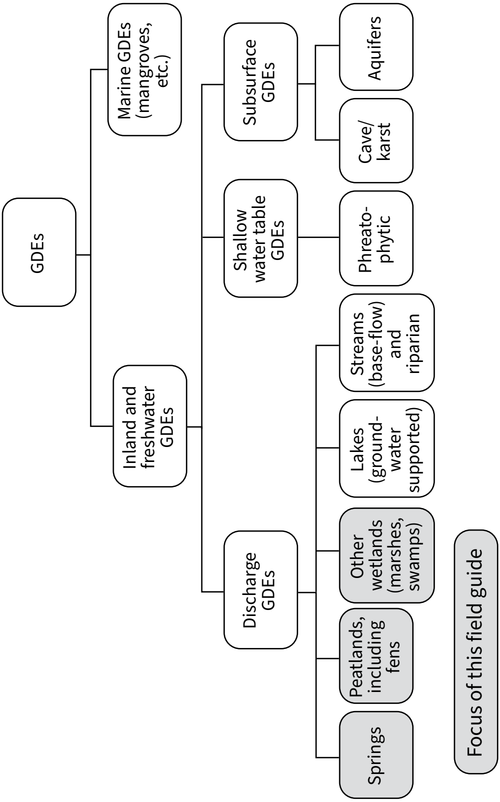

Figure 2.—Diagram of GDE types, with the highlighted types (on bottom left) representing those for which this field guide was designed.

Spring ecosystems develop where groundwater is exposed at and may flow from the Earth's surface, influencing biota that require or use such habitats (Stevens et al. 2021). Because the existence of the ecosystem depends on the emergence of subterranean water, springs are considered as groundwater-dependent ecosystems. Spring ecosystems are delimited by the extent of habitat wetted by the spring. Seeps are wet sites that have immeasurably small discharge, but nonetheless are regarded as springs. Wet meadows are helocrenic springs with diffuse discharge that may only be measurable through analysis of the wetted area. Such habitats include ciénegas at elevations below 2000 meters (m) in Southwestern North America and fens at higher elevations throughout the Northern Hemisphere. Such habitats may internally contain springs with discrete channels and measurable discharge; however, many helocrene springs do not develop discrete outflow channels. In many cases, GDE helocrenes are springs that are covered by unconsolidated materials, such as glacial sediments, colluvium or alluvium, pumice, or organic matter (e.g., peat) and are saturated at the ground surface. Wetlands may or may not be fed by groundwater, so distinguishing between springs and non-GDE wetlands requires specific protocols described in this document. Groundwater emerging at the ground surface is the common thread that links fens to other spring types and their associated ecosystems.

It is important to recognize that some wetlands are not supported by groundwater, but are formed from water that originates exclusively from precipitation and associated surface runoff. Such wetlands are called ombrogenous hydrological systems (National Wetlands Working Group 1997). Mitsch and Gosselink (2007) define ombrogenous as "rain fed." Ombrogenous wetlands are not the focus of this field guide, although the field guide may have components that could be used to evaluate ombrogenous wetlands.

This field guide is intended for those wetlands that are supported by groundwater that has come in contact with mineral soils or bedrock. Such wetlands are termed "minerogenous" hydrological systems (National Wetlands Working Group 1997) or "minerotrophic peatlands" (Mitsch and Gosselink 2007), and are by far the most common type of wetland on NFS land. Minerogenous wetland systems are normally situated at positions in the landscape lower than adjacent terrain, such that water and transported mineral elements are introduced by groundwater.

Minerogenous hydrological systems have a strong linkage with the physical and chemical nature of the geological environment and generally involve the regional groundwater system. They are not restricted by local climatic conditions because the groundwater source is generally sufficient to maintain soil saturation and associated wetland processes. By contrast, ombrogenous hydrological systems (or ombrotrophic peatlands, as described by Mitsch and Gosselink (2007)) are not dependent on groundwater and are highly restricted geographically because of local climatic conditions. In arid and semiarid regions, many wetlands are supported by groundwater. In humid regions, distinction of groundwater support of wetlands becomes more difficult. Nevertheless, many wetlands in humid regions are highly groundwater dependent.

Because it is not always easy to verify a wetland's dependence on groundwater, a site-specific assessment is necessary. One source of information to help determine groundwater dependence is a publication by The Nature Conservancy (Brown et al. 2007), which includes decision trees for determining groundwater dependence, such as the one for wetlands, which is adapted for this level I field guide in box 2.

In summary, this level I field guide is intended for the inventory and monitoring of a subset of GDEs, specifically springs and groundwater-dependent wetlands (described in table 2). The primary basis for determining which systems to include in the GDE field guide is hydrology, specifically the primary water source. This field guide provides a very general classification of wetlands to indicate which types of wetlands are covered (see fig. 2 and table 2).

Box 2

Decision Tree for Identifying Groundwater-Dependent Wetlands

(based on Brown et al. 2007, with modifications for this field guide)

Answer the questions in sequence. A **bold** answer indicates likely groundwater dependence, and subsequent questions need not be answered.

1. Is the wetland seasonal?
   Yes—Low likelihood of groundwater dependence
   No—Go to next question
2. Does the wetland occur in one of these landscape settings:
   (a) slope break, (b) intersection of a confined aquifer with a slope, (c) stratigraphic change, or (d) along a fault?
   Yes—High likelihood of groundwater dependence
   No—Go to next question
3. Is the wetland associated with a spring or seep?
   Yes—High likelihood of groundwater dependence
   No—Go to next question
4. Does the wetland have signs of surface inflow?
   No—High likelihood of groundwater dependence
   Yes—Go to next question
5. Are the wetland soils organic, muck, or peat?
   Yes—High likelihood of groundwater dependence
   No—Go to next question
6. Is the wetland saturated even after surface inputs become dry and during extended periods with no precipitation?
   Yes—
      Are the wetland soils clay, hardpan, or impermeable?
         No—High likelihood of groundwater dependence
         Yes—Low likelihood of groundwater dependence
   No—Low likelihood of groundwater dependence

Table 2.—Important GDE characteristics and the GDE types covered by this field guide.

Characteristics	Springs	Peatlands, including fens	Other wetlands
Hydrology	Completely groundwater dependent	Minerotrophic; always groundwater dependent	Minerotrophic; dependent on groundwater, precipitation, and sometimes stream inflow
Water table position	At ground surface or, for artesian, a piezometric surface above the ground surface	At or slightly below surface, or piezometric surface above the ground	Above or below ground surface; can fluctuate dramatically; can have periodic standing water
Soils and peat or muck depths	Mostly mineral soils; sometimes a small accumulation of peat	Accumulation of peat or muck up to several meters; little or no mineral soil within plant-rooting zone for fens	Usually little or no peat or muck accumulation; sometimes wood-rich peat
Redox conditions*	Oxic to anoxic depending on geochemistry and residence time of water in aquifer	Anoxic slightly below the surface, leading to the accumulation of peat or muck	Temporary soil anoxia during times of high water table or standing water

* Redox (short for reduction-oxidation) conditions describe a key chemical characteristic in hydrologic systems that controls the availability of many elements and the propensity of the system to support the accumulation of organic matter, such as peat and muck. At the ground surface, redox conditions are often controlled by the availability of oxygen.

Characteristics	Springs	Peatlands, including fens	Other wetlands
Water movement within GDEs	Standing or flowing water	Slow to imperceptible flow on surface	Periodic standing or flowing water
Water chemistry	Highly variable; from acidic to basic, temperatures vary, can be thermal, can be saline	Minerotrophic, acidic (poor fens) to basic (rich fens); can be iron rich or calcareous	Highly variable, from acidic to basic
Vegetation	Graminoids, forbs, shrubs, bryophytes, and trees; variable amount of wetland vegetation	Bryophytes, graminoids, and low shrubs; lichens; sometimes trees; always wetland vegetation	Tall woody plants and forbs (swamps) or emergent graminoids and floating aquatic macrophytes (marshes); mostly wetland vegetation

Springs

Springs are points at which groundwater reaches and may flow from the surface of the Earth, and spring ecosystems are the landscapes that are influenced by groundwater exposure and discharge. Spring ecosystems are often small in size and discharge. Groundwater flow paths vary in length and groundwater residence time varies in duration, based on geologic stratigraphy, composition, and structure, as well as climate, elevation, and other physical factors (Stevens et al. 2021). Springs can support complex assemblages of subterranean, aquatic, wetland, riparian, and upland biota, including endemic organisms. As ecosystems, springs often exhibit high levels of ecosystem individuality related to variation in geochemistry, groundwater and springbrook flow paths, biogeographic history, short- and long-term human influences, and complex material and trophic energy exchanges between the aquifer, the spring, the surface drainage network, and adjacent upland ecosystems (Stevens 2020). Potentially high levels of ecological interactivity (particularly at unshaded springs and those in arid regions) has prompted some researchers to regard springs as "keystone ecosystems," ecologically highly interactive points in landscapes that exert inordinate influences on adjacent upland ecosystems.

Springs have been described as "zero-order streams" (Stevens et al. 2021), functioning as the headwaters of low-order streams. A springbrook is a habitat component of a spring ecosystem in which emerging groundwater may pass back into the ground ("losing springbrooks"), or over distance may develop into a low-order perennial stream. A springbrook can be distinguished from a surfaceflow-dominated low-order stream based on channel geomorphology. Springbrook channel geometry is typically erratic, nonsymmetrical, and slightly, but not overly incised. In contrast, surfaceflow-dominated channels are characterized by symmetrical sinuosity generated by regular flooding, with terrace development and incision a function of upstream landscape factors.

The point at which the channel manifests surfaceflow-dominated sinuosity is the downstream-most extent of spring influence. That point also is reflected in changes in the turnover of aquatic macroinvertebrate assemblage. Therefore, in addition to the wetted area influence of the spring source, the spring's influence extends downstream to the point at which surface processes override the spring's discharge influences. Two issues related to the description of the springbrook habitat are: (1) springbrook length can be influenced by the magnitude of discharge (i.e., a larger spring discharge may generate a longer springbrook channel); and (2) rheocrene springs emerge in surfaceflow-dominated channels and therefore may have no effective springbrook channel, although they may locally influence the surfaceflow-dominated channel.

Wetlands Dependent on Groundwater (including peatlands)

The level I field guide recognizes that a variety of wetland types are dependent on groundwater, with many different regional characteristics, classifications, and names. It also affirms that groundwater dependence spans a continuum from completely groundwater dependent to not dependent, with varying levels of dependence between these end members. In this field guide, however, there is no need to distinguish among these different types of groundwater-dependent wetlands. For the purposes of this sampling field guide, all are considered wetlands, including fens, marshes, swamps, wet meadows, and depressional wetlands.

This field guide, however, does distinguish in some ways between fens (i.e., wetlands that have accumulations of peat or muck) and groundwater-dependent wetlands that do not have peat or muck accumulations. Peat and muck are partially decayed plant material that accumulate under saturated conditions where there is little oxygen to facilitate decomposition.

Another way to evaluate these types of wetlands is with the criteria for wetland delineation used by the U.S. Army Corps of Engineers (1987).

Limitations on Use

This field guide is not intended to be used for evaluating some specific nonmarine GDEs:

- Groundwater-dependent lakes and associated riparian areas.
- Base-flow streams and associated riparian areas.

Because of the distinct characteristics of those systems, it is not practical to include them in this field guide. It is expected that other field guides will address those systems, although they may not focus on groundwater conditions and processes. The Forest Service has also developed a guide to characterize and monitor riparian areas (Merritt et al. 2017).

In addition, some wetland systems that look similar to GDEs, but are not dependent on groundwater, are not specifically targeted by this field guide:

- Bogs
- Insurgences and sinkholes in karst areas
- Pocosins—a type of bog in the Southeastern United States (described in Richardson 2003)
- Carolina Bays of the southeastern U.S. Coastal Plain (described in Sharitz 2003)
- Other wetlands not supported by groundwater

Because of the similarities between these systems and GDEs, this GDE field guide may be useful for inventorying and monitoring certain components of those systems.

GDE types that would be difficult to sample with this (and perhaps any) field guide include geysers, gushets, and hanging gardens. This field guide is not designed for underground sampling (e.g., in caves), although it would be appropriate to use for sampling the surface outflow from caves. Springs that include large open water areas (large exposure springs and large limnocrenes) could involve substantial safety concerns and would be difficult to comprehensively sample with this field guide. They require limnological sampling techniques, which are beyond the scope of this field guide.

Settings where this field guide has not been tested include tropical, subtropical, arctic, subarctic, tundra, and permafrost areas, which are beyond the scope of this field guide.

Using the Level I Field Guide

The level I field guide describes specific procedures for field data collection for select GDEs; however, several important activities precede and follow field data collection. In fact, only about one-half of the expected total cost for implementing this field guide is associated with field data collection. The remainder comes from establishing the objectives; selecting an appropriate inventory or monitoring design; training; providing quality assurance and control; providing project administration and data entry; and, most importantly, analyzing and evaluating the information collected. Significant cost savings associated with field data collection can be obtained by spending time "data mining" before the field activities.

The recommended sequence of activities for implementing this field guide is represented in figure 3.

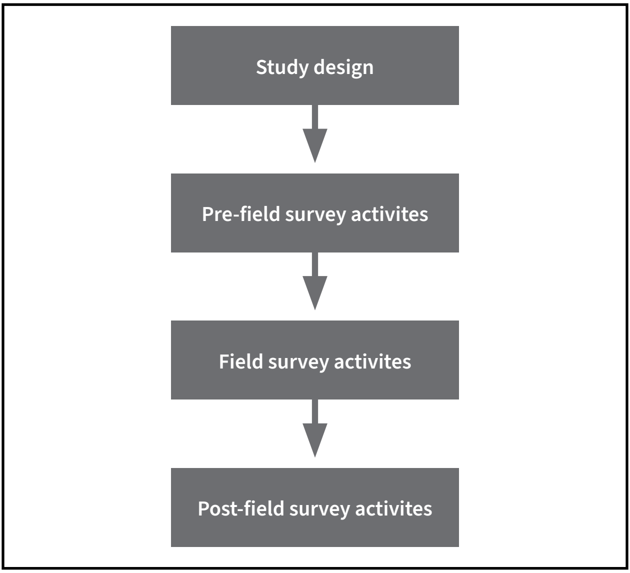

Figure 3.—Recommended approach for successfully using this field guide.

1. **Study design**—Developed by user (not described in detail in this field guide).
   A. Identify management questions and set inventory and monitoring objectives.
   B. Determine the area of interest and selection of sites—systematic, stratified, random design, etc.
   C. Create the sampling and remeasurement schedule.
   D. Identify the relationship to other inventory and monitoring programs and data.
   E. Coordinate with other agencies, Tribes, States, and Forest Service units.
   F. Develop quality assurance and control procedures, including training and data management.
2. **Pre-field survey activities**—
   A. Gather and review background information about sites, which is obtained in the office with focus on existing maps, remote sensing data, and legacy data (data mining).
   B. Establish field logistics and plan for site access, including travel and access restrictions and safety issues.
   C. Interpret available map and remote sensing images.
3. **Field survey activities**—
   A. Use the "Field Survey Activities" part of this field guide to conduct data collection. Data can be collected on paper field forms (see appendix 1)or on a mobile device with the Survey123 GDE Level I Inventory app.
   B. Apply Management Indicator Tool (onsite).
4. **Post-field survey activities**—
   A. Enter data into Springs Online (https://springsdata.org) if surveyors used paper field sheets. If surveyors used Survey123, review entered data. This process should be completed as soon as possible, while surveyors' memories are fresh.
   B. Conduct laboratory analyses of samples, and identify flora and fauna specimens if collected.
   C. Review Management Indicator Tool entries.

D. Review and evaluate collected information in Springs Online (see https://springstewardshipinstitute.org/database-manual-1/).

Skills and Time Required

A broad set of skills is necessary to conduct the sampling outlined in this field guide, which means that several specialists will be needed to collect quality data. The skills required are summarized in the following list:

- Office
  - Geographic information system (GIS), map interpretation
  - Data acquisition—from data warehouses, etc. (which will likely take several days to accomplish)
  - Logistics—transportation, equipment, access, safety, etc.
  - Data entry, specimen identification, and quality control
- Field—Botany
  - Understanding of basic wetland plant ecology
  - Familiarity with regional flora and proficiency in identifying common wetland plant species (i.e., capable of sight recognition of dominant species to the level of genus and species, provided plants are at the proper phenological stage, or capable of sight recognition of dominant species to the family, and proficiency in keying in the field)
  - Ability to collect and press plant specimens so that they will be suitable for later identification or verification
- Field—Animals
  - Familiarity with quantitative and qualitative methods of sampling for aquatic macroinvertebrates, familiarity with regional fauna and proficiency in identifying common faunal species, as well as collection, curation, and identification of specimens
- Field—Hydrology/Hydrogeology
  - Ability to measure flow and water quality, as well as calibration of equipment
  - Ability to describe the hydrogeologic setting of the feature, including aquifers, rock types, geologic structures, and groundwater flow system
  - If monitoring wells or piezometers are to be installed, the ability to install, survey, and monitor them

- Field—Soils
    - Ability to describe the soils at a site (by augering soil cores, digging pit, or other means)
    - Ability to determine soil texture by feel
    - Familiarity with standard soil nomenclature, soil stratigraphy, soil morphology, and USDA Natural Resources Conservation Service (NRCS) soil taxonomy
    - Ability to interpret soil features, particularly hydric soil features, and infer soil processes within a landform setting

With a team of a few (probably two or three) people who have the skills previously outlined, it is anticipated that the field data collection described in this field guide will take about 2 hours to complete. Should a team not possess skills in a particular area, (e.g., botany), it is best to focus on areas in which they are familiar.

When To Sample

No time is ideal for sampling all the attributes described in this field guide. The pros and cons to sampling at different times of the year are summarized here.

Winter

- Hydrology—Good time to determine base flow; very difficult to sample water table in deep snow or when ground is frozen. (In some settings, groundwater discharge prevents ground from freezing.)
- Soil—Very difficult to sample soils in deep snow or when ground is frozen. (In some settings, groundwater discharge prevents the ground from freezing.)
- Vegetation—Very difficult to identify plants and to quantify their abundance.
- Miscellaneous—Might be difficult to access some sites (because of snow). In warmer settings, winter might be a time to avoid excessive heat; there would probably be less disturbance to the site, such as trampling, as a result of field guide implementation. Winter use by herbivores can be observed.

Early in Growing Season

- Hydrology—Hydrology might be highly influenced by weather events (such as snowmelt, high runoff, or rain), and water chemistry measurements may be biased by spring runoff.
- Soil—Soil can generally be sampled.
- Vegetation—Difficult to identify plants and to quantify their abundance.
- Miscellaneous—Access may be a problem for some sites.

Middle of Growing Season

- Hydrology—Good time to measure water table, although flow and water table could be influenced by weather events (such as rain).
- Soil—Good time to do soil sampling.
- Vegetation—Good time to identify plants and to quantify their abundance.
- Miscellaneous—Most sites are accessible. Livestock use can be observed.

Late in Growing Season

- Hydrology—Good time for determining groundwater influence, although water tables may be lower than they are in midseason, making some water chemistry measurements difficult.
- Soil—Good time for sampling whole soil profiles.
- Vegetation—In general, a good time to identify most plants, but some plants may have reached senescence, making identification difficult.
- Miscellaneous—Good time for observing or measuring effects of use by herbivores.

The weather conditions always need to be recorded and considered when evaluating the data. For example, rain can alter pH and conductivity and raise the water table.

Preventing Damage to Sites

Springs, fens, and other GDE wetlands are relatively uncommon on the landscape in most areas and are also vulnerable to impacts from activities associated with data collection. Small GDE sites are particularly vulnerable because the impacts are concentrated over a small area. Appendix 2, "Site Protection Guidelines," outlines specific suggestions for minimizing damage to the plants, soils, and hydrologic processes of these valuable ecosystems.

Pre-Field Survey Activities (in office)

This section explains what information should be gathered or acquired in the office before going out to the field. This information can be compiled in the office using existing data in Forest Service Enterprise Data Warehouse (EDW) applications, National Hydrography Database (NHD), National Wetland Inventory (NWI), Springs Online, range program databases, and through map and remote sensing (including photo) interpretation. Some of this information might be updated after the site visit, when field-determined coordinates for the site can be plotted on the map.

Obtain information necessary to address some of the Management Indicator Tool statements before going to the site. Review the applicable land resource management plan to determine whether the plan recognizes and provides direction for conservation and protection of the site. Identify whether any management activities have taken or are currently taking place at the site. Also, identify if any authorized uses are located at the site and the terms and conditions of those authorizations.

Site Information

Feature Not Found

There can be instances where a GDE is mapped, but a site visit does not result in the discovery or classification of a GDE. Springs data in NHD often do not represent the actual location of the spring; it is important to explore up to a 100-meter radius surrounding the erroneous location when safe and possible. If no GDE is located in that radius, or an existing feature does not meet the criteria of a GDE, then this should be documented and described in the site description. Where a diversion or outflow is mapped as a spring and the source is located elsewhere, it is best practice to document that and inventory the source as a new location with the same name but with "Source" added to the name.

Site Name

Description—The site name is a descriptive name for the site, such as the common name of a spring or wetland. This is a required field.

Source—The site name can be obtained from the following:

- Springs Online, the mapping service published by the EDW, or from a geodatabase provided by the Springs Stewardship Institute. The spring name may not be correct, however. Many are listed as "Unnamed" or by the NHD ID number, while USGS maps may include a name, or the land agency may have named it. In general, it is best to defer to the land agency.
- Maps—
    - USGS quadrangle map (these names are also listed in the USGS Geographic Names Information System).
    - Forest Service primary base series maps, which are the Forest Service version of the USGS quadrangle map.
- Management plans, such as a forest plan, project plan, or allotment plan, or existing authorizations that specify the site by name.
- If no site name exists in the sources previously listed, create a descriptive name that is representative—and respectful—of the site. It is helpful if this name is unique. For example, there are many springs named "Big," "Little," "Warm," "Cold," "Willow," "Coyote," etc.

SiteID

Description—The SiteID is a unique identifier from Springs Online for each GDE site. It is necessary for managing the data in the field. It is the basis for relationships with all survey data in the Springs Online database. The same SiteID should be used for different sampling events at the same site (such as monitoring over time).

Source—The SiteID may be obtained from Springs Online, from the mapping service published by the EDW, or from a geodatabase provided by the Springs Stewardship Institute. As many springs are already in this database, it is important to locate it to avoid adding a duplicate GDE. Refer to https://springstewardshipinstitute.org/searching-for-springs. If no spring exists, please add it to Springs Online, and the system will generate a SiteID. If data are entered into Survey123, enter the SiteID if one exists. If not, one will be generated during the import process.

State

Description—The U.S. State, possession, or territory where the site is located. This is a required field.

County

Description—The county or equivalent in which the site is located. This is a required field.

Land Unit

Description—The land ownership where the site is located. This is a required field.

Options include Forest Service; U.S. Department of the Interior (DOI) agencies, such as U.S. Fish and Wildlife Service and Bureau of Land Management; county government; etc.

Land Unit Detail

Description—On Forest Service lands, the ranger district in which the site is located. For other land agencies, this should be the equivalent (e.g., Grand Canyon National Park.) This is a required field.

Proclaimed National Forest

Description—The national forest, grassland, or prairie in which the site is located. This field is only applicable when land status is Forest Service.

Land Manager ID

Description—The land manager ID is different than the Springs Online ID and is used if the unit performing the survey has their own ID system.

Site Description

Describe the setting, history, and landscape context. This information should remain the same across multiple surveys.

Site Sensitivity

Some springs sites have cultural, biological, or physical attributes that make them sensitive to disturbance and data from these sites may be proprietary. Indicate the sensitivity level of the site.

Access Directions

Coordinates

Determine or estimate UTM coordinates or latitude/longitude in decimal degrees before the site visit to help with the field crew arrival at the site. Update or confirm the coordinates during the field survey.

Driving Route

Provide driving directions from the nearest town to the site (if the site is beside a road) or to a place where a vehicle is parked before walking to the site (e.g., a trailhead). Confirm or update these as necessary upon reaching the site.

Hiking Route

Provide hiking directions from a location where a vehicle is parked to the site. Give precise access directions beginning with a landmark (e.g., a named point on the topographic map, a major highway, marked trailhead) readily locatable on a 7.5-minute topographic map as the starting point. Use clear sentences that will be understandable to someone who is unfamiliar with the area and who has only these directions to follow. Give distances and use compass directions (distinguishing true north or magnetic north).

When possible, provide a GPS path and the ArcMap project name where data are stored for use in Trimble or other GPS data logger. Avoid ambiguous words such as “above,” “near,” beyond,” “on the back side of,” or “past.” If site locations lack major landmark features as guides, use township, range, and section information from topographic maps. Although the sample sites may not be permanently marked, others may want to relocate them for long-term monitoring purposes. Careful documentation of the access route and obvious landmarks are, therefore, important. Update or confirm the directions upon reaching the site. Note any challenges related to access, such as crossing private land, making a climb, or hiking across rugged terrain.

Mapping

This section describes maps and map sources necessary to locate and describe the site. A list of useful geologic map resources follows:

- Overview of USGS geology products and work—http://geology.usgs.gov/
- Link to National Geologic Maps Database website for downloading by State, etc.—http://ngmdb.usgs.gov/ngmdb/ngm_catalog.ora.html
- Link to State geological surveys—http://www.stategeologists.org/

Geologic Map Source

Record the source for geologic mapping.

Geologic Map Unit

Determine the geologic unit at the site from the geologic map. It can be helpful for establishing the hydrogeologic setting. This can be derived spatially once a GPS location is established for the site and a digital geologic layer is obtained.

Soil Map Source and Unit

This is the soil map unit or the soils classification. This can be derived spatially once a GPS location is established for the site and a digital soil layer is obtained.

Archaeological, Paleontological, Cultural, or Historic Sites or Use

Research records for cultural resources or historic use (e.g., archaeological or paleontological sites) at sites to be inventoried. This will help limit damage to important cultural resources.

Available Data

Seek out and list other sources of data that are available about the site.

Field Survey Activities

Field forms are in appendix 1. Metric units of measure are highly recommended to facilitate data summarization. Disturb the site as little as possible while collecting data, as described in appendix 2, "Site Protection Guidelines." Appendix 3 lists equipment needed to implement this field guide.

Survey Information

Survey Date

Record the calendar month, day, and year the site was visited. This is a required field.

Time

Record the time of day for the start and end of the field data collection. Use 24-hour time. Recording the duration reflects the intensity of the survey.

Examiners

Record the first and last names of the crew that is doing the field data collection. This is a required field.

Project Name

Description—The project name is a descriptive term for the field guide implementation effort. A project can be a data collection activity containing multiple data collection sites guided by a specific purpose. Multiple sites can be within the same project. This is a required field.

Source—The project team will create this name. It should be short (maximum 30 characters), yet descriptive (e.g., not “springs inventory”). Record it consistently across all inventories.

Weather

Weather can be important when interpreting water chemistry and water level information; for example, rain can alter the pH and conductivity measurements and raise the water table.

Record evidence of precipitation (rain or snowfall) during the sampling visit or evidence of recent rain or snowfall.

- ☐ Recent rain
- ☐ Rain during survey
- ☐ Snowfall, hail, or sleet during survey
- ☐ Snow on ground
- ☐ No current/recent precipitation

Air Temperature

Record the daytime air temperature at the time of the visit. Indicate F or C

Area of GDE

For very small or unusual sites, see box 3 before proceeding.

Box 3

Note for Very Small Sites

Very small sites are vulnerable to damage from disturbance caused by the crew collecting data. Follow these guidelines for sampling very small sites (see appendix 2):

- Walk outside of the GDE site as much as possible.
- Record vegetation information from outside the GDE if possible.
- Take photos and draw the site sketch from outside the site.
- Consider skipping soil core and water table measurements.
- Conduct water measurements carefully.
- Make only one trip (or very few) in/across the GDE for measurements.

Note for Unusual Sites

At sites on walls, such as gushets and hanging gardens, record whatever information can be observed from a safe distance.

Other suggestions include—

- Take pictures.
- Use binoculars.
- Use a range finder.

Description—This is a measure of the area or size of the GDE site. A GDE site generally has distinctive vegetation that is present because of the proximity to the water table. In some settings, such as drier regions, a very clear boundary may exist, which is evident from different vegetation or topographic differences, between the GDE and the uplands. In other settings, a more gradual transition from wetland to upland will occur, with significant zones of transition that include both wetland and upland plant species and very little change in slope. In such cases, the determination of the boundary of the wetland is somewhat subjective, and must be based, ultimately, on either a judgment call or detailed sampling. The following guides will help determine the extent of the GDE.

Hydrology—Water on the surface of the ground, or saturated ground (not from recent precipitation), can be an indication that the area is part of the GDE, although the absence of water does not preclude it from being part of the GDE.

Vegetation—The GDE will typically have obligate, facultative wet, and facultative wetland species, as distinguished by the Wetland Indicator Status of the U.S. Fish and Wildlife Service (1988). The edge of the GDE will generally be associated with a transition from those wetland species to more upland species. The presence of bryophytes could be indicative of a GDE wetland, although the absence of bryophytes does not indicate that it is not part of the GDE.

Landform—A change in slope (from flatter to steeper) can be associated with the edge of the GDE.

Peat or muck—The presence of peat or muck can indicate a GDE wetland. A boundary, with peat or muck on one side and no peat or muck on the other, could be an indication of the edge of the GDE. The absence of peat or muck does not preclude it from being within the GDE.

Spring—A spring will include an orifice, where water emerges, and possibly a pool and/or channel. Include the orifice and emergence zone, which generally includes obligate and facultative wetland plant species, as distinguished by the Wetland Indicator Status of the U.S. Fish and Wildlife Service (1988), which are supported by the groundwater discharge or shallow water table. A key question in the application of this field guide is how much of an associated springbrook should be included in the site area. The response can be an arbitrary choice, based on a set run-out distance; a subjective decision, based on how far the riparian zone appears to be strongly influenced by the spring; or a more objective decision, such as one used in western arid regions, which considers the downstream boundary of the spring to be the point where the springbrook water temperature changes by 2 degrees Celsius. Pros and cons accompany each of these alternatives. In this field guide, 20 to 50 meters of the run-out stream, or springbrook, are included in the site area for sampling. If it is desirable to inventory (or monitor) a longer distance of a springbrook, then a stream and/or riparian protocol should be used to collect the data, which would then be considered as a separate (although companion) set of data from those collected from the spring as a part of this field guide.

How to measure and record—If possible, walk around the perimeter of the GDE when measuring or estimating size (to avoid excessive trampling). Determine the size of the GDE site (including all the spring and wetland features present) by one of the following methods (listed in order of highest to lowest recommendation):

1. Measure the average width and length
2. Estimate the size using maps or images
3. GPS traverse of GDE edge
4. Sketch the perimeter in an app on a mobile device using an image in the background
5. Other (describe in site condition notes)

Site Condition

Describe the condition of the site. This is different than the site description and can change between surveys.

Georeferencing

Reference Point

Description—A reference point is a unique feature on the ground that can be clearly described and plotted on the sketchmap, and relocated for future sampling visits.

How to measure and record—For springs, the reference point should be the spring source. For wetlands that are relatively small, the reference point could be the center of the wetland or the wettest part of the wetland. For larger GDEs, the reference point could be the center of the site or some distinguishing feature within the GDE.

At the reference point, record the latitude and longitude coordinates that will enable someone to return to or near that location. Also record specific information or features that can be used to relocate the exact position of the reference point, ideally including a monumented tree, stake, fence, large boulder, or the distance and direction from some permanent feature such as a road or stream crossing.

Indicate where the reference point is on the site sketch (see "Photographs" section).

GPS Model

Record the make and model of the GPS equipment used and the accuracy or position error (in meters).

Latitude and Longitude (from GPS)

Record the latitude and longitude at the reference point. This should be recorded in decimal degrees.

- Latitude decimal degree: Latitude in a degree value. Consists of the latitude in degrees to at least six decimal places.
- Longitude decimal degree (negative for North America): Longitude in a degree value. Consists of the longitude in degrees to at least six decimal places.

Universal Transverse Mercator Coordinates (paper form only)

UTM zone—This is the zone for the UTM projection. It can be obtained from quad maps or from GPS devices. UTM zone coordinates measure in meters east and north from two perpendicular reference baselines.

Easting—This is the distance in meters, east or west, from the central meridian of the UTM zone, which is designated at a value of 500,000 meters.

Northing—This is the distance in meters north from the equator from the UTM zone origin, which is designated as a value of zero meters. (This field guide addresses only north latitudes.)

Horizontal Datum

Description—This is the GPS datum used to record the location information in the field.

How to measure and record—Record the datum for the projection at the "reference point."

- ☐ World Geodetic System of 1984 (WGS-84) (recommended).
- ☐ North American Datum of 1927 (NAD-27).
- ☐ North American Datum of 1983 (NAD-83).

Georeference Source

Description—Source for determining the site location.

How to measure and record—Record how the site location was determined (GPS, map, survey GPS, or other).

GPS Equipment

Description—The make and model of the GPS equipment.

How to measure and record—Record the make and model of the GPS equipment used and the approximate GPS accuracy.

Elevation

Description—The elevation of the site in meters.

How to measure and record—Record the elevation in meters with a GPS unit at the reference point. Substantial error in GPS measurements may exist, but these data are generally adequate to characterize site elevation. Surveyors may get a better estimate using a topographic map. Note how elevation was determined.

- ☐ GPS unit
- ☐ Topographic map (if necessary, interpolate between two contour intervals)
- ☐ Other:

Georeference Comments

Note anything that influenced the consistency, completeness, or reliability of spatial information (e.g., position error is high).

Site Sketch Map

Description—This is a hand sketch of the site that includes sample locations, important features, etc. The sketch map is useful for understanding the site and to facilitate relocating the site on return visits. The sketch is also useful where GDE sites may be close to one another and map/GPS coordinates weakly describe the relative location of sample sites.

How to measure and record—Draw a sketch (hand-drawn map or electronic) of the site (see example in figure 4). One way to do this is to use an aerial photo to trace the boundary of the GDE onto a blank page that then becomes the sketch of the site.

Graph paper is useful for drawing the sketch map, using the lines as known distances. The items in the following list should be captured and documented on the sketch map for each site.

- Reference point (described previously)
- Approximate locations/dimensions of major geomorphic surfaces
- Springs—
  - Spring source
  - Channel locations
  - Structures including spring boxes, troughs, and pipelines
  - Location of pools, if any
- Areas of standing water (indicate deepest part)
- Location of measurements—
  - Soil holes
  - Water table measurement locations
  - Wells/piezometers
  - Water quality samples
- Structures or other man-made features, such as roads, in or adjacent to GDE
- Indication of north (true recommended, or magnetic)
- Indication of scale
- Boundaries of GDE, or the delineation of the area sampled if only a portion of the site was sampled (the site was divided)

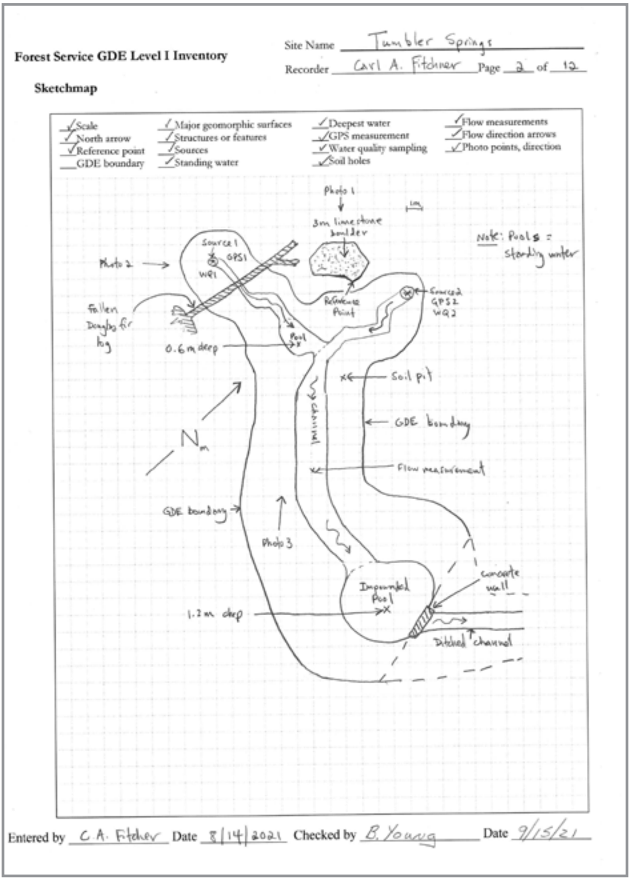

Figure 4.—Site sketch map example.

Site Geomorphology

GDE Type

Description—A general classification of the GDE type at the site, with the option of a secondary type.

How to measure and record—Record the primary (dominant) GDE type and secondary GDE type present at the site (figs. 5 and 6). Only one primary type and one secondary type can be recorded.

This classification system is based on Springer and Stevens 2009, and further refined in Stevens et al. 2021. The dichotomous key to spring types is in appendix 8. Diagrams, photographs, and descriptions, are available at https://springstewardshipinstitute.org/key.

- Anthropogenic—A spring ecosystem created by human action. This should only be designated as a secondary type because classification is based first on function.
- Cave—Groundwater emerges in or from a cave; common in karst terrain.
- Exposure—Groundwater is exposed at the land surface but does not have persistent surface inflow or outflow; occurs in karst (sinkholes) and lava flows but could form in other types of vertical conduits into an aquifer.
- Fountain—A nonthermal artesian spring that is forced above the land surface by stratigraphic head-driven pressure or CO_2.
- Geyser—Intermittent spring, driven by geothermal heat or gas pressure, that emerges explosively.
- Gushet—Discrete source of flow pouring from a cliff face; typically emerge from perched, unconfined aquifers, often with dissolution enhancement along fractures; exhibit thin sheets of water flowing over rock faces.
- Hanging garden or wet wall—Spring that emerges along geologic contacts or fractures and seeps, drips, or pours onto the underlying landscape; typically emerging from perched, unconfined aquifers.
- Helocrene—Spring that emerges diffusely from low-gradient wetlands; often indistinct or multiple sources seeping from shallow, unconfined aquifers (may include fens and ciénegas).

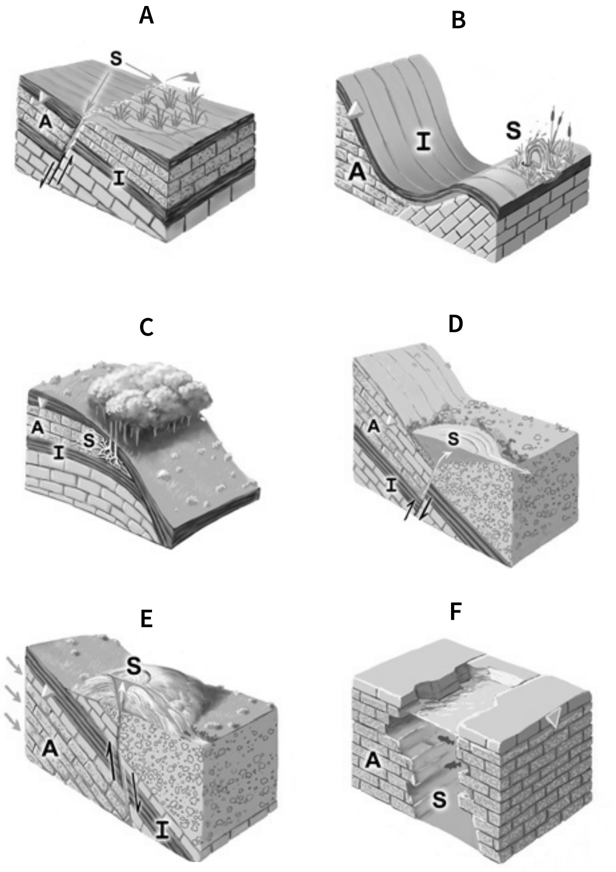

Figure 5.—Lentic spring types, including (A) helocrene, (B) fountain, (C) hypocrene, (D) limnocrene, (E) mound-forming, and (F) exposure springs. “A” on each figure stands for aquifer; “I” represents impermeable infiltration barrier (aquitard); “S” stands for surface groundwater expression (spring source). (Stevens et al. (2021), Springs Stewardship Institute, and John Wiley & Sons)

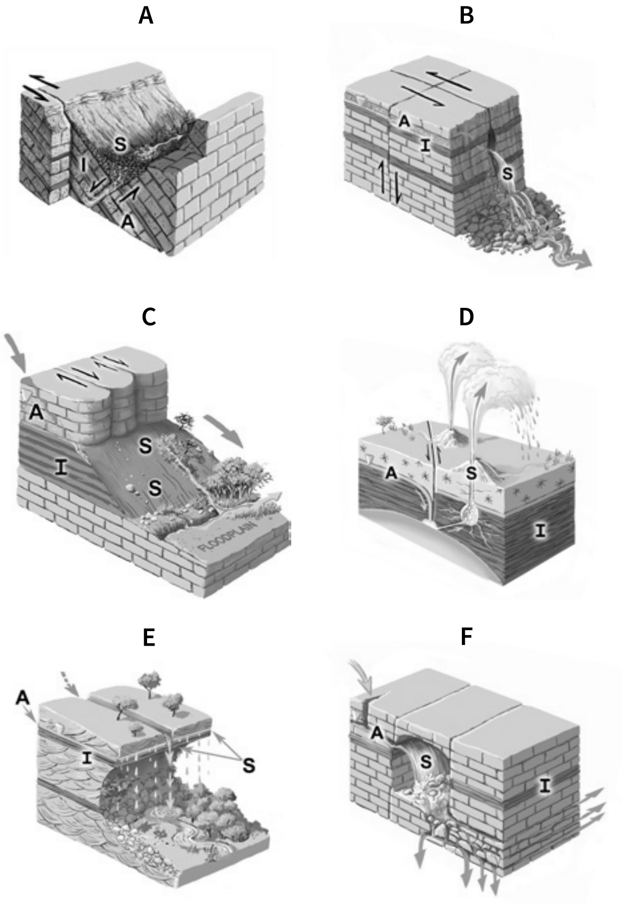

Figure 6.—Lotic spring types, including (A) rheocrene, (B) gushet, (C) floodplain and upland hillslope, (D) geyser, (E) hanging gardens, and (F) cave springs. “A” on each figure stands for aquifer; “I” represents impermeable infiltration barrier (aquitard); “S” stands for surface groundwater expression (spring source). (Stevens et al. (2021), Springs Stewardship Institute, and John Wiley & Sons)

- Hillslope—Spring that emerges on a hillslope, often with indistinct or multiple sources of groundwater; flow usually focuses into a springbrook channel downstream. Rheocrenic hillslope springs emerge within a stream floodplain.
- Hypocrene—A buried spring where groundwater levels come near, but do not reach, the surface, typically due to aquifer confinement, low discharge, or high evapotranspiration. In humid regions these features may be equivalent to shallow groundwater areas including wet meadows.
- Limnocrene—Groundwater emerges in pool(s).
- Mound—Spring that emerges from a mound of mineralized precipitate (often carbonate), organic matter (e.g. peat), or ice (e.g. pingos), frequently at magmatic or fault systems. May also include springs issuing from peat mounds.
- Rheocrene—A spring that upwells into an established stream channel, including springs that emerge into an otherwise dry stream channel, as well as subaqueous springs that provide gaining flow to a stream. In contrast, hillslope springs emerge with no established channel upslope of the source.

Source Geomorphology

Description—The source geomorphology is the kind of structure that may be controlling the flow of groundwater to the GDE, such as a geologic contact or fault plane. Many GDEs occur on geologic structures because they can create preferential pathways for the flow of groundwater. This is helpful for understanding the hydrogeologic setting of the site and from where groundwater is sourced.

How to measure and record—Record the type of geologic structure (preferential groundwater flow path) that is discharging water to the site. Observe the geologic units and geologic structure and compare that to a geologic map. Record your conclusions based on the following list:

- Bedding—Planar surfaces that visibly separate layers of stratified rock.
- Conduit—Tubular opening, common in karst terrain.
- Contact—Planar surfaces that separate different rock units.
- Fault—Fracture or a zone of fractures along which there has been displacement.
- Fracture—Fracturing in rock, without displacement.

- Seepage or filtration—Groundwater is exposed or discharged through numerous small openings in permeable material.
- Other or unknown.

Surficial Material

Description—This is the kind of unconsolidated material occurring at the surface. Many GDEs, particularly fens, develop on unconsolidated surficial materials. The type of material can influence the water chemistry and ecology.

How to measure and record—Record the kind of material occurring at the surface. Surficial materials are defined as nonlithified, unconsolidated sediments. They are materials produced by weathering, sediment deposition, biological accumulation, and human and volcanic activity. They include residual materials weathered from rock in situ; transported materials composed of mineral, rock, and organic fragments deposited by water, wind, ice, gravity, or any combination of these agents; accumulated materials of biological origin; materials moved and deposited by human actions; and unconsolidated pyroclastic sediments. Record the primary surficial material; secondary surficial materials may also be recorded.

- ☐ Alluvium—An unconsolidated accumulation of stream deposited sediments, including sands, silts, clays, or gravels.
- ☐ Colluvium—Soil material and rock fragments moved downhill by creep, slide, slough, or local wash and deposited at the base of steep slopes.
- ☐ Eolian deposit—Wind-deposited sediments.
- ☐ Glacial deposit—Includes unsorted and unstratified till, including moraines, which are generally exposed in the uplands; and glacial meltwater deposits of sorted and stratified deltaic, stream, and lake sediments.
- ☐ Human-caused or constructed—Natural and man-made materials that have been artificially emplaced.
- ☐ Lacustrine sediments—Sediments deposited in lakes.
- ☐ Landslide deposit—Sediment deposited by downslope movement of a sorted or poorly sorted mass of soil or rock of mixed grain sizes, including rock falls, slumps, mud flows, debris flows, and earth flows.
- ☐ Marl—A friable deposit consisting of clay and calcium carbonate.

- ☐ Residuum—Weathered bedrock.
- ☐ Rock—Bedrock with no surficial material present.
- ☐ Talus deposit—An accumulation of angular rock debris at the base of a cliff or steep slope that was produced by physical weathering.
- ☐ Tufa or travertine deposits—Travertine is a sedimentary rock, formed by the precipitation of carbonate minerals from solution in ground and surface waters, or geothermally heated hot springs. Similar, but extremely porous, deposits formed from ambient temperature water are known as tufa.
- ☐ Volcanic unconsolidated material—Ash or mudflow.
- ☐ Other/unknown.

Lithology, Primary (groundwater source aquifer)

Description—Primary lithology describes the geologic materials such as bedrock or other surficial materials under a site. The groundwater source aquifer refers to the aquifer from which the groundwater is emanating. **The primary lithology is generally the groundwater source aquifer.** Primary lithology is useful for understanding the groundwater flow patterns. The location and hydrology of GDEs are controlled by the geology, and the type of rock can influence the water chemistry and ecology of the feature.

How to measure and record—If evidence in the field exists, then record one of the following primary lithology descriptors. If no evidence in the field exists, then answer this question in the office using the electronic resources listed in the "Mapping" section. If the groundwater emerges from a talus or other unconsolidated material at the base of a slope, then try to determine the upgradient geologic unit from which the groundwater is originating. The important bedrock lithology or geologic unit is the one supporting the aquifer that supplies water to the feature.

- ☐ Igneous
- ☐ Sedimentary
- ☐ Metamorphic
- ☐ Unconsolidated

Lithology, Secondary

Description—This is a finer scale description of the lithology of rock units occurring at the site and is tiered to the primary lithology of the aquifer from which the groundwater is emanating, or the original rock type that weathered to form the parent or surficial material.

How to measure and record—If evidence in the field exists, record the secondary lithology (tiered to the primary lithology) from the list in appendix 4.

Evidence of Groundwater

Record the evidence that this ecosystem is groundwater supported. Use the decision tree in box 2 to help with this determination. Multiple answers are allowed.

- ☐ Flow from a spring source, contact, joint, or fault—indicating spring
- ☐ Peat or muck accumulation significant
- ☐ Standing water
- ☐ Wetland vegetation
- ☐ Other/Unknown

Relative Area of GDE

Description—The percent of the area covered in general categories of GDE settings (complexes of springs, wetlands, open water, and other settings).

How to measure and record—Estimate the percent of the area within the GDE site that is covered by the following settings (must sum to 100 percent).

- Spring emergence
- Channel (such as springbrook or other channel)
- Peatland
- Wetland/riparian
- Open water (standing, not generally flowing)
- Other or unknown

Slope

Description—The general incline of the site.

How to measure and record—Measure in degrees. This is measured as an average for the site.

Aspect

Description—The general direction that the site faces along the fall line.

How to measure and record—Record the azimuth that the landscape faces as an average. Record in degrees, 0 to 360, noting whether the reading is true north or magnetic north. If the site is flat (common with a helocrene or limnocrene), leave this value blank (a zero value indicates it is a north-facing site).

Water Table (wetlands)

In general, water table measurements will be done at wetlands and not at springs, although exceptions do occur. Water table data will be collected at one point, which may be in the boreholes created during soil sampling, or other locations.

Note: One-time water table measurements give only a general idea of the water table for a site. Multiple measurements during the season using piezometers would provide information about the variability (or seasonality) of the water table.

Flow Patterns for Site

Description—This indicates whether the inflow and outflow are surface water, groundwater, or a combination of the two. This helps to characterize the overall water budget of the wetland. The water budget of wetlands varies in the dependence on groundwater inflow/outflow or surface water inflow/outflow.

How to measure and record—

Inflow (select one):

- Dominated by groundwater inflow
- Dominated by surface water inflow and/or precipitation
- Both groundwater and surface water inflow

Outflow (select one):

- Dominated by groundwater outflow
- Dominated by surface water outflow
- Both groundwater and surface water outflow
- Dominated by evapotranspiration

Location of Water Table Measurements

Description—The location within a wetland where a water table depth measurement is taken will be at either an unbiased or targeted location. In general, wells or piezometers are required for meaningful, long-term water table monitoring.

How to measure and record—Establish locations using one of these methods:

- ☐ Center of site (unbiased)
- ☐ Pool
- ☐ Downgradient from orifice
- ☐ Other (targeted):

Source of Water Table Measurements

Description—This indicates the source of the water table depth measurement or where it was taken in a wetland. This helps with interpreting the water table data.

How to measure and record—If wells are installed, the water table measurements should be taken from the wells rather than from the soil core boreholes. Note which of the following sources was used:

- ☐ Depression
- ☐ Soil hole
- ☐ Standing water
- ☐ Well/piezometer
- ☐ Other:

Hole Depth

Description—This is the maximum depth of the hole in centimeters where the water table data are collected. If the soil hole is used, then this will be the same value entered for the soil hole depth.

How to measure and record—Measure the depth in centimeters of the pit or borehole from the surface to the bottom of the hole.

Water Table Depth

Description—This attribute helps to establish the depth to water below the ground surface in wetlands. It would probably not be measured at springs that do not have an associated wetland, because the water table or piezometric surface at a spring is by definition at the surface.

This attribute helps provide an understanding of conditions that influence plant species, particularly wetland plant species that are highly dependent on a shallow water table for survival. Small changes in water table depth can cause changes in wetland plant community composition.

How to measure and record—Groundwater depth (centimeter) is measured in the borehole from the soil core or by augering a hole. The appropriate depth of a hole is somewhat site specific, but would typically be 0.5–1 meter or to the bottom of the peat (where applicable). Be aware that once the hole penetrates below the bottom of a peat layer, the water level may rise in the borehole, indicating artesian conditions. Peat layers are occasionally confining units and can sometimes "float" on the underlying aquifer. Therefore, in those situations, the water level measured in a hole would represent the piezometric surface of the hydrogeologic unit underlying the peat, which frequently exhibit strong upward vertical hydraulic gradients. To get the true water table elevation within the peat, the borehole must not penetrate through the base of the peat.

Before measuring water table depth, allow time for water in holes to equilibrate (at least 30 minutes, but preferably a few hours). Water table measurement could be taken just prior to refilling the boreholes at the end of the field day, which would provide time for the water in the hole to equilibrate with the water table.

If water is at or above the surface, then it is not necessary to auger a hole or measure water table depth. The water table would be at the surface or at a depth of zero.

Steps to measure water table depth:

- Auger a hole approximately 0.5 to 1 meter in depth. A hole can also be dug using a sharpshooter shovel, although this creates more disturbance to the wetland.
- Allow the water level in the hole to equilibrate. Monitor the water level depth to determine when the water level has stabilized.
- Lay a shovel or similar object across the top of the soil pit opening and measure from the bottom of this object. Record the distance to water.
- For standing water, record zero, which indicates the water is at or above the ground surface.

If no water remains in the hole, even after waiting for a period of time, then record it as "dry."

Soils

Refer to the soils map to get an idea of the range of expected soils and whether the mapped soils are consistent with the soils observed at the site. Soil attributes apply mostly to wetland sites.

A single soil sample is taken to get a general idea of the amount of organic material and wetland soil features present. This sample is generally taken from the center of the site.

These soil sampling methods are generalized from USDA NRCS (2006) and Schoeneberger et al. (2002) and are intended to give a general characterization of the soils and focus mainly on the level and duration of saturation. Information on the soil profile gives an indication of the amount of peat development and peat texture, the degree of water table fluctuation, and some indication of the underlying aquifer materials. This field guide is not intended for soil mapping purposes or to generate rigorous characterizations of soil profiles for the entire wetland site. Methods here should not be used when regulatory or jurisdictional requirements must be met.

There are various ways to take soil samples, such as with a soil shovel (sharpshooter), an auger (to extract a core), or a soil push probe. A technique that minimizes disturbances is recommended. If an auger is used, soil texture should influence the size of auger to be used. Water table elevations may also be recorded in the soil holes and these locations would also be logical locations for piezometers or minipiezometers should long-term water table monitoring be necessary (see Hydrology section). The depth of the soil sample should be about 50 centimeters to 1 meter, if possible. Advancement of the hole can stop when a total of 40 centimeters of organic soil is measured.

Wet soils and standing water are more difficult for soil sampling, but in many instances, it can be accomplished if the water is not too deep. Sampling soils at springs is not necessary if only a mineral substrate exists; however, if organic soil exists at a spring, then soil information should be recorded. The following list describes some reasons why soils information might not be collected:

- Small site, where sampling is considered too destructive
- Threatened, endangered, or sensitive plant or animal species present at the site
- Gravel, cobble, or boulder substrate
- Deep water
- Frozen ground

An equipment list for soil data collection is in appendix 3.

Location of Soil Sample

Description—This is the location within the site where soil information is collected.

How to measure and record—Record the location of the soil sample as one of the following:

- ☐ Targeted, center of site
- ☐ Targeted, other:
- ☐ Unbiased, random
- ☐ Unbiased, systematic

Method of Extracting Soil

Description—This is the method or tool used to extract and observe soil. When analyzing soil information for the site, this will provide the level of reliability in the data collection effort.

How to measure and record—Record one of the following for each hole or core:

- ☐ Auger/core
- ☐ Push probe
- ☐ Shovel
- ☐ Other:

Depth of Peat or Muck

Description—Organic soils that develop in saturated (water-logged) conditions that prevent decomposition. Histosols, histic epipedon, and the presence of fibric soil material (peat), hemic soil material (mucky peat), and sapric soil material (muck) are considered the maximum expression of anaerobiosis and are interpreted as indicators of extremely long-term saturation.

Organic soil materials have organic carbon content (by weight) of 12 to 18 percent or more, depending on the clay content of the soil. Laboratory analysis of organic carbon content can be done if needed to respond to specific management questions. Dig to at least 40 cm. Digging deeper to document deeper peat is always beneficial, but documenting soil conditions to at least 40 cm is necessary to characterize the wetland as a fen.

How to measure and record—Record the depth in centimeters where the peat, mucky peat, and muck layers begin and end in the first 40 centimeters. In wetlands, live roots and rhizomes are concentrated in the top 20–25 cm below the surface—this is living plant material, not peat. The definitions for the different organic layers to record are listed below:

- Peat (fibric)—Undecomposed or weakly decomposed organic material; plant remains are distinct and identifiable; yields clear to weakly turbid water; no peat escapes between fingers.
- Mucky peat (hemic)—Moderately to well-decomposed organic material; plant remains recognizable but may be rather indistinct and difficult to identify; yields strongly turbid to muddy water; amount of peat escaping between fingers ranges from none up to one-third; residue is pasty.
- Muck (sapric)—Strongly to completely decomposed organic material; plant remains indistinct to unrecognizable; amounts ranging from about one-half to all escape between fingers; any residue is almost entirely resistant remains, such as root fibers and wood.

Depth to the Mineral Layer

Description—This is a measure of the depth in centimeters to the first dominantly mineral layer below any organic layer that may be present. If there exists a significant organic layer, such as peat, then the mineral layer would be below that. If there is a small or nonexistent organic layer, then this depth will be shallow.

How to measure and record—Measure the depth from the surface to the first mineral layer (would be zero if no organic layer exists).

Texture of Mineral Layer

Description—Texture describes the mineral particle sizes and proportions in a sediment, such as clay, silt, and sand.

How to measure and record—Conduct a tactile evaluation of the soil texture of the first underlying mineral layer.

Color of Mineral Layer

Description—Color is useful to understand the composition of the soil and gives clues about the conditions the soil is subjected to.

How to measure and record—Describe the color of the first underlying mineral layer, using the Munsell color system chart.

Redoximorphic Features

Description—The type and location of redoximorphic features within the soil profile are used to interpret the degree of water saturation. Redoximorphic features, a result of iron (Fe) and manganese (Mn) oxidation and reduction, are not expected in organic soils, thus, there is no need to record redoximorphic features in histosols (40 centimeters or more of the upper 80 centimeters is organic soil); mineral soils having a histic epipedon (surface horizons of 20 centimeters or more thick of organic soil material and underlain by mineral soil material with a chroma of 2 or less); or mineral soils having peat, mucky peat, muck, or a mucky modified soil texture within 30 centimeters of the surface.

For all other soils, redoximorphic features can indicate the duration of saturation. Under long duration (many weeks to months) of water saturation and reduction, Fe oxide depletion features occupy the entire groundmass. The Fe oxide-depleted groundmass appears grayer or lighter in color. Short duration of water saturation or rapid fluctuation of water tables results in Fe/Mn oxide nodules and coatings.

How to measure and record—Record the presence and depth of the following features:

- Redoximorphic concentrations—Redox concentrations include soft masses, pore linings, nodules, and concretions (see glossary for definitions).
- Redoximorphic depletions—Bodies of low chroma (2 or less) having value of 4 or more where Fe/Mn oxides have been stripped or where both Fe/Mn oxides and clay have been stripped, see glossary for definitions. Soils having an abundance of gleyed material are saturated for long duration resulting in thorough reduction of iron to Fe+2 (ferrous iron). It is the presence of ferrous iron that is responsible for the greenish colors of gley. An absence of iron concentrations within a gleyed zone indicates a stable reducing environment and that periodic, or seasonal, fluctuation of soil saturation does not occur at that depth.
- Reduced matrices—A soil matrix that has low chroma and high value, but in which the color changes in hue or chroma when the soil is exposed to air. The color change should occur within 30 minutes.

Note: In soils derived from dark parent materials (value 4 or less, chroma 2 or less), redoximorphic features may be difficult if not impossible to recognize in the field.

Hydrogen Sulfide Odor

Description—A “rotten-egg smell” indicates that sulfate is being reduced, and therefore the soil is anaerobic. In most hydric soils, the hydrogen sulfidic odor occurs only when the soil is saturated and anaerobic.

How to measure and record—Record as a yes/no response if the odor is detected as the hole is dug and the soil is removed.

Reaction To Dilute HCL

Description—A carbonate reaction can help identify systems supported by calcareous aquifers. This is a measure that is useful for identifying rich fens. This is a yes/no response.

How to measure and record—Acid (hydrochloric acid diluted to a 10 percent solution, or vinegar) is applied directly to an unweathered soil specimen. A positive reaction confirms the presence of carbonates. The effervescence using vinegar usually requires a hand lens to observe and only works on carbonate minerals that have a strong reaction with hydrochloric acid. The specimen can be given time (1 to 2 minutes) to react. Dolomitic carbonates react slowly; the reaction can be easily overlooked. Carbonates may occur in specific locations, such as along faces of peds. Several specimens and locations should be tested. Dolomitic carbonates or specimens with a low content of carbonates may be more easily recognized with acid concentrations greater than 10 percent.

Depth of Hole

Description—This is the maximum depth of the hole that was dug for soils data collection.

How to measure and record—Measure the depth of the pit or borehole from the surface to the bottom of the hole, in centimeters.

Fen Characteristics

Description—This is a search for areas with fen characteristics within the site. Fens are groundwater-influenced peatlands with high water tables. The consistently high water table creates anaerobic conditions that slow decomposition, which leads to the development of peat or muck, which is plant material in various stages of decomposition (Mitsch and Gosselink 2007).

For purposes of this field guide, we are first looking for areas with accumulations of peat or muck (supported by groundwater), which we call "fen characteristics," and secondarily whether the soil meets the U.S. Fish and Wildlife Service's (1999) definition of a fen.

In some areas of the United States, fens have special designation and protection (FWS 1999), and the Forest Service may wish to categorize wetlands as fen or nonfen wetlands. Common criteria and the U.S. Fish and Wildlife Service's (1999) definition used to classify a wetland as a fen are (1) the wetland is primarily supported by groundwater, and (2) the wetland has organic soils meeting the USDA NRCS (2010) definition of a histosol or a histic epipedon in at least some part of the contiguous wetland (box 4).

Box 4

Classifying Organic Soils

The "Keys to Soil Taxonomy" (USDA NRCS 2014) requires that histosols have organic soil materials that meet one or more of the following:

1. Overlie cindery, fragmental, or pumiceous materials and/or fill their interstices and directly below these materials have a densic, lithic, or paralithic contact.
2. When added with the underlying cindery, fragmental, or pumiceous materials, total 40 centimeters (cm) or more between the soil surface and a depth of 50 cm.
3. Constitute two-thirds or more of the total thickness of the soil to a densic, lithic, or paralithic contact and have no mineral horizons or have mineral horizons with a total thickness of 10 cm or less.
4. Are saturated with water for 30 days or more per year in normal years (or are artificially drained), have an upper boundary within 40 cm of the soil surface, and have a total thickness of either—
    a. 60 cm or more if three-fourths or more of their volume consists of moss fibers or if their bulk density, moist, is less than 0.1 g/cm^3.
    b. 40 cm or more if they consist either of sapric or hemic materials, or of fibric materials with less than three-fourths (by volume) moss fibers and a bulk density, moist, of 0.1 g/cm^3 or more.
5. Are 80 percent or more, by volume, from the soil surface to a depth of 50 cm or to a glacic layer or a densic, lithic, or paralithic contact, whichever is shallowest.

Box 4 (continued)

The “Keys to Soil Taxonomy” (USDA NRCS 2014) defines a **histic epipedon** as a layer (one or more horizons) that is characterized by saturation (for 30 days or more, cumulative) and reduction for some time during normal years (or is artificially drained) and either:

1. Consists of organic soil material that—
   a. Is 20 to 60 cm thick and either contains 75 percent or more (by volume) *Sphagnum* fibers or has a bulk density, moist, of less than 0.1.
   b. Is 20 to 40 cm thick.
2. Is an Ap horizon that, when mixed to a depth of 25 cm, has an organic-carbon content (by weight) of—
   a. 16 percent or more if the mineral fraction contains 60 percent or more clay.
   b. 8 percent or more if the mineral fraction contains no clay.
   c. 8 + (clay percentage divided by 7.5) percent or more if the mineral fraction contains less than 60 percent clay.

Most histic epipedons consist of organic soil material. Item 2 provides for a histic epipedon that is an Ap horizon consisting of mineral soil material. A histic epipedon consisting of mineral soil material can also be part of a mollic or umbric epipedon.

USDA NRCS (2010) also states the following: “It is a general rule that a soil is classified as an organic soil (histosol or histel) if more than one-half of the upper 80 centimeters (32 inches) of the soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic materials.”

How to measure and record—If a fen (groundwater-influenced peatland) was encountered during the systematic sampling, then record “yes” to the following fen characteristics question and use the soils data to determine if it meets the U.S. Fish and Wildlife Service’s (1999) definition of a fen; no further searching is necessary.

If fen characteristics have not been observed during the site visit, then do a fen search by systematically walking through the site. The objective is not to find all fen areas at the site, but to determine if any fen areas exist at the site. While doing the search, pay particular attention to the wettest areas, where groundwater is at or near the surface for extended periods. Specific characteristics sometimes (but not always) associated with fens are—

- Presence of peat
- Open water surrounded by a floating mat of vegetation
- Groundwater influenced
- High water table
- Abundant mosses
- Soft or spongy surface that bounces or shakes when walked on
- Herbaceous vegetation of obligate wetland species (defined in the glossary under "wetland indicator status")
    - A list of fen indicator species or "peat forming" species would be helpful, but they do not exist for all areas. One example of a fen indicator species list for California (region 5) is in appendix B of Weixelman and Cooper (2009).
- Patterned microtopography (hummock ridges and hollows)

If some of the previous characteristics are encountered in a particular area of a site, then evaluate the soil in that area as a target site (using methods described in this "Soils" section) to look for peat or muck. Record whether or not fen characteristics were observed.

- ☐ Yes, fen characteristics were observed at the site.
- ☐ No, fen characteristics were not observed at the site.
    - In addition to the absence of the previous characteristics of fens, other clues indicating that it is probably not a fen include redoximorphic features or rock (cobble or larger) on ground surface. Areas influenced by beaver activity may appear like a fen, but may not actually be a fen.

Also answer whether the site has soil that meets the USDA NRCS (2014) definitions of a histosol or histic epipedon:

- ☐ Yes, histosol or histic epipedon observed at the site.
- ☐ No, histosol or histic epipedon not observed at the site.

Water Quality

Some core field-derived water quality parameters are included to help characterize the site. These are the following: temperature, specific conductance, pH, and either oxidation/reduction potential (ORP) or dissolved oxygen (DO). In addition, water samples may be collected for laboratory analysis of a wider range of water quality parameters, if they are needed to address the management requirements for the field guide implementation.

Detailed instructions for collecting water samples from wells and surface waters and analyzing those samples, along with quality assurance/quality control procedures can be found in the USGS "National Field Manual for the Collection of Water-Quality Data" (National Field Manual). The National Field Manual provides guidelines and standard procedures for USGS and other Government agency personnel who collect samples used to assess the quality of the Nation's surface water and groundwater resources. Each chapter of the National Field Manual is published separately and revised periodically. Newly published and revised chapters are posted on the USGS web page "National Field Manual for the Collection of Water-Quality Data," https://www.usgs.gov/mission-areas/water-resources/science/national-field-manual-collection-water-quality-data-nfm.

If there are wells, the water quality samples should be taken from the wells with a bailer or pump. For springs or discharge areas within wetlands, water quality measurements should always be taken at the source. Water in wetlands may be ponded or flowing. In either case, targeted samples should be collected from an area that has sufficient depth, is within the wetland, and away from inlets (natural or anthropogenic) because inlets may influence the composition of the water sample. In summary, water quality sampling should be done at one of the following locations, which are listed in order of preference:

- Wells in wetlands (if present) and at the source (orifice) of springs.
- Where flowing water exists in wetlands.
- Standing surface water.
- Holes created by the soil sampling.
    - Time is needed for water to equilibrate.
    - Water quality may be affected by the digging process.

Location of Water Quality Measurements

Description—The location within a wetland or spring where a water sample or measurement is collected.

How to measure and record—Surface water quality sampling should be completed before collecting data for other indicators to avoid degrading the water while completing other sampling tasks. Use flagging if necessary to keep crew members clear of the water sampling location until the water has been sampled. The location of the water quality measurement is either an unbiased location or a targeted location.

- Unbiased—
  - Center of site
- Targeted location—
  - Spring source (recommended for springs)
  - Down-gradient from spring source
  - Stream exiting wetland
  - Standing water
  - Hole (dug or augered, including soil sample hole)
  - Well/piezometer
  - Other:

Time of Water Quality Measurements

Description—This is the time of day that the sample or measurement was collected. This information will help with the interpretation of the data because many water quality parameters fluctuate diurnally because of temperature changes, evapotranspiration, and photosynthesis.

How to measure and record—Record the time of day in 24-hour time that the sample or measurement was taken.

Temperature of Water

Description—This is the temperature of the groundwater discharging at the spring or wetland. Water temperature is an important factor structuring aquatic communities, and it may give insight into the source of the groundwater. The temperature of water discharging from a spring is particularly meaningful. The temperature of water discharging to the surface of a wetland is not an accurate measure of groundwater temperature, but it provides general evidence about the temperature of the groundwater.

How to measure and record—One way to measure water temperature is with an electronic device that also measures dissolved oxygen or conductivity. Calibration is not necessary for temperature measurements using a high-quality device. Record in degrees Celsius. Expected ranges of values are 4 to 60 degrees Celsius. For springs unaffected by geothermal heating, the water temperature is generally close to the average annual temperature of the recharge area.

Water pH

Description—pH is the measure of hydrogen ion activity, which indicates the acidity or alkalinity of water. It is measured on a scale from 0 to 14, with a pH of 7 indicating neutral conditions. Smaller numbers indicate acidic conditions; larger numbers indicate basic conditions. The pH typically responds to hydrologic disturbance in wetlands; therefore, pH can be an indicator of disturbance. The pH is also important in classifying wetland sites (Cowardin et al. 1979), and defining rich and poor fens.

Aquatic fauna and flora are also sensitive to pH conditions. The pH of rain is about 5.6, but can range from 5.6 to about 4.5.

How to measure and record—Measure the pH of the water using a hand-held field meter. The meter should be kept clean, with fresh batteries, and calibrated at least daily, following the manufacture's recommendation. pH probes generally have a limited lifetime, and a backup probe should always be carried. A backup meter is highly recommended. Record in standard pH units. The expected range of pH values is 4.0 to 8.0.

Specific Conductance of Water

Description—Specific conductance (also called electrical conductance, or conductivity) is the measure of the ability of an aqueous solution to carry an electrical current. This ability is dependent on the amount of dissolved ions in the solution, and is, therefore, an indicator of total dissolved solids in the solution. Conductivity provides insight into water sources and it is an indicator of conditions important to aquatic life because of requirements to maintain osmoregulatory balance. Conductivity typically responds to hydrologic disturbance in wetlands. Conductance is also important in classification of wetland sites (Cowardin et al. 1979).

How to measure—Measure conductivity using a field meter. The meter should be kept clean, with fresh batteries, and calibrated periodically following the manufacture's recommendation. Most high-quality meters do not require frequent calibration. Record in microsiemens/centimeter (µS/cm). Expected ranges of values are 10 to 5,000 µS/cm.

Oxidation-Reduction Potential or ORP (DO is an Alternative)

Description—Oxidation-reduction (redox) reactions (reactions involving electron transfer) mediate the behavior of both inorganic and organic chemical constituents by affecting solubility, reactivity, and bioavailability. This data will help provide information about the biogeochemistry of wetlands, which is controlled largely by oxidation-reduction reactions. Expected values for redox potential (also called Eh) range from -300 millivolts (mV) to +700 mV (fig. 7). Redox potential is significantly affected by the oxygen content of the soil and porewater. In oxidized systems where aerobic organisms function, the range is very narrow, approximately +300 mV to about +700 mV. Below values of +300 mV, facultative anaerobes (primarily bacteria) function down to about 0 mV. Below this range, obligate anaerobes function. In wetland (waterlogged or flooded) soils, ORP can be anywhere along the entire scale. Where oxygen is present in wetland soil, the ORP can be as high as in a drained soil, but where oxygen is not present, ORP can be very low (-250 to -300 mV) (U.S. EPA 2008). The Eh-pH diagram in figure 8 can be used to interpret the ORP measurements.

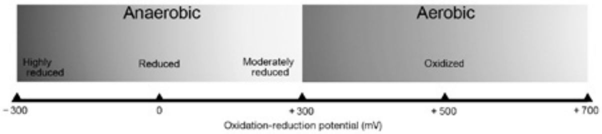

Figure 7.—Range of ORP values for wetlands.

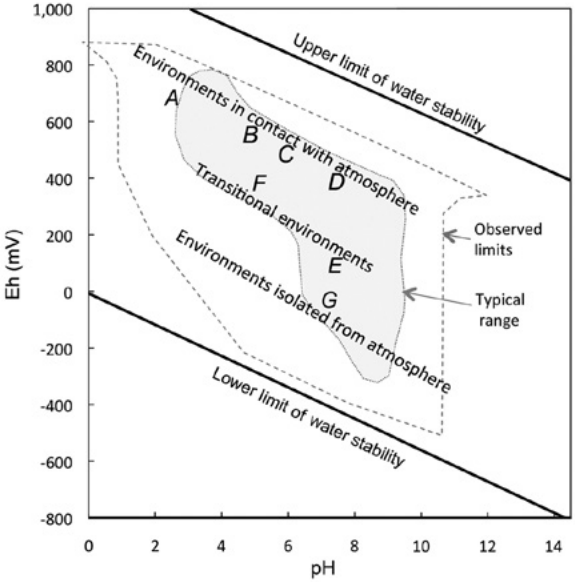

Figure 8.—Distribution of Eh-pH values in natural aqueous environments. Zone A is acidic mine drainage, B is rain, C is stream water, D is ocean water, E is groundwater, F is bog water, and G is anaerobic wetlands (redrawn from Langmuir 1996 and Baas-Becking et al. 1960).

Note: Measured ORP values have to be converted to Eh to be able to use the Eh-pH diagram in figure 8. Converting ORP measurements to Eh depends on the type of ORP electrode used. The electrode manufacturer typically provides conversion factors for various temperatures.

How to measure and record—Measure the ORP of the water using a hand-held field meter that has been calibrated using Zobell solution. ORP in water is measured in wells, springs, and standing or flowing water. The meter should be kept clean, with fresh batteries, and calibrated daily following the manufacturer's recommendation. Record in mV.

Dissolved Oxygen or DO (alternative to ORP)

Description—This is a measure of the amount of DO in the groundwater discharging at a spring or wetland. DO at a spring gives insight into the source of the groundwater discharging and the residence time in the aquifer. In a wetland, DO is a function of the biogeochemical processes taking place.

Because fish and other aquatic organisms cannot survive without oxygen, DO is an important water quality parameter for surface water systems. Cold water holds more oxygen than warm water. Pure water at 4 degrees Celsius (40 degrees Fahrenheit) can hold about 13.2 milligrams per liter (mg/L) DO at 100 percent saturation, while pure water at 25 degrees Celsius (77 degrees Fahrenheit) can hold only 8.4 mg/L at 100 percent saturation. Water with a high concentration of dissolved minerals cannot hold as much DO as pure water.

How to measure and record—Measure DO using a field meter. The meter should be kept clean, with fresh batteries, and calibrated at least daily following the manufacture's recommendation. If there are weather fronts moving through the area, it may be necessary to calibrate before each measurement. Record DO in mg/L. Expected ranges of values for DO are 0 to 13 mg/L.

Flow

Occurrence of Surface Water

Describe the occurrence of surface water at the site using one of the following categories:

- Dry—no evidence of groundwater
- Saturated soil with no open water
- Patches of standing or flowing water
- Extensive standing water
- Flowing water in developed channel
- Extensive standing and flowing water

Flow Method and Location

Record the location of flow measurement and the method used to measure flow (or discharge). The method will vary depending on the site type. Options are:

- Volume
- Weir
- Current meter
- Flume

Flow Rate

Description—This is a measure of the discharge in liters per second from the aquifer to the surface. This attribute is more important for springs than wetlands supplied by diffuse discharge. The flow of a spring is important for both ecological reasons and human uses of the spring water. In many cases, the flow of a spring correlates with the ecological functions and values of the spring habitat.

Where to measure flow—If measuring a single channel, measure discharge where the flow is greatest, as many springs gain in volume with some distance downstream. In some situations, there will not be a single distinct channel where flow can be measured, in which case follow these guidelines:

- If there are multiple channels, and if they all converge to a single channel, measure discharge in the single channel as close as possible to the confluence of all of the multiple channels.
- If there are multiple channels that do not converge, then measure flow in as many channels as possible. Record each measure with an explanation that it is different (completely or partially) than other measures of flow at the site.
- For hanging gardens and wet walls, if possible, take a flow measurement at the base of the wall where flow coalesces into a channel. If this is not possible, photo documentation of the wetted area of rock face is an option.
- If flow is very diffuse (as in a sloped wetland or seep), then flow measurements may not be possible.

How to measure and record—Flow measurement applies mainly to springs, but can be applied to wetlands that have flowing water, such as in an inflow, an outflow, or distinct channels.

Measure the quantity of water discharging from the GDE with one of the methods listed in appendix 6, which also describes the measurement methods. Flow should be measured and recorded multiple times (three times is recommended) at the same location to increase accuracy. Multiple measures at different locations might also be necessary to capture the totality of flow. Record and store all flow measurements (in the field and in the database) to allow for accurate analysis of flow for the site.

Also record an estimate of the percent of the surface discharge that was captured.

For limnocrenes that do not have outflow, the static head change method is used. For limnocrenes that have an outflow, use one of the other measurement techniques described previously.

If flow was not measured, then explain why by selecting one of these options:

- ☐ Diffuse outflow
- ☐ No outflow
- ☐ Spring is dry
- ☐ Hazard
- ☐ Little outflow
- ☐ Other:

Note: It may be difficult to estimate the discharge of springs and wetlands that (1) are small, (2) have water that is shallow and broadly or unevenly spread over a wide area, or (3) have limited moving water. Discharge often changes throughout the day (because of evapotranspiration), seasonally, or annually, which decreases the effectiveness of single measurements to precisely quantify long-term discharge characteristics. Highly quantitative discharge measurement would be a component of a level III survey.

Record notes on flow—Make notes on evidence of recent high discharges, such as high water marks, oriented vegetation, or debris on or above the channel or floodplain.

Hydroperiod

Description—This describes the temporal flow characteristics of a spring. This information is valuable for assessing the importance of the spring for habitat for aquatic organisms. Perennial springs are frequently of higher value for aquatic and terrestrial species than are ephemeral springs.

How to measure and record—Estimate the hydroperiod of the spring. If the field visit takes place in the dry season and the spring is flowing, it is likely perennial.

- ☐ Perennial (must have continuous flow at time of visit)
- ☐ Ephemeral (visible evidence of flow, known to flow at certain times of the year)
- ☐ Unknown/not determined

Photographs

Description—Photos of the site are taken and stored electronically. Photos help to visualize the site, to compare one site to another, and to record change over time.

How to measure and record—A brief description of methods for photo point monitoring is presented here. More detailed instructions can be found in the Forest Service, Pacific Northwest Research Station publication "Photo Point Monitoring Handbook" (Hall 2001): https://www.fs.fed.us/pnw/pubs/pnw_gtr526.pdf. One photo can represent multiple points, as long as they are all noted.

Note: Photo points can be captured in a GPS and marked as such. The digital image can be stored with that point location and viewed by simply clicking on a point within a GIS project file.

Instructions for photos—

- Record the distance from camera to photo point (so that the same distance can be used in the future when the photo points are repeated). It is helpful to capture a photo at a unique feature (such as one end of a tank, a prominent stump or rock, etc.), and describe the location and direction the photo is taken.
- Height of camera—
    - If possible, take the photo at a height of 1.5 meters above the ground, or record the height above the ground.
- Light and time of day—
    - If possible, take photos in the middle of the day rather than early in the morning or late in the afternoon.
    - If possible, do not take photos looking into the sun.
- Photo identification board/card/sheet—
    - In each photo (top corner is recommended) include a white board, card, or sheet with the following information written on it:
        - SiteID
        - Photo number from the camera
        - Date

- Note the following on the photo form:
    - Information from photo identification card (SiteID, photo number, and date)
    - A caption for the photograph the subject in the photographed scene, including the location of the photographer and the direction of the photograph
    - Distance from camera to the object in the photo
    - Orientation of camera (compass bearing)
    - Time of day
- To improve comparability for rephotographing, take photos as close as possible to the time and date of previous photos.

Take photos for the following locations (some photos may serve more than one purpose, as long as each is noted):

- ☐ Reference point (defined previously)
- ☐ Center of site
- ☐ Water measurement locations
- ☐ Soil core locations
- ☐ Spring source (if applicable)
- ☐ For springs with outflow channels—
    - Looking downstream, standing at/near source
    - Looking upstream (or uphill), standing at/near source
- ☐ Flow measurement locations
- ☐ Overview, from a hill (if possible)

Vegetation

Only very general information about vegetation is recorded in this level I field guide. If quantitative data about vegetation is desired then the level II field guide should be used.

Surrounding Vegetation

Description—This is a general description of the vegetation (generally upland) immediately surrounding the groundwater dependent ecosystem, as forested, shrubland, or herbaceous.

How to measure and record—Indicate the type of vegetation that is in the area immediately surrounding the GDE site using the following list of physiognomic orders from the National Vegetation Classification Standards (NVCS) as described in Brohman and Bryant (2005).

- Tree dominated—Areas where tree life form (see growth habit at NRCS PLANTS database at http://plants.usda.gov/) has at least 10 percent cover in the uppermost strata during the peak growing season.
- Shrub dominated—Areas where shrub and/or subshrub life forms are at least 10 percent cover in the uppermost strata.
- Herbaceous/nonvascular dominated—Areas where herbaceous and/or nonvascular life forms are at least 10 percent cover in the uppermost strata.
- No dominant vegetation type—Areas where vegetation cover is at least 1 percent, but the area does not classify as tree, shrub, or herbaceous/nonvascular dominated.
- Nonvegetated—Nonvegetated is usually associated with open water or land-use-dominated, human-modified land, such as heavy industrial, commercial, and transportation facilities.

Bryophytes

Description—This is a very general measure of the abundance of bryophytes (mosses, liverworts, and hornworts) at the site. Bryophytes can be important components of wetlands in terms of ecosystem functioning and as indicators of condition.

How to measure and record—Record the general abundance of bryophytes using the classes listed below:

- ☐ None
- ☐ Minor component
- ☐ Common component
- ☐ Very abundant

Dominant Life Form

Description—This is a ranking of the life forms with the greatest canopy cover in the GDE site. The cover for a life form is the total area covered by all species of that life form.

How to measure and record—Rank the dominant life forms of plants rooted in the GDE using the categories listed below. It is appropriate to rank two life forms with the same number if they have the same (approximate) amount of cover.

Rank (1 is most and 6 is least):

- ☐ Tree
- ☐ Shrub and subshrub
- ☐ Graminoid
- ☐ Forb/herb
- ☐ Aquatic plants (submerged or floating)
- ☐ Bryophyte

Dominant Species

Description—This is a list of the dominant species within each life form. The dominant species within a life form is the species with the greatest canopy cover in that life form.

How to measure and record—Record the dominant plant species for each life form in the GDE. Record scientific names (such as *Picea engelmannii*) that are listed in the NRCS PLANTS database at http://plants.usda.gov/. It is critical that only one species be entered for each category. If the species is unknown, enter the highest taxonomic level (e.g., genus *Carex* or *Poa,* or family Brassicaceae, or even unknown graminoid.) Additional species can be listed under "Species of Interest" discussed below.

Plant Specimens

Description—Plant specimens are useful for identifying unknown species, confirming species identifications, providing vouchers, and helping with the training of future field technicians.

How to measure and record—If one of the dominant species is not known, then a specimen should be collected. Specific instructions for plant specimen collection are—

- Use the 1 in 20 rule as a guide: if fewer than 20 individuals are present at the site, do not collect the plant; instead, describe the plant, the setting, and take a photo.
- Collect as much of the plant as is reasonable, including—
  - Flowers or fruits
  - Belowground parts, to show whether it has a caudex, tap root, rhizomes, etc. (clean dirt from the roots)
  - For woody plants, a portion of a branch with leaves and flowers/fruits/cones
  - Two pieces (stems or branches)

- Complete a label (appendix 5) for each specimen with the following: plant (or unknown number), collection number, date, site name, project/unit, collector, answers to questions about the plant.
- Place small plants and seeds into an envelope or other small container.
- Press the specimen in a plant press as soon as possible, with the label included.
- Air out specimens so they do not get moldy.
- List all collected specimens on a sheet or notebook.
- Make sure that any other data collectors at the site use the same unknown numbers for the same plants.

An experienced botanist should identify these specimens later, and that identification can be entered into the database in place of what taxon was entered.

Plant List

Description—List species present at the site that are of interest for management, such as invasive, nonnative, or rare species. Also list species that are specific to GDEs or a subset of GDEs such as a calciophyle, which is a plant that grows well in high-calcium settings. A regional list of invasive species would be helpful, as would a guide to identifying them.

How to measure and record—List the scientific name of any species of interest to the highest taxonomic level possible (e.g., *Carex*), and include a description in the comments. If a specimen is collected, include this same descriptive information with the specimen (described below) so that the record can be related to the collection.

Aquatic and Terrestrial Fauna

Description—Springs and wetlands can provide important habitat for aquatic and terrestrial fauna, which can be important for management and restoration. Aquatic macroinvertebrates, in particular, are useful bioindicators because some taxa are sensitive to disturbance while others are tolerant.

How to measure and record—Record the important taxonomic groups of animals observed at the site. Important taxonomic groups that occur in GDEs are those with species that have the greatest implication for management. These can include threatened and endangered species, sensitive species, spring-specific species (spring snails), fish, amphibians, reptiles, invertebrates, and mammals. For invertebrates, enter the taxon to the highest level possible, the number observed, life stage, and any comments. For vertebrates, enter the scientific or common name, means of detection (observed, sign, or call), age class if known, and any comments. If the number is not known (e.g., countless, or only sign), leave it blank and estimate the number in the comments if possible. A substantial amount of training is needed to identify many of these species, but identifying most groups of animals, and many nonnative species, may be accomplished with minimal training. Appendix 7, "Identification of Freshwater Invertebrates," provides representative drawings of groups of aquatic macroinvertebrates that may be found in springs and other GDEs and a "Key to Macroinvertebrate Life in the River." For level I surveys, the presence or absence of important species or groups is an important goal.

Voshell (2002) is a useful publication for identifying freshwater invertebrates that can be used by a minimally trained person for a level I survey. In addition, many State agencies and universities host websites with macroinvertebrate identification keys.

List any known invasive species that are present. Invasive species could include zebra mussel, red-rimmed melania, or New Zealand mud snail. See the USGS "Nonindigenous Aquatic Species" web page (https://nas.er.usgs.gov/) for lists and information on invasive freshwater mollusks and crustaceans.

List any rare or sensitive species that are present.

List any GDE-specific species that are present and explain interest.

Natural and Anthropogenic Disturbance

Record any disturbances observed at the site. This can provide managers with information on activities or structures that may be detrimentally affecting the structure and function of the site. It can be helpful to make notes about disturbances observed.

Hydrologic Alteration

Description—This is a list of activities or structures that have altered the natural hydrologic function of the system. This can provide managers with information on activities or structures that may be having a detrimental effect on the hydrologic function of the feature. Multiple answers are allowed.

How to measure and record—

- ☐ Water diversion—Water permanently diverted away from spring habitat (ditch, pipeline, spring box, or other form of dewatering)
- ☐ Water diversion—Water eventually returns to spring habitat
- ☐ Upgradient extraction of surface water or groundwater
- ☐ Downgradient capture of surface water or groundwater
- ☐ Extraction of water within a wetland
- ☐ Extraction of water at spring source
- ☐ Regulated water flow by impoundment/dam
- ☐ Pollution
- ☐ Flooding
- ☐ Wells
- ☐ Other:
- ☐ None observed

Volume and Percent Diverted

Record the volume and percentage (to nearest 10 percent) of water being diverted (noted previously) at the time of inspection. Indicate whether this was a visual estimate or a measurement (e.g., flow meter). Inspect flow upstream and downstream of diversion, as well as water in the conveyance, if possible, to determine percentage being diverted.

Soil Alteration

Description—This is a list of the major types of soil alteration found at the site. Multiple answers are allowed.

How to measure and record—

- ☐ Channel erosion
- ☐ Compaction
- ☐ Debris flow
- ☐ Deposition
- ☐ Displacement of soil
- ☐ Erosion (general)
- ☐ Evaporate deposition
- ☐ Excavation
- ☐ Ground disturbance (general)
- ☐ Gully erosion
- ☐ Mass wasting
- ☐ Mining
- ☐ Pedestals or hummocks (created by people or animals)
- ☐ Pedestals (small-scale, rain-splash induced)
- ☐ Pipes
- ☐ Rill erosion

- ☐ Ruts (from vehicle tread)
- ☐ Sheet erosion
- ☐ Slump
- ☐ Splash erosion/soil crust
- ☐ Wind erosion
- ☐ Soil mixing/churning
- ☐ Soil removal (peat mining)
- ☐ Trails by people
- ☐ None observed
- ☐ Other:

Structures

Description—This is a list of the kinds of structures present at the site. Multiple answers are allowed.

How to measure and record—

- ☐ Buried utility corridors
- ☐ Enclosure (such as spring house, spring box, or concrete enclosure)
- ☐ Erosion control structure
- ☐ Exclosure fence
- ☐ Oil and gas well
- ☐ Pipeline
- ☐ Point source pollution
- ☐ Power lines
- ☐ Road (includes construction and maintenance)
- ☐ None observed
- ☐ Other:

Recreation Effects

Description—This is a list of recreational activities in evidence at the site. Multiple answers are allowed.

How to measure and record—

- ☐ Camp sites
- ☐ Tracks or trails by vehicles (all-terrain vehicle, 4-wheel drive, etc.)
- ☐ None observed
- ☐ Other:

Animal Effects

Description—This is a list of animal-related impacts to the site. This includes impacts from both domestic and wild animals. Multiple answers are allowed.

How to measure and record—

- ☐ Beaver activity
- ☐ Feral animals
- ☐ Grazing or browsing (by ungulates)
  - ○ Wild animals
  - ○ Livestock
- ☐ Trails by animals
- ☐ Trampling (by ungulates, native or nonnative)
- ☐ None observed
- ☐ Other:

Miscellaneous

Description—These are potential disturbances that do not fit in the categories described previously. Multiple answers are allowed.

How to measure and record—

- ☐ Fire
- ☐ Tree cutting (timber harvest or other)
- ☐ Refuse disposal
- ☐ None observed
- ☐ Other:

Archaeological, Paleontological, Cultural, or Historic Sites or Use

Description—This is a list of any archaeological, paleontological, cultural, or historic sites or other human use of the site. Many springs in arid regions have a long history of use by Native Americans and others. Some have spiritual values associated with them. Some fens have preserved remains of extinct animals. Knowledge of sensitive sites will limit inadvertent damage to these resources.

How to measure and record—Record evidence of archaeological, paleontological, and cultural resources or historic use (e.g., archaeological, paleontological, historic sites).

Management Indicator Tool

Responses to the Management Indicator Tool statements are used to identify potential need for management action based upon observations and information collected during the field guide implementation. This information may be useful for prioritizing sites needing additional monitoring or other management actions. The tool should be completed at the site, using a field crew consensus approach, and conclusions validated or confirmed later in the office based on a review of the data collected and other records or information available at the office (e.g., land status records, land and resource management plans). Some of the statements, particularly "Administrative Context," may require review of records before the field visit.

This tool uses "true" or "false" answers, which require interpretation by the field team and have undefined cutoffs. Make the best judgment possible and include comments and explanations where uncertainty or mitigating factors influenced the assessment. In particular, provide comments for all responses of "false (no)," "does not apply," or "unable to assess."

False answers indicate issues of concern that might pose problems for the long-term functioning of the GDE or, when observed at multiple sites, indicate a need for management attention.

There is no summary scoring system based on the results of this tool. It is up to the specialist involved in data collection and the decisionmaker responsible for management to interpret the inventory results.

The following resources were used for assessing management needs and to develop portions of the Management Indicator Tool:

- "Assessing proper functioning condition for fen areas in the Sierra Nevada and Southern Cascade ranges in California: a user guide" (Weixelman and Cooper 2009)
- "A user guide to assessing proper functioning condition and the supporting science for lentic areas" (DOI 2020)
- "Springs ecosystem assessment protocol scoring criteria" (Stevens et al. 2016)

Following are the 25 management indicator statements to address. The last seven indicators are Forest Service-specific administrative questions that may not be easily answered by surveyors who are not Forest Service specialists. If the survey crew is inexperienced in administrative issues, these indicators can be left blank.

1 **Aquifer functionality:** ***No evidence suggests that the aquifer supplying groundwater to the site is being affected by groundwater withdrawal or loss of recharge.***

GDEs exist where groundwater reaches the earth's surface, often through complex and lengthy geologic flow paths. The consistent supply of groundwater maintains flows in springs and high water tables in wetlands. This supply of groundwater is essential to maintain the GDE and, in many cases, unique plant and animal communities. This statement asks whether activities exist that interrupt or deplete this supply—reducing flows in springs or lowering water tables in wetlands.

Examples

This indicator would be answered "Yes" in the following circumstances:

- No evidence suggests that groundwater extraction is adversely affecting the site.
- Evidence of soil saturation exists, or standing water is apparent.
- Plants that are obligate wetland and/or facultative wetland species are abundant at the site, taking into consideration the setting and site potential.
- None of the adverse effects in the following list are observed.

This indicator would be answered "No" in the following circumstances:

- Groundwater extraction, such as pumping wells or mining that intersects the water table, damages aquifer functionality.
- There is depletion of recharge to the aquifer through paving, soil compaction, vegetation manipulation, etc.
- Soil saturation in a wetland, or flow of a spring, is less than in the past. One indicator of this could be where upland and facultative upland plant species are encroaching into areas formerly dominated by obligate wetland and facultative wetland species, indicating a loss of groundwater. Another indicator could be if hydric soils are present beyond the current extent of the GDE, suggesting that the GDE has decreased in size.

The only definitive way to detect aquifer functionality issues is through installation and monitoring of piezometers in wetlands and frequent monitoring of flow in springs.

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2 **Watershed functionality:** ***Within the watershed, no evidence suggests upstream/upgradient hydrologic alteration that could adversely affect the GDE site.***

The focus of this statement is on surface water, although groundwater and surface water are connected in most watersheds and activities affecting one of these resources can potentially affect the other. The watershed that is the focus of this statement would generally be a 6th-level (12-digit) watershed hydrologic unit code. The condition of the surrounding uplands can greatly affect the condition of a GDE. Changes in upland condition can influence the magnitude, timing, or duration of overland flow events, which could result in erosion or deposition of sediment in the GDE. The purpose of this indicator is to determine if activities within the watershed have adversely affected the feature.

Although a correlation can exist, the focus here is on whether the uplands are contributing to degradation of the GDE, and not on the condition of the uplands.

Examples

This indicator would be answered "Yes" in the following circumstances:

- The site is receiving a normal range of surface flows, even if disturbance exists within its watershed.
- None of the adverse effects in the following list are observed.

This indicator would be answered "No" in the following circumstances:

- Upslope road ditches and cross drainage structures were installed in a manner that concentrates overland flows and shallow groundwater away from the site, causing desiccation of soils.
- Flow has been added from a diversion, and excessive erosion or deposition is taking place as a result of this increased flow.
- Trail development has intercepted, diverted, or concentrated overland flows initiating a headcut that is draining the site.
- Upslope road ditches, culverts, etc., are failing or in need of repair.

3 **Water quality:** ***Changes in water quality (surface or subsurface) are not affecting the GDE site.***

GDEs are complex biogeochemical systems where water, nutrients, sediments, microclimate, and biota interact as part of the natural processes. The ecology of a GDE is affected by the quality of the water supporting the site. Changes in water quality can have detrimental effects on the flora and fauna. GDEs are susceptible to pollution from a number of activities. Pollutants may be toxic, which may harm or eliminate aquatic life. Inputs of nutrients (e.g., nitrogen, phosphorus) can increase the growth of aquatic vegetation and bacterial abundance and lower dissolved oxygen concentrations. These effects may cause intolerant macroinvertebrate communities to be replaced by communities that associated with impaired aquatic systems.

The geology of some watersheds naturally yields constituents (salts, iron, nutrients, calcium carbonates, etc.) that can inhibit growth for certain plant species. Examples of GDEs that have naturally limiting water quality conditions that favor some flora and fauna over others are thermal springs, travertine/tufa depositing springs, low pH springs, iron fens, and calcareous fens. Understanding the geology, soils, and water source is important to be able to accurately assess the causes of the water quality data. In some cases, unusual water chemistry values could be natural, and, in other cases, they could be because of management activities.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Water quality is within the expected range of variability.
- None of the adverse effects in the following list are observed.

This indicator would be answered “No” in the following circumstances:

- Data collected indicate poor water quality (requires knowledge of expected range of variability for the site).
- Sources of pollution such as mining waste or tailings, landfills, herbicides, pesticides, or accidental spills of hazardous chemicals and waste along roads exist.
- There has been excessive use by nonnative ungulates (such as wild horses and burros, cattle, and sheep) or native

ungulates that have (1) deposited fecal matter and increased nutrients in the water or (2) damaged vegetation, allowing increased amounts of sediment and nutrients to enter the aquatic system.

- Sewage disposal on site, or sewage from offsite septic systems or lagoons has allowed pollutants to leach into the groundwater and move to springs along a hydraulic gradient.
- In some cases, excessive algae may be an indicator of nutrient loading in the water.
- Vegetation shows signs of stress from chemicals in the water.

Foul smells or discolored water should be further investigated to determine whether a water quality problem exists, or whether the foul smell is from natural anaerobic conditions and the discoloration is from a natural accumulation of organic matter.

If a problem is identified, water samples should be collected and analyzed and the results compared against relevant water quality criteria.

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4 **Landform stability:** ***No evidence indicates human-caused mass movement or other surface disturbance affecting the GDE site stability.***

In general, stable landforms are at a state of equilibrium with physical conditions and processes that affect a site such as climate, slope, soil, soil moisture, and geology. Anthropogenic disturbances in the watershed, including the GDE, can cause instability in landforms. The intent of this indicator is to identify activities or causes of landform instability at the GDE site.

Natural mass wasting can occur where groundwater discharges on a slope because geologic materials become saturated with water, the angle of repose is reduced to a very small value, and the material tends to flow like a fluid. This is because groundwater reduces grain-to-grain frictional contact. As a result, some discharge wetlands are associated with slope failures that are natural, but they could also be partially the result of management activities.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Only natural mass movement, such as slumping, occurs.
- None of the adverse effects in the following list are observed.

This indicator would be answered “No” in the following circumstances:

- Excessive sediment deposition has occurred.
- Stream channel alteration has occurred, beyond what is natural.
- Streambank erosion or a headcut is affecting site stability.
- Slope failure has occurred from unnatural causes.
- A road cut or failing infrastructure (such as retaining walls, log cribs) is causing slope instability.

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5 **Runout channel:** ***The channel, if present, is functioning naturally and is not entrenched, eroded, or otherwise substantially altered.***

Runout channels from springs or wetlands support flora and fauna that are an important and often unique part of the biodiversity of a site, therefore the condition of the runout channel is important to assess. Changes in channel and bank morphology or substrate composition can alter habitat.

Runout channels are groundwater-fed streams that emerge from spring orifices (referred to as springbrooks or spring runs) or within groundwater-fed wetlands. Surface drainage areas to these springs can be very small, often much smaller than the recharge area of the springs. The major differences in controls on the channel morphology found between the spring-dominated and runoff-dominated channels are the discharge regime and the sediment input (Griffiths et al. 2008). The hydrology unique to spring-dominated channels and the lack of fine-grained sediment input combine to create the observed differences. Channels downstream of springs are typically straight, or, if sinuous, they are without regularity to the pattern. Bars are absent or poorly defined, but islands or downed timber are common in the channel. Springflow-dominated channels are a special habitat of running waters because of the relatively uniform temperature and the deoxygenated groundwater contribution to the stream (Springer and Stevens 2009). Springflow-dominated systems may be sufficiently stable habitats to allow for evolutionary microadaptation and, ultimately, speciation (McCabe 1998).

Examples

This indicator would be answered “Yes” in the following circumstances:

- The runout channel is functioning naturally.
- None of the adverse effects in the following list are observed.

This indicator would be answered “No” in the following circumstances:

- Bank morphology has been changed by ungulate trampling, vehicles, or other activities.
- Channel morphology has been changed by excavation, ditching, or redirection.
- The channel is entrenched.
- Erosion of streambanks is beyond the natural range that would be expected at the site.

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6 **Soil integrity:** ***Soils are intact and functional. For example, saturation is sufficient to maintain hydric soils, if present; there is not excessive erosion or deposition.***

The purpose of this indicator is to evaluate the condition of the soil and to determine if the soil has been affected by excessive disturbance. Management activities can alter the soil and the hydrologic conditions that affect the soil. In the case of wetlands, intact hydric soils are a useful indicator that the duration and frequency of saturation has been sufficient to maintain wetland soil characteristics. Soil saturation creates anaerobic conditions, which leads to the reduction, translocation, and accumulation of iron, manganese, sulfur, and carbon compounds (redoximorphic features). Saturation also slows decomposition of plant material, which can lead to the accumulation of peat (over long-term periods). This soil integrity indicator is intended to assess whether such hydric soils are being maintained in those areas where hydric soils would be expected. In the case of springs without hydric soils, the intent is to determine if soil disturbance (erosion, deposition, compaction, etc.) has occurred.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Hydric soils are present and soil saturation is close to the ground surface.
- None of the adverse effects in the following list are observed.

This indicator would be answered “No” in the following circumstances:

- Soil compaction or erosion because of livestock, vehicles, or other sources.
- Desiccated peat or oxidized organic matter is observed at the site.
- Peat soils are churned because of livestock hoof action. (This refers to the stirring of the peat layer that causes organic matter to be mixed into the underlying mineral layer. The soil structure is altered and is massive or platy.)
- Pedestals created by hoof shear, hoof compaction, and disruption of root systems.
- Post holes/puddling that result from logging equipment, recreational vehicles, livestock, and wildlife.

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7 **Vegetation composition:** ***The site includes anticipated cover of plant species associated with the site environment, and no evidence suggests that upland species are replacing hydric species.***

Vegetation composition is an expression of environmental conditions and management activities. The abundance of plant species will respond to changes in hydrologic conditions at a GDE. In some cases, certain species disappear altogether from a site because of changes in water table or spring flow. Vegetation composition can also change because of disturbances and management activities. The relatively consistent availability of water at GDEs supports hydric plants, which are generally more abundant at GDEs than in the surrounding uplands.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Expected vegetation for the setting and environment is present, which would generally include obligate (OBL) or facultative wetland (FACW) species of the Wetland Indicator Status (FWS 1988). Primarily native species.

This indicator would be answered “No” in the following circumstances:

- Wetland vegetation seems to have been greatly reduced or eliminated.
- Overstory of wetland woody species but a lack of wetland understory species, suggesting recent hydrologic changes (because herbaceous vegetation is generally more responsive to changes in hydrology than woody species).
- Evidence suggesting that upland species have increased.
- Dominance by nonnative or invasive plants.

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8 **Vegetation condition:** ***Vegetation exhibits seasonally appropriate health and vigor.***

This statement is intended to evaluate the health or vigor of the vegetation, based on a visual assessment. The condition of vegetation can be adversely affected by management activities.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Sites that have dense, robust vegetation growth that is healthy-looking in terms of leaf color, size, and shape.

This indicator would be answered “No” in the following circumstances:

- Sites that have discolored, decadent, weakened, or unusually sparse vegetation.
- Evidence of severe grazing or browsing by livestock and/or native ungulates, such as hedged plants.

9 Threatened, endangered, and sensitive species; species of interest/concern (SOI/SOC); or focal floral species: *Anticipated floral species are present (will vary by ecological region and will require some baseline information).*

Some GDEs support threatened, endangered, or sensitive species; SOI/ SOC; or focal floral species. The intent of this indicator is to identify sites that support these important plant species.

GDEs can be floristically diverse, supporting many rare and uncommon vascular plant species and bryophytes. GDEs can be unique habitats that support a higher level of biodiversity than the surrounding landscape. An array of plant species is known to be endemic to, or inhabit, these locations.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Threatened, endangered, or sensitive species; SOI/SOC; or focal floral species were observed at a site whether or not they had been identified at the site before.
- No threatened, endangered, or sensitive species; SOI/SOC; or focal floral species were observed, and none were anticipated.

This indicator would be answered “No” in the following circumstances:

- Threatened, endangered, or sensitive species; SOI/SOC; or focal floral species were not observed at a site but had been documented at the site previously.
- Threatened, endangered, or sensitive species; SOI/SOC; or focal floral species were expected to be at the site but were not observed.

10 Faunal species: *Anticipated aquatic and terrestrial faunal species associated with the site environment are present.*

Some GDEs have habitats that support aquatic and terrestrial faunal species. The intent of this indicator is to identify sites that support important animal species.

Wetlands support many different types of animals, including invertebrates, fish, amphibians, reptiles, birds, and mammals. Because of the transitional nature of wetlands, both aquatic and terrestrial animals live in wetlands. Wetlands provide food sources, protection from weather and predators, resting sites, reproductive sites, and molting grounds for wildlife (Cooper 1989). Wetlands provide this habitat function for many species of fish and wildlife, including some that are threatened or endangered. Many species of animals that are not typically considered to be wetland species also use wetlands.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Anticipated faunal species were observed at a site, whether or not they had been identified at the site before.
- No faunal species were anticipated, and none were observed.

This indicator would be answered “No” in the following circumstances:

- Anticipated faunal species were not observed at a site but they had been documented at the site previously.
- Faunal species were anticipated to be at the site, but they were not observed.

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11 **Threatened, endangered, or sensitive species; SOI/SOC; or focal faunal species:** ***Anticipated faunal species are present (will vary by ecological region and will require some baseline information).***

GDEs can be unique habitats that support a higher level of biodiversity than the surrounding landscape. An array of threatened, endangered, or sensitive species; SOI/SOC; or focal faunal species is known to be endemic to, or use, GDEs. The intent of this indicator is to identify sites that support important animal species.

Examples

This indicator would be answered “Yes” in the following circumstances:

- Threatened, endangered, or sensitive species; SOI/SOC; or focal faunal species were observed, whether or not they had been identified at the site before.
- No threatened, endangered, or sensitive species; SOI/SOC; or focal faunal species were anticipated, and none were observed.

This indicator would be answered “No” in the following circumstances:

- Threatened, endangered, or sensitive species; SOI/SOC; or focal faunal species were not observed but had been documented at the site previously.
- Threatened, endangered, or sensitive species; SOI/SOC; or focal faunal species were expected to be at the site but were not observed.

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12 **Invasive species:** ***Invasive floral and faunal species are not established at the site.***

Invasive plant and animal species have a detrimental effect on the ecological functioning of GDEs. This statement asks if invasive animal or plant species have become established at the site. It is useful to know where invasive species have been established, so that controls can be implemented. Identifying the occurrence of invasive species before they infest a site is useful information.

Various characteristics of invasive species allow them to displace native vegetation at sites that have been disturbed by water impoundments, excessive grazing, recreation, and other activities. By displacing native vegetation, they reduce habitat that formerly provided critical nesting, feeding, and spawning habitat for wildlife species. Several nonnative vertebrates and invertebrates have been introduced into springs in Western North America, and in some cases, populations of native aquatic species have either been reduced or extirpated as a result.

Some plant species that are considered to be invasive in springs or wetlands, at least in some States, include purple loosestrife, tamarisk, common reed, reed canarygrass, and many others. Invasive animals could include the zebra mussel and many others.

Examples

This indicator would be answered “Yes” in the following circumstances:

- No invasive species (or very few individuals) were observed at the site.

This indicator would be answered “No” in the following circumstances:

- Invasive animal or plant species are established at the site.

Lists of invasive plants can be obtained for States and many counties or online at http://plants.usda.gov/.

13 **Flow regulation:** ***Flow regulation is not adversely affecting the site.***

Alteration of surface or subsurface flow patterns may affect the functionality of a site (Gurrieri 2020). This statement is intended to determine if flow regulation has occurred at the site, which can have significant effects on the biota. For areas where wetland vegetation is important, a change in flow patterns may mean a change in vegetation type (wetland species to upland species), creating a site unable to function properly. For others, it may mean a decrease in extent of wetland or complete wetland loss.

Effects of diversion are similar to the consequences of a drought that causes springs and wetlands to become drier. In general, species richness declines as diversion increases, and functional shifts in the structure of aquatic and wetland communities occur. As diversion increases, intolerant aquatic taxa (e.g., mayflies, caddisflies, crenobiontics) are replaced by tolerant taxa (e.g., midges, beetles, corixids), and nonnative and upland vegetation becomes more abundant.

Examples

This indicator would be answered “Yes” in the following circumstances:

- No flow regulation exists at the site.
- Flow regulation structures are stable, accommodate flows, and do not adversely affect the ecology of the site.
- Diversions remove very small amounts of water and have minimal effects on ecology.

This indicator would be answered “No” in the following circumstances:

- There exists channelization or redirection of flow, delivery of water through pipes and concrete channels to tanks and reservoirs, excavation and installation of spring boxes, ditching wetlands to drain them, or impounding spring sources. (These structures are designed to capture and divert water for uses such as livestock watering, domestic use, or irrigation.)
- Flow diversion is causing the area of wetland vegetation and soils to contract.

14 **Construction and road effects:** ***Construction, reconstruction, or maintenance of physical improvements, including roads, are not adversely affecting the site.***

Roads can cause negative ecological effects to ecosystems, plants, and wildlife. The effects of road construction and operation on wetlands and springs include negative effects from changes to the chemistry and biology of the local area to changes in hydrology that go beyond the immediate area of the road. Loss of wildlife habitat, loss of species, and biodiversity are other consequences of such changes. In addition, roads are barriers that can cause habitat fragmentation and edge effects, which may affect some plant and animal species. Roads are also corridors that can facilitate the spread of invasive species.

Examples

This indicator would be answered "Yes" in the following circumstances:

- No evidence suggests that construction or roads are affecting the GDE.

This indicator would be answered "No" in the following circumstances:

- Within the site, roads have caused trampling, soil compaction, erosion, disturbance (because of noise or motion), pollution, nutrient loading, or introduction of invasive plant species.
- Road is channelizing runoff and delivering sediment to the site.
- Physical improvements, such as buildings, latrines, water development structures, piping, and parking lots, are affecting the site.
- Stormwater runoff from a road or parking lot is entering a wetland.

15 **Fencing effects:** ***Protection fencing and exclosures are appropriate and functional.***

Fences are sometimes used to exclude animals or people from spring or wetland sites to prevent damage to vegetation, alteration of sediment flux, or adverse effects on water quality. Proper placement and maintenance of fences is required to meet conservation objectives. This indicator assesses if the fences are appropriately designed, located, and maintained, and if they are working as intended.

Examples

This indicator would be answered "Yes" in the following circumstances:

- Fencing was properly designed and is functioning to exclude whatever it was intended to exclude, such as livestock, wild animals, vehicles, and recreation use.

This indicator would be answered "No" in the following circumstances:

- Fence is down, damaged, or broken.
- Fence was not designed or constructed in a manner that effectively protects the ecologically valuable portions of the site.

16 **Herbivore effects:** ***Herbivory is not adversely affecting the site.***

This indicator documents whether grazing or browsing by native or nonnative animals is adversely affecting the site. This refers to effects from animals such as cattle, sheep, horses, burros, elk, deer, or moose.

Many springs and wetlands have been altered by grazing and trampling of livestock, as well as other nonnative and native ungulates. Excessive grazing in GDEs can damage or alter vegetation, lead to increased water temperature, cause soil erosion (including streambank erosion), and add sediment and nutrients to aquatic systems. Those changes can damage habitat for wildlife, fish, and other aquatic fauna, such as macroinvertebrates.

Examples

This indicator would be answered "Yes" in the following circumstances:

- No evidence indicates adverse effects from grazing or browsing by native or nonnative ungulates.

This indicator would be answered "No" in the following circumstances:

- Native or nonnative ungulates have caused excessive removal of vegetation, abnormally low height (including hedging of shrubs) or cover of vegetation, or major changes in species composition.
- Native or nonnative ungulates' hoof action has caused trampling of vegetation, soil erosion, or other ground disturbance.

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17 **Recreational effects:** ***Recreational uses, including trails, are not adversely affecting the site.***

Recreational activities can negatively affect GDEs. Off-road vehicle use is increasing on NFS lands and has damaged many wetland and spring habitats. Sada (2001) documented how trampling by recreationists affected the abundance and distribution of spring-dwelling mollusks. The effect on springs is similar to those caused by excessive livestock and wildlife activity in riparian and aquatic systems, where it has degraded riparian vegetation and increased water temperature, the amount of fine substrates, and nutrient loading (Fleischner 1994, Kauffman and Krueger 1984).

Examples

This indicator would be answered "Yes" in the following circumstances:

- None of the adverse effects in the following list are observed.

This indicator would be answered "No" in the following circumstances:

- Camping, hiking, and associated refuse have adversely affected the site.
- Recreation use along a springbrook has caused decreased vegetation height or cover (through trampling or other damage).
- Vehicles have caused erosion, soil compaction, damage to vegetation, or other adverse effects.
- Other recreational activities (trails, horseback riding, etc.) have adversely affected the site.

18 **Other disturbance effects:** ***Wildland fire, insect, disease, windthrow, avalanche, or other disturbances are not adversely affecting the site.***

This indicator documents adverse effects from disturbances not captured in other statements, such as fire, blowdown, pest infestation, disease, and avalanches.

Examples

This indicator would be answered "Yes" in the following circumstances:

- None of the adverse effects in the following list have had a significant adverse effect on the site.

This indicator would be answered "No" in the following circumstances:

- Significant amounts of dead or dying vegetation (particularly trees and shrubs) from insect infestation, disease, or wildfire are found in the site.
- Evidence suggests that blow down, pest infestation, disease, avalanches, debris flow, or other natural disturbances have had a significant adverse effect on the site.

19 **Cultural values:** ***Archaeological, historical, or Tribal values will not affect inventory, restoration, use, or management of this site.***

Many springs, particularly in the Southwestern United States, have cultural and or historical significance that could require consultation with Tribes or State historic preservation offices.

Examples

This indicator would be answered "Yes" in the following circumstances:

- No evidence indicating archaeological, historical, or Tribal resources at the site.

This indicator would be answered "No" in the following circumstances:

- Archaeological, historical, or Tribal resources could be affected by inventory, restoration, use, or management of the site.
- Site sacredness is recognized by Tribes or non-Tribal agencies.

- Site has potential for National Register of Historic Places status.
- Artifacts, petroglyphs, ruins, water works, or dwelling sites are present.

20 **Land ownership:** ***The entire site and immediate area are under the jurisdiction and management of the Forest Service.***

This indicator simply documents that the site is managed by the Forest Service and, thus, the land manager has the authority to control undesirable or unauthorized activities at the site.

Examples

This indicator would be answered "Yes" in the following circumstances:

- Entire site is within Forest Service jurisdiction.

This indicator would be answered "No" in the following circumstances:

- Part, or all, of the site is not within Forest Service jurisdiction.

21 **Other landowner actions:** ***Activities or management on lands outside Forest Service jurisdiction are not adversely affecting the site.***

This indicator documents whether the site is under threat from actions by adjacent landowners.

Examples

This indicator would be answered "Yes" in the following circumstances:

- None of the adverse effects in the following list are observed.

This indicator would be answered "No" in the following circumstances:

- A large pumping well is located adjacent to the site, outside of NFS lands, and is dewatering the site.
- Other activities outside of NFS lands are adversely affecting the site.

22 **Land management plan:** ***The land and resource management plan provides for effective site protection.***

Forest or grassland plans define desired conditions or standards and guidelines for management of forest resources.

Examples

This indicator would be answered "Yes" in the following circumstances:

- The forest or grassland plan states that springs and wetlands are managed to promote long-term viability of ecological function.

This indicator would be answered "No" in the following circumstances:

- The forest plan does not recognize that springs and wetlands are managed to promote long-term viability of ecological function.

23 **Environmental compliance:** ***Authorized and administrative uses are in compliance and are not adversely affecting the site.***

Water developments are authorized under special-use authorization regulations. This indicator is used to alert the land manager of unauthorized activities that need to be addressed.

Examples

This indicator would be answered "Yes" in the following circumstances:

- None of the adverse effects in the following list are observed.

This indicator would be answered "No" in the following circumstances:

- A water development was not constructed as specified in the permit.
- Grazing within the site is not in compliance with allotment management plan requirements.

24 **Water Uses:** ***There are no substantial water uses in the watershed or in the aquifer supplying groundwater to the site that could directly or cumulatively adversely affect the GDE.***

The purpose of this indicator is to assess the scope and extent of water use (including that from water rights) within the watershed and/or aquifer to assess the potential for direct or cumulative adverse effects to the GDE.

Water use from surface or groundwater sources should be accounted for under either State or Federal authority. All water use, whether exempt from State application procedures or not, needs to be properly documented and tracked relative to the amount of water used and location of withdrawal and use. Information from the Water Rights and Uses (WRU) database/site visit field form, which can be included in the GDE inventory process, is used to assess if there is substantial water use, individually or cumulatively, from water uses.

Examples

This indicator would be answered “Yes” in the following circumstances:

- The density of water uses and rights is small relative to streamflow availability or aquifer capacity.
- Water uses and water rights that affect the site have been inventoried and accounted for and are being used as intended and within the limits of the right or exemption.
- Infrastructure adjacent to the site or within the watershed has evidence of maintenance and is functioning well.

This indicator would be answered “No” in the following circumstances:

- The density of water uses and rights is moderate to high relative to streamflow availability or aquifer capacity.
- Water uses and water rights have not been inventoried; many uses are unidentified or unknown, with little to no information on amount or frequency of use.
- Infrastructure adjacent to site or within the watershed is extensive, with no inventory information to assess the extent of infrastructure and water use.

25 **Water Rights:** ***Water rights have been filed for the site under State law or water uses exempted under State law are documented. Forest Service Federal reserved rights are documented as appropriate. Third-party water use is in accordance with all elements of the water right or conditions of the exemption and with the Forest Service authorization that allows the use.***

The purpose of this indicator is to assess the water rights and uses disposition of the site (see description under the previous “water uses” section). Information from the WRU database and site visit field form, which can be included in the GDE inventory process, is used to assess if there is substantial water use, individually or cumulatively, from water uses.

Examples

This indicator would be answered “Yes” in the following circumstances:

- A reasonable amount of water is being consumed for the specific purpose. Amount and timing of water withdrawal is comparable to similar uses at sites/watersheds with similar conditions.
- If metered, metering is accurate and measurements are used in assessments.
- The water right or use is valid and used in accordance with specifications of the right or use.
- Infrastructure and diversions are in good working condition.

This indicator would be answered “No” in the following circumstances:

- Water right or use is in violation of exemptions and is not authorized under State law or subject to forfeiture.
- Water is not metered and is required to be metered under State law or special-use permit.
- Infrastructure is not maintained and water use is not controlled.

Post-Field Survey Activities (in office)

After the field survey, additional activities need to be completed in the office or laboratory to supplement or enhance the field data. These activities are described in the following list (in the same manner they are listed in the "Using the Level I Field Guide" section in the beginning of this field guide).

Obtain or Verify Data

Based upon the location data (UTM or latitude/longitude) acquired at the site, the following are examples of attributes that can be determined, verified, or updated in the office, primarily with GIS tools.

- Site name (an existing site name that was not known at the field visit may exist)
- Primary lithology (groundwater source aquifer)
- Secondary lithology

Laboratory Analyses

If samples or specimens were collected in the field, then they need to be transferred to a location where they can be analyzed. Plant specimens should be taken to a botanist or herbarium for identification. Macroinvertebrate specimens should be sent to a laboratory that follows general processing and identification guidelines for identification (described in the Lab Identification part of the Aquatic Macroinvertebrates section). Water samples and soil samples should be sent to a laboratory that follows standardized guidelines of quality assurance.

Data Management Procedures

Field data recorded either on paper forms or field data recorders should be provided to the Enterprise Data Warehouse (EDW) database as soon as possible after the fieldwork, while surveyors' memories are fresh. This is accomplished through Springs Online (https://springsdata.org). This database is managed by Springs Stewardship Institute (SSI) under an MOU and agreement with the Forest Service. SSI regularly submits Forest Service data to the EDW, which is in turn provided back to the forests.

Paper Field Sheets—Surveyors who completed paper field sheets can manually enter the data and upload images into Springs

Online. SSI can provide the necessary permissions, and assist with this process. If the spring's location data are already electronic (e.g., in a geodatabase or spreadsheet), SSI can import those data, saving a great deal of time.

Data submitted from the Survey123 App will be imported into Springs Online. However, it is important that surveyors conduct quality control measures prior to this data transfer.

Once data have been imported or entered, Springs Online has robust reporting capacity for quality assurance and quality control (QA/QC) reviews. This includes summary reports that users can export and review to identify obvious data entry errors.

Photos taken with a digital camera should be downloaded, labeled, and stored in a location that is associated with the other site information. Handwritten materials such as drawings and notes should be scanned into electronic format and stored in a location that is associated with the other site information.

Validate and Confirm Management Indicator Tool Entries

The responses to the Management Indicator Tool should be compared to the summarized field data in the office. This will either confirm the field responses or provide information that can be used to edit the field responses. For example, it may have been noted that there were no invasive species at the site, but the summarized data in the office may indicate that there were indeed significant amounts of invasive plants or animals. The response to the statement on invasive species would then be updated based on the summarized field data.

Glossary

Some definitions are taken from Mitsch and Gosselink (2007).

anoxia—Waters or soils with no dissolved oxygen.

aquifer—A saturated underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be extracted using a well. An aquifer can be confined, unconfined, or partially confined. The aquifer can be perched, local, or regional. Aquifers are connected to the hydrologic cycle through recharge, within and between unit flow, and through discharge.

artesian—Condition in which a confined aquifer is under pressure such that the static level within a cased borehole rises above an impermeable (confining) layer (e.g., peat layer) or in which water discharges to the surface from an unlined borehole.

base-flow stream—A perennial stream supported by groundwater discharge during periods of low or no precipitation or snowmelt.

bog—A peat-accumulating wetland that has no significant inflows or outflows and supports acidophilic mosses, particularly *Sphagnum*. In general, bogs are supported by precipitation.

bryophytes—Nonvascular land plants (mosses, liverworts, and hornworts) that have tissues and enclosed reproductive systems but lack vascular tissue that circulates liquids. They neither have flowers nor produce seeds because they reproduce via spores.

Carolina Bay—Elliptical depressions or shallow basins that occur throughout the Southeastern United States Coastal Plain. Their hydrology is dominated by precipitation inputs and evapotranspiration losses, and they range from nearly permanently inundated to frequently dry.

cave—A natural underground space formed by various geologic processes. Caves are common in **karst** terrain and areas of psuedokarst.

ciénega—Usually a wet, marshy area at the foot of a mountain, in a canyon, or on the edge of a grassland where groundwater reaches the surface. Often, a ciénega does not drain into a stream but instead evaporates. Also called **helocrene.**

crenobiontic—Organisms that live only in springs.

exposure spring (one of the spheres of discharge, as described by Springer and Stevens 2009)—Groundwater is exposed at the land surface but does not have surface inflow or outflow. Exposure springs occur in **karst** (sinkholes) and psuedokarst (lava flows) but could form in other types of vertical conduits into an aquifer.

fen—In general, wetlands that develop where a relatively constant supply of groundwater to the plant rooting zone maintains saturated conditions most of the time and the water chemistry reflects the mineralogy of the surrounding and underlying soils and geological materials. The U.S. Fish and Wildlife Service (1999) uses two criteria to classify a wetland as a fen: (1) the wetland is primarily supported by groundwater and (2) the wetland has organic soils meeting the U.S. Department of Agriculture, Natural Resources Conservation Service (2010) definition of a **histosol** or a **histic epipedon** in at least some part of the contiguous wetland.

fibric—Organic soil material that contains ¾ or more recognizable fibers (after rubbing between fingers) of undecomposed plant remains. Bulk density is usually very low and water-holding capacity very high. Also referred to as **peat.**

forb—Herbaceous flowering plant that is not a graminoid.

fountain spring (one of the spheres of discharge, as described by Springer and Stevens 2009)—Cool, artesian springs that are forced above the land surface by artesian or gas pressure.

geyser (one of the spheres of discharge, as described by Springer and Stevens 2009)—Geothermal springs that emerge explosively and usually erratically. A geyser is a hot spring characterized by intermittent discharges of water that are ejected turbulently by a vapor phase.

graminoid—True grasses *(Poaceae)* or grass-like plants, such as sedges *(Cyperaceae)* or rushes *(Juncaceae).*

groundwater—All water below the ground surface, including water in the saturated and unsaturated zones.

groundwater-dependent ecosystems (GDEs)—Communities of plants, animals, and other organisms whose extent and life processes are dependent on access to or discharge of **groundwater.**

gushet (one of the spheres of discharge, as described by Springer and Stevens 2009)—Discrete sources of flow pouring from cliff faces. Gushets typically emerge from perched, unconfined

aquifers, often with dissolution enhancement along fractures, exhibit thin sheets of water flowing over rock faces.

hanging garden or wet wall (one of the spheres of discharge, as described by Springer and Stevens 2009)—Springs that emerge along geologic contacts or fractures and seep, drip, or pour onto underlying walls. Hanging gardens in the Southwestern United States typically emerge from perched, unconfined aquifers in Aeolian sandstone units.

helocrene (one of the spheres of discharge, as described by Springer and Stevens 2009)—Low-gradient springs and/or wetlands; often indistinct or multiple sources of groundwater. Also called **wet meadows** or **ciénegas.**

hemic—Organic soil material at an intermediate degree of decomposition that contains ⅙ to ¾ recognizable fibers (after rubbing between fingers) of undecomposed plant remains. Bulk density is usually very low and water-holding capacity very high. Also referred to as **mucky peat.**

herbaceous—A plant that has leaves and stems that die down to the ground at the end of the growing season. They have no persistent woody stems.

hillslope (one of the spheres of discharge, as described by Springer and Stevens 2009)—**Springs** and/or **wetlands** on a hillslope (generally 20- to 60-degree slope), often with indistinct or multiple sources of **groundwater.**

histic epipedon—An 8- to 16-inch layer at or near the surface of a mineral hydric soil that is saturated with water for 30 consecutive days or more in most years and contains a minimum of 20 percent organic matter when no clay is present or a minimum of 30 percent organic matter when clay content is 60 percent or greater. Soils with histic epipedons are inundated or saturated for sufficient periods to greatly retard aerobic decomposition of the organic surface and are considered to be hydric soils.

histosol—Histosols **(organic soils)** develop under conditions of nearly continuous saturation and/or inundation. All histosols are hydric soils except folists, which are freely drained soils occurring on dry slopes where excess litter accumulates over bedrock. Organic hydric soils are commonly known as **peats** and **mucks.**

hypocrene (one of the spheres of discharge, as described by Springer and Stevens 2009)—A buried spring where flow does not reach the surface. This term is common to the Southwestern United States. Elsewhere, these features may be equivalent to shallow groundwater areas, including **fens.**

hyporheic zone—Area of a stream bed and bank where surface and ground waters mix. A similar area, the hypolentic zone, exists in lakes and ponds.

insurgence—The point of inflow for surface water into subsurface conduits in **karst** areas.

jurisdictional wetlands—Those areas that are inundated or saturated by surface or ground water (hydrology) at a frequency and duration sufficient to support and that, under normal circumstances, do support a prevalence of vegetation (hydrophytes) typically adapted for life in saturated soil conditions (hydric soils). Wetlands generally include swamps, marshes, bogs, and similar areas (40 Code of Federal Regulations 232.2(r)).

karst—A terrain or type of topography generally underlain by soluble rocks, such as limestone, gypsum, and dolomite, in which the topography is chiefly formed by dissolving the rock; karst is characterized by sinkholes, depressions, caves, and underground drainage. Psuedokarst is an area of depressions, caves, and internal drainage that result from volcanic activity.

limnocrene (one of the spheres of discharge, as described by Springer and Stevens 2009)—Groundwater emerges in one or more pools.

marsh—A frequently or continually inundated **wetland** characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

mineralized mounds (one of the spheres of discharge, as described by Springer and Stevens 2009)—**Springs** that emerge from (usually carbonate) precipitate mounds.

minerogenous—See **minerotrophic peatlands.**

minerotrophic peatlands—Peatlands that receive water that has passed through mineral soil. Also called minerogenous hydrological systems.

muck—Organic soil material in which the original plant parts are not recognizable. Contains more mineral matter and is usually darker in color than peat. Also referred to as **sapric** material.

mucky peat—Organic soil material in which a significant portion of the original plant parts are recognizable, and a significant part is not. Also referred to as **hemic** material.

ombrogenous—**Peatland** with inflow from precipitation only. Also called ombrotrophic.

organic soil—Organic soils **(histosols)** develop under conditions of nearly continuous saturation and/or inundation. All organic soils are hydric soils except folists, which are freely drained soils occurring on dry slopes where excess litter accumulates over bedrock. Organic hydric soils are commonly known as **peats** and **mucks.**

peat—Organic soil material that is undecomposed or weakly decomposed. The plant remains are distinct and identifiable.

peatland—A generic term for any **wetland** that accumulates partially decayed plant matter **(peat).**

phreatophyte—Plant whose roots generally extend downwards to the water table and customarily feed on the capillary fringe. Phreatophytes are common in **riparian** habitats. Term literally means "well" plant or water-loving plant.

piezometer—Small-diameter well open at a point or over a short length in the aquifer to allow measurement of hydraulic head at that location.

pocosin—Peat-accumulating, nonriparian freshwater wetland, generally dominated by evergreen shrubs and trees and found on the Southeastern Coastal Plain of the United States. The term comes from the Algonquin word for "swamp on a hill."

redoximorphic features—Features formed by the reduction, translocation, and/or oxidation of iron and manganese oxides; used to identify hydric soils.

rheocrene (one of the spheres of discharge, as described by Springer and Stevens 2009)—Flowing springs that emerge directly into one or more stream channels.

riparian—Pertaining to the bank of a body of flowing water; the land adjacent to a river or stream that is, at least periodically, influenced by flooding. Riparian sometimes is used to indicate the banks of lakes and ponds subject to period inundation by wave action or flooding.

sapric—Organic soil material that contains less than one out of six recognizable fibers (after rubbing between fingers) of undecomposed plant remains. Bulk density is usually very low, and water holding capacity very high. Also referred to as **muck.**

seep—A discharge of water that oozes out of the soil or rock over a certain area without distinct trickles or rivulets.

specific conductance—A measure of an aqueous solution's ability to carry an electrical current (also called electrical conductance or conductivity).

spring—A place where groundwater flows naturally from the earth into a body of surface water or onto the land surface.

springbrook—Runout channel from a **spring,** which may become a stream at some distance from the spring source.

spring source—The location where the spring emerges from the ground onto the land surface. Also referred to as the spring orifice.

swamp—**Wetland** dominated by trees or shrubs.

Terrestrial Ecological Unit Inventory (TEUI)—The national program of ecological classification within the Forest Service that was developed to classify ecological types and map ecological units to a consistent standard across National Forest System lands. TEUI establishes terrestrial mapping units derived from a combination of core datasets, which uniquely characterize a spatial region, including climate, geology, geomorphology, soil regime, and vegetation.

upland—Land that is not influenced by a consistent source of surface water or groundwater and, therefore, does not support **wetland** vegetation or hydric soil development as would a wetland or **riparian** area.

wet meadow—Area that is saturated with water for much of the year but does not have standing water, except for brief periods, during the growing season.

wetland—In general, wetlands are lands on which water covers the soil or is present either at or near the surface of the soil or within the root zone, all year or for varying periods of time during the year, including during the growing season. The U.S. Fish and Wildlife Service defines wetlands as "lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water… (and) have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; or (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year" (Cowardin et al. 1979). See also **jurisdictional wetland.**

wetland indicator status—A system of categorizing plant species in terms of their probability of occurring in **wetlands.** The system was developed by the U.S. Fish and Wildlife Service (1988). It has five general categories: obligate, facultative wetland, facultative, facultative upland, and upland. Obligate species almost always occur in wetlands, whereas upland species almost never occur in wetlands, as described in table 3.

Table 3.—Wetland indicator status codes and descriptions (FWS 1988).

Wetland indicator status	Code	Estimated probability a species occurs in wetlands
Obligate	OBL	Almost always (99%)
Obligate –	OBL –	
Facultative wetland +	FACW +	
Facultative wetland	FACW	Usually (67–99%)
Facultative wetland –	FACW –	
Facultative +	FAC +	
Facultative	FAC	Equally likely to occur in wetlands or nonwetlands (34–66%)
Facultative –	FAC –	
Facultative upland +	FACU +	
Facultative upland	FACU	Not usually (1–33%)
Facultative upland –	FACU –	
Upland +	UPL +	
Upland	UPL	Almost never (1%)

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Appendix 1. Field Forms

Forms are available from the Forest Service Washington Office groundwater program.

Forest Service GDE Level 1 Inventory

Site Name ____________________

Recorder ____________________ Page ___ of ___

Site Information

Springs Online Site ID ____________ State _____ County ____________

Land unit (Forest Service, BLM, private, etc.) ____________

Land unit detail (district) ____________

Proclaimed national forest ____________

Note: If no GDE is located within 100 meters of a mapped location, or feature is not a GDE, please describe in "Site Description" below and update in Springs Online.

Land manager ID ____________ Designation (wilderness, etc.) ____________

Site description (setting, history, context, cultural concerns, etc.):

Access directions (route):

Sensitivity (select one):
- ☐ Not sensitive
- ☐ Location is sensitive
- ☐ Survey data are sensitive
- ☐ Nothing about this spring should be released

General Survey Information

Survey date ____________ Time start ______ End ______

Examiners (full names) ____________

Project ____________

Area of GDE (m^2) ______

Weather:
- ☐ Recent rain
- ☐ Rain during survey
- ☐ Snowfall, hail, or sleet during survey
- ☐ Snow on ground
- ☐ No current or recent precipitation

Air Temperature ______ °F or °C

Area determined by (select one):
- ☐ Measuring average length and width
- ☐ Estimating
- ☐ Estimation from map or image
- ☐ GPS traverse of GDE boundary
- ☐ Sketching perimeter on image with GPS
- ☐ Other (describe in general notes)

Site condition (survey notes):

Georeferencing

GPS Model ____________

GPS accuracy or position error (m) ____________

Georeference comments ____________

Georeference source (select one):
- ☐ GPS
- ☐ Map
- ☐ Survey GPS
- ☐ Other ______

Datum (select one):
- ☐ NAD83
- ☐ WGS84
- ☐ NAD27

Latitude DD ____________ Longitude DD ____________

UTM zone ______ Easting ______ Northing ______

Elevation ______ ft or m

Elevation determined by:
☐ GPS ☐ Topo map ☐ Other ______

Reference point description:

Entered by: ____________ Date ______ Checked by: ____________ Date ______

Forest Service GDE Level 1 Inventory

Site Name ____________________

Recorder ____________________ Page ___ of ___

Sketchmap

Use the checklist to verify you have included all aspects of the survey site

___ Scale	___ Major geomorphic features	___ Deepest water	___ Flow measurements
___ North arrow	___ Structures or features	___ GPS measurement	___ Flow direction arrows
___ Reference point	___ Sources	___ Water quality sampling	___ Photo points, direction
___ GDE boundary	___ Standing water	___ Soil holes	

Entered by: ____________ Date ________ Checked by: ____________ Date ________

Forest Service GDE Level 1 Inventory

Site Name ____________________

Recorder ____________________ Page ___ of ___

Site Geomorphology

GDE Type
Indicate primary (1) and secondary (2)

- ___ Anthropogenic (secondary only)
- ___ Cave
- ___ Exposure
- ___ Fountain
- ___ Geyser
- ___ Gushet
- ___ Hanging garden
- ___ Helocrene
- ___ Hillslope
- ___ Hypocrene
- ___ Limnocrene
- ___ Mound
- ___ Rheocrene

Surficial Material
Indicate primary (1) and secondary (2)

- ___ Alluvium
- ___ Colluvium
- ___ Eolian deposit
- ___ Glacial deposit
- ___ Human caused/constructed
- ___ Lacustrine sediments
- ___ Landslide deposit
- ___ Marl
- ___ Residuum
- ___ Rock (no surficial material present)
- ___ Talus deposit
- ___ Tufa or travertine deposit
- ___ Volcanic ash
- ___ Other/unknown ____________

Source Geomorphology
Indicate primary (1) and secondary (2)

- ___ Bedding
- ___ Conduit
- ___ Contact
- ___ Fault
- ___ Fracture
- ___ Seepage or filtration
- ___ Other/unknown ____________

Primary Lithology
(groundwater source aquifer)

- ☐ Igneous
- ☐ Sedimentary
- ☐ Metamorphic
- ☐ Unconsolidated

Geology Notes (to add to survey notes in Springs Online):

Secondary Lithology

GDE

Evidence of Groundwater
(multiple answers allowed)

- ☐ Flow from spring source, contact, joint, or fault
- ☐ Peat/muck accumulation
- ☐ Standing water
- ☐ Wetland vegetation
- ☐ Other

Relative Area of GDE
(must sum to 100)

- ___ % spring emergence
- ___ % channel
- ___ % wetland/riparian
- ___ % open water
- ___ % peatland
- ___ % other/unknown

Characteristics

- ___ Average slope (degrees)
- ___ Aspect (magnetic north) or
- ___ Aspect (true north)

Water Table

Inflow Pattern (select one):

- ☐ Groundwater inflow dominated
- ☐ Surface water inflow dominated
- ☐ Both groundwater and surface

Outflow Pattern (select one):

- ☐ Groundwater outflow dominated
- ☐ Surface water outflow dominated
- ☐ Both groundwater and surface
- ☐ Evapotranspiration dominated

Measurement location description:

Location (select one):

- ☐ Center of site
- ☐ Pool
- ☐ Downgradient from orifice
- ☐ Other ____________

Source (select one):

- ☐ Depression
- ☐ Soil hole
- ☐ Standing water or pool
- ☐ Well/piezometer
- ☐ Other ____________

Water Table Depth (cm) ________ Hole Depth (cm) ________ Is Hole Dry? ☐

Entered by: ____________ Date ________ Checked by: ____________ Date ________

Forest Service GDE Level 1 Inventory

Site Name ____________________

Recorder ____________________ Page ___ of ___

Soils

Soil Hole Location (select one):
- ☐ Targeted, center of site
- ☐ Targeted, other
- ☐ Unbiased, random
- ☐ Unbiased, systematic

Extraction Method(select one):
- ☐ Auger/core
- ☐ Push probe
- ☐ Shovel
- ☐ Other ________

Hole depth (cm) ________

Soil pit comments:

Depth of peat or muck:

Layer	Upper depth (cm)	Lower depth (cm)
Peat (fibric)		
Mucky peat (hemic)		
Muck (sapric)		

Fen characteristics observed? ◯ yes ◯ no

Comments ____________________

Histosol or histic epipedon observed? ◯ yes ◯ no

Comments ____________________

Depth to mineral layer (cm) ________

Texture ____________________

Color ____________________

Redox concentrations ____________________

Redox depletions ____________________

Reduced matrices ____________________

Hydrogen sulfide odor? ◯ yes ◯ no

Reaction to HCl? ◯ yes ◯ no

Water Quality

Measurement Location (select one):
- ☐ Spring source
- ☐ Down-gradient of source
- ☐ Stream exiting wetland
- ☐ Standing water
- ☐ Center of site
- ☐ Hole
- ☐ Well/piezometer
- ☐ Other ________

Source of Water (select one):
- ☐ Standing water
- ☐ Flowing water
- ☐ Other ________

Time (24 hr) ________

Parameter	Measurement	Device	Comment
Water temp. (°C)			
Air temp (°C)			
pH			
Specific Cond (µS/cm)			
ORP (mV)			
DO (mg/L)			
DO %			

Flow

Flow Measurement Method (select one):
- ☐ Volume
- ☐ Weir
- ☐ Current meter
- ☐ Flume
- ☐ Other ________

Flow measurement location:

Site % captured ________

Flow (L/s) ________

Reason if Flow Not Measured (select one):
- ☐ Diffuse outflow
- ☐ Hazard
- ☐ Little outflow
- ☐ No outflow
- ☐ Spring is dry
- ☐ Other ________

Surface Water (select one):
- ☐ Dry—no evidence of groundwater
- ☐ Saturated soil with no open water
- ☐ Patches of standing or flowing water
- ☐ Extensive standing water
- ☐ Flowing water in developed channel
- ☐ Extensive standing and flowing water

Additional notes on flow:

Hydroperiod (select one):
- ☐ Perennial
- ☐ Ephemeral/intermittent
- ☐ Unknown/not determined

Entered by: ____________ Date ________ Checked by: ____________ Date ________

Forest Service GDE Level 1 Inventory

Site Name ______________________

Recorder ______________________ Page ____ of ____

Flow (continued)

Raw Flow Measurements (optional):

Measurement location	Volume unit	Time unit

If multiple locations, average or add together? ______________

Photographs

Photo No.	Location	Caption	Distance	Orientation
	Reference point			
	Center of site			
	Water chemistry measurement			
	Soil core sampling			
	Spring source (if applicable)			
	View downstream from source			
	View upstream from source			
	Flow measurement			
	Overview from a hill			

Photographer name(s) ______________________

Entered by: ______________ Date ________ Checked by: ______________ Date ________

Forest Service GDE Level 1 Inventory

Site Name ______________________

Recorder ______________________ Page ___ of ___

Vegetation

Surrounding Vegetation (select one):
- ☐ Herbaceous/nonvascular
- ☐ Shrub dominated
- ☐ Tree dominated
- ☐ No dominant life form
- ☐ Nonvegetated

Bryophyte Abundance (select one)
- ☐ None
- ☐ Minor component
- ☐ Common component
- ☐ Very abundant

Dominant life form	Rank (1 = most, 6 = least)	Dominant species (enter only one)	Specimen collected?
Tree			
Shrub/sub-shrub			
Graminoid			
Forb/herb			
Aquatic plants			
Bryophyte			

Plant List

Species	Setting, comment, collection notes

Entered by: ______________ Date __________ Checked by: ______________ Date __________

Site Name ______________________

Recorder ______________________ Page ___ of ___

Aquatic and Terrestrial Fauna

Faunal Species

Invertebrate Taxon	Number	Lifestage	Detection	Comments

Vertegrate Species	Number	AgeClass	Detection	Comments

Entered by: ______________ Date __________ Checked by: ______________ Date __________

Forest Service GDE Level 1 Inventory

Site Name ______________________

Recorder ______________________ Page ___ of ___

Disturbances

Hydrologic Alteration (multiple okay)
- ☐ Water diversion (permanently diverted)
- ☐ Water diversion (water eventually returns to site)
- ☐ Upgradient extraction of surface water or groundwater (prespring emergence)
- ☐ Downgradient capture of surface water or groundwater (postspring emergence)
- ☐ Extraction of water within a wetland
- ☐ Extraction of water at spring source
- ☐ Regulated water flow by impoundment/dam
- ☐ Pollution
- ☐ Flooding
- ☐ Wells
- ☐ None observed
- ☐ Other: ______________________

Diverted volume (include unit of measure) ____________

Percent diverted ____________

Soil Alteration (multiple okay)
- ☐ Channel erosion
- ☐ Compaction
- ☐ Debris flow
- ☐ Deposition
- ☐ Displacement of soil
- ☐ Erosion (general)
- ☐ Evaporate deposition
- ☐ Excavation
- ☐ Ground disturbance (general)
- ☐ Gully erosion
- ☐ Mass wasting
- ☐ Mining
- ☐ Pedestals or hummocks (by people or animals)
- ☐ Pedestals (small-scale, rain-splash induced)
- ☐ Pipes
- ☐ Rill erosion
- ☐ Ruts (from vehicle tread)
- ☐ Sheet erosion
- ☐ Slump
- ☐ Splash erosion/soil crust
- ☐ Wind erosion
- ☐ Soil mixing/churning
- ☐ Soil removal (peat mining)
- ☐ Trails by people
- ☐ None observed
- ☐ Other: ______________________

Structures (multiple okay)
- ☐ Buried utility corridors
- ☐ Enclosure (such as spring house, spring box, or concrete enclosure)
- ☐ Erosion control structure
- ☐ Exclosure fence
- ☐ Oil and gas well
- ☐ Pipeline
- ☐ Point source pollution
- ☐ Power lines
- ☐ Road (includes construction and maintenance)
- ☐ None observed
- ☐ Other: ______________________

Recreational Effects (multiple okay)
- ☐ Camp sites
- ☐ Tracks or trails by vehicles (ATV, 4-wheel drive, etc.)
- ☐ Non observed
- ☐ Other: ______________________

Animal Effects (multiple okay)
- ☐ Beaver activity
- ☐ Feral animals
- ☐ Grazing or browsing (by ungulates)
- ☐ Wild animals
- ☐ Livestock
- ☐ Trails by animals
- ☐ Trampling (by ungulates, native or nonnative)
- ☐ None observed
- ☐ Other: ______________________

Miscellaneous (multiple okay)
- ☐ Fire
- ☐ Tree cutting (timber harvest or other)
- ☐ Refuse disposal
- ☐ None observed
- ☐ Other: ______________________

Archaeological, paleontological, cultural, historic sites/use:

Entered by: ______________ Date ________ Checked by: ______________ Date ________

Forest Service GDE Level 1 Inventory

Site Name ______________________

Recorder ______________________ Page ___ of ___

Management Indicator Tool

Management Indicators	True (Yes)	False (No)	Does not apply	Unable to assess	Comment
Hydrology					
1. **Aquifer Functionality:** No evidence suggests that the aquifer supplying groundwater to the site is being affected by groundwater withdrawal or loss of recharge.					
2. **Watershed Functionality:** Within the watershed, no evidence suggests upstream/ upgradient hydrologic alteration that could adversely affect the GDE site.					
3. **Water Quality:** Changes in water quality (surface or subsurface) are not affecting the groundwater dependent ecosystem site.					
Geomorphology and Soils					
4. **Landform Stability:** No evidence of human-caused mass movement or other surface disturbance affecting the GDE site stability.					
5. **Runout Channel:** The channel, if present, is functioning naturally and is not entrenched, eroded, or otherwise substantially altered.					
6. **Soil Integrity:** Soils are intact and functional. For example, saturation is sufficient to maintain hydric soils, if present; there is not excessive erosion or deposition.					
Biology					
7. **Vegetation Composition:** Site has anticipated cover of plant species associated with the site environment, and no evidence suggests that upland species are replacing hydric species.					
8. **Vegetation Condition:** Vegetation exhibits seasonally appropriate health and vigor.					
9. **TES, SOI/SOC, Focal Floral Species:** Anticipated floral species are present (will vary by ecological region and will require some baseline information).					
10. **Faunal Species:** Anticipated aquatic and terrestrial faunal species associated with the site environment are present.					
11. **TES, SOI/SOC, Focal Faunal Species:** Anticipated faunal species are present (will vary by ecological region and will require some baseline information).					
12. **Invasive Species:** Invasive floral and faunal species are not established at the site.					

Entered by: ______________ Date ________ Checked by: ______________ Date ________

Forest Service GDE Level 1 Inventory

Site Name ______________________

Recorder ______________________ Page ___ of ___

Management Indicator Tool (continued)

Management Indicators	True (Yes)	False (No)	Does not apply	Unable to assess	Comment
Disturbances					
13. **Flow Regulation:** Flow regulation is not adversely affecting the site.					
14. **Construction and Road Effects:** Construction, reconstruction, or maintenance of physical improvements, including roads, is not adversely affecting the site.					
15. **Fencing Effects:** Protection fencing and exclosures are appropriate and functional.					
16. **Herbivore Effects:** Herbivory is not adversely affecting the site.					
17. **Recreational Effects:** Recreational uses, including trails, are not adversely affecting the site.					
18. **Other Disturbance Effects:** Wildland fire, insect, disease, wind throw, avalanches, or other disturbances are not adversely affecting the site.					
Administrative Context					
19. **Cultural Values:** Archaeological, historical, or Tribal values will not affect inventory, restoration, use, or management of this site.					
20. **Land Ownership:** The entire site and immediate area is under the jurisdiction and management of the Forest Service.					
21. **Other Landowner Actions:** Activities or management on lands outside Forest Service jurisdiction are not adversely affecting the site.					
22. **Land Management Plan:** The land and resource management Plan provides for effective site protection.					
23. **Environmental Compliance:** Authorized and administrative uses are in compliance and are not adversely affecting the site.					
24. **Water Uses:** There are no substantial water uses in the watershed, or in the aquifer supplying groundwater to the site, that could directly or cumulatively adversely affect the GDE.					
25. **Water Rights:** Water rights are filed for the site under State law or water uses exempted under State law are documented. Forest Service Federal reserved rights documented as appropriate. Third-party water use is in accordance with all elements of the water right or conditions of the exemption and with Forest Service authorization that allows the use.					

Entered by: ______________ Date __________ Checked by: ______________ Date __________

Appendix 2. Site Protection Guidelines

This section is provided to help minimize the disturbance from the data-collection process by researchers, managers, and data collectors. The potential disturbances that can result from the data-collection process include the following:

- Trailing, erosion, geomorphic alteration (from foot traffic, etc.)
- Destruction or alteration of vegetation
- Damage to peat
- Soil compaction and altered soil-water storage
- Hydrologic alteration from water measurement activities (wells, etc.)
- Spread of invasive species (by data collectors or managers).

To prevent damage to sites, please follow these guidelines:

Minimize

- Number of people who visit the site
- Duration of visits
- Frequency of visits
- Walking on site
- Digging holes
- Destructive sampling
- Collecting plant or animal specimens
- Bringing heavy equipment to site
- Placing heavy gear on wet areas
- Using unsterilized equipment (nets, etc.)

Pre-Site Visit

- Decontaminate shoes/boots and equipment that will be brought to site to prevent importing invasive species or disease.
- Plan the visit to use the time wisely and to minimize the amount of walking on the site.

During the Site Visit

- Set equipment, especially heavy items, outside wet areas (in uplands).
- Consider taking pictures, or recording observations, instead of collecting specimens.

- Sit, eat lunch, etc., outside the wet area.
- Walk around the groundwater-dependent ecosystem site, rather than through it, as much as possible.
- Do multiple things on each trip through the site to minimize trampling.
- Place temporary wood planks on walking paths to avoid creating ruts that redirect and channelize water.

Post-Site Visit—Decontamination

At the end of each site visit, to prevent the spread of invasive species, decontaminate shoes/boots, waders, and all equipment used at the site. If you do not know if the decontamination was done after the last visit, then follow these procedures before a field visit.

1. Use a scrub brush (toothbrush for small equipment) and water to remove all visible mud, vegetation, and other material.
2. Dry the boots and equipment.
3. Soak boots in a Clorox solution or some other solution (such as Sparquat or 409) depending on the regional invasive species of concern.
4. Rinse with water (distilled for equipment).
5. Allow boots and equipment to air dry (in the sun works best).

Appendix 3. Equipment List

- Field forms (appendix 1)
- Clipboard
- Smart phone or tablet
- Pencils
- Notebook or paper (waterproof)
- Graph paper (for sketch map)
- Calculator
- Topographic map of site
- Aerial photograph of site
- GPS (global positioning system) unit
- Compass
- Clinometer
- Watch, stopwatch, or other timer
- Photography
    - Camera
    - Photo scale
    - Board or card for identifying photo location
- Water quality
    - Temperature probe
    - pH probe
    - Oxidation-reduction potential (ORP) probe or dissolved oxygen (DO) probe
    - Water conductivity probe
    - Spare probes (temperature, pH, DO, ORP, and conductivity) and cable
- Flow measurement (one or more of following)
    - Weir plate (and bubble level)
    - Current meter
    - Flume (and bubble level)
    - Volumetric container(s)
    - Float (flagging, float device)
    - Current meter
    - Wading rod
    - Short pipe (for concentrating and measuring low flows)
- Soil/subsurface
    - Shovel, spade, auger, and/or push probe with clean-out tool

    - Soil knife/trowel
    - Hand lens (10x or combination lenses)
    - pH kit
    - Soil description sheets
    - Water/spray bottle
    - Soil color book (Munsell color chart with gley color plates)
    - Dilute hydrochloric acid (HCl) with dropper
    - Local soil survey
    - Bailing can—where groundwater can fill soil pits
- Vegetation
    - Plant press (with cardboard, newspaper, and felt)
    - Plant lists and identification resources for region
    - Sample bags
    - Digging tool (could be same as for soil sampling)
- Fauna
    - Animal lists and identification resources for region
    - Binoculars (for observing birds and other wildlife, or plants on cliff wall)
    - Aquatic macroinvertebrate and vertebrate sampling tools, as desired, such as hand net
- Decontamination materials/supplies

Appendix 4. Secondary Lithology

The secondary lithology list in the following table is based on USDA Forest Service (2009).

Primary lithology	Secondary lithology
Igneous extrusive	Analcite basalt
Igneous extrusive	Andesite
Igneous extrusive	Andesite porphyry
Igneous extrusive	Basalt
Igneous extrusive	Basalt porphyry
Igneous extrusive	Basaltic andesite
Igneous extrusive	Basanite
Igneous extrusive	Dacite
Igneous extrusive	Dacite porphyry
Igneous extrusive	Felsite
Igneous extrusive	Latite
Igneous extrusive	Latite porphyry
Igneous extrusive	Leucite dasanite
Igneous extrusive	Leucite phonolite
Igneous extrusive	Leucite tephrite
Igneous extrusive	Limburgite
Igneous extrusive	Limburgite porphyry
Igneous extrusive	Melilitite
Igneous extrusive	Nepheline latite
Igneous extrusive	Nepheline latite porphyry
Igneous extrusive	Nephelinite
Igneous extrusive	Obsidian
Igneous extrusive	Oceanite
Igneous extrusive	Olivine basalt
Igneous extrusive	Olivine nephelinite
Igneous extrusive	Perlite
Igneous extrusive	Phonolite

Primary lithology	Secondary lithology
Igneous extrusive	Phonolite porphyry
Igneous extrusive	Pitchstone
Igneous extrusive	Pumice
Igneous extrusive	Quartz basalt
Igneous extrusive	Quartz latite
Igneous extrusive	Quartz latite porphyry
Igneous extrusive	Rhyolite
Igneous extrusive	Rhyolite porphyry
Igneous extrusive	Scoria
Igneous extrusive	Tephrite
Igneous extrusive	Tephrite porphyry
Igneous extrusive	Tinguaite
Igneous extrusive	Trachyte
Igneous extrusive	Trachyte porphyry
Igneous extrusive	Trap
Igneous extrusive	Vitrophyre
Igneous extrusive	Wyomingite
Igneous intrusive	Alaskite
Igneous intrusive	Alkali granite
Igneous intrusive	Alkali syenite
Igneous intrusive	Anorthosite
Igneous intrusive	Aplite
Igneous intrusive	Charnockite
Igneous intrusive	Diabase
Igneous intrusive	Diorite
Igneous intrusive	Diorite porphyry
Igneous intrusive	Ditroite
Igneous intrusive	Dunite
Igneous intrusive	Fergusite
Igneous intrusive	Foyaite

Primary lithology	Secondary lithology
Igneous intrusive	Gabbro
Igneous intrusive	Gabbro porphyry
Igneous intrusive	Gabbro/diorite
Igneous intrusive	Granite
Igneous intrusive	Granite porphyry
Igneous intrusive	Granodiorite
Igneous intrusive	Granodiorite porphyry
Igneous intrusive	Graphic granite
Igneous intrusive	Harzburgite
Igneous intrusive	Lamprophyre
Igneous intrusive	Larvikite
Igneous intrusive	Leucite syenite
Igneous intrusive	Luxullianite
Igneous intrusive	Malignite
Igneous intrusive	Missourite
Igneous intrusive	Monzonite
Igneous intrusive	Monzonite porphyry
Igneous intrusive	Nepheline monzonite
Igneous intrusive	Nepheline monzonite porphyry
Igneous intrusive	Nepheline syenite
Igneous intrusive	Nepheline syenite porphyry
Igneous intrusive	Nordmarkite
Igneous intrusive	Norite
Igneous intrusive	Olivine gabbro
Igneous intrusive	Pegmattite
Igneous intrusive	Peridotite
Igneous intrusive	Picrite
Igneous intrusive	Pulaskite
Igneous intrusive	Pyroxenite
Igneous intrusive	Quartz diorite

Primary lithology	Secondary lithology
Igneous intrusive	Quartz diorite porphyry
Igneous intrusive	Quartz gabbro
Igneous intrusive	Quartz monzonite
Igneous intrusive	Quartz monzonite porphyry
Igneous intrusive	Quartz syenite
Igneous intrusive	Shonikite
Igneous intrusive	Sodalite syenite
Igneous intrusive	Syenite
Igneous intrusive	Syenite porphyry
Igneous intrusive	Syenodiorite
Igneous intrusive	Theralite
Igneous intrusive	Theralite porphyry
Igneous intrusive	Troctolite
Igneous intrusive	Uncompahgrite
Igneous intrusive	Uolite
Metamorphic	Actinolite hornfels
Metamorphic	Actinolite marble
Metamorphic	Actinolite schist
Metamorphic	Actinolite-epidote marble
Metamorphic	Albite-mica schist
Metamorphic	Amphibolite
Metamorphic	Amphibolite gneiss
Metamorphic	Andalusite hornfels
Metamorphic	Andalusite schist
Metamorphic	Andalusite spotted slate
Metamorphic	Andalusite-biotite hornfels
Metamorphic	Anorthosite gneiss
Metamorphic	Anthophyllite hornfels
Metamorphic	Arkose gneiss
Metamorphic	Augen gneiss

Primary lithology	Secondary lithology
Metamorphic	Biotite gneiss
Metamorphic	Biotite spotted slate
Metamorphic	Biotite-chlorite schist
Metamorphic	Black slate
Metamorphic	Brucite marble
Metamorphic	Calc-silicate hornfels
Metamorphic	Calcareous slate
Metamorphic	Calcite schist
Metamorphic	Carbonaceous slate
Metamorphic	Chiastolite schist
Metamorphic	Chiastolite spotted sate
Metamorphic	Chlorite marble
Metamorphic	Chlorite schist
Metamorphic	Chloritoid schist
Metamorphic	Chondrodite marble
Metamorphic	Conglomerate gneiss
Metamorphic	Cordierite hornfels
Metamorphic	Cordierite-anthophyllite hornfels
Metamorphic	Crystalline metamorphic
Metamorphic	Diabase gneiss
Metamorphic	Diopside marble
Metamorphic	Diorite gneiss
Metamorphic	Eclogite
Metamorphic	Epidote amphibolite
Metamorphic	Epidote gneiss
Metamorphic	Epidote hornfels
Metamorphic	Epidote-chlorite schist
Metamorphic	Flaser conglomerate
Metamorphic	Flaser diorite
Metamorphic	Flaser granite

Primary lithology	Secondary lithology
Metamorphic	Gabbro gneiss
Metamorphic	Garnet biotite gneiss
Metamorphic	Garnet gneiss
Metamorphic	Garnet hornfels
Metamorphic	Garnet-chlorite schist
Metamorphic	Garnet-pyroxene amphibolite
Metamorphic	Glaucophane schist
Metamorphic	Gneiss
Metamorphic	Granite gneiss
Metamorphic	Granodiorite gneiss
Metamorphic	Granofels
Metamorphic	Granulite
Metamorphic	Graphite marble
Metamorphic	Graphite schist
Metamorphic	Graywacke gneiss
Metamorphic	Green slate
Metamorphic	Greenschist
Metamorphic	Greenstone
Metamorphic	Hornblende-biotite schist
Metamorphic	Hornfels
Metamorphic	Kyanite hornfels
Metamorphic	Kyanite schist
Metamorphic	Magnetite
Metamorphic	Marble
Metamorphic	Meta-argillite
Metamorphic	Metaconglomerate
Metamorphic	Metaquartzite
Metamorphic	Metasedimentary melange
Metamorphic	Metasedimentary rocks
Metamorphic	Metasedimentary alcareous

Primary lithology	Secondary lithology
Metamorphic	Metasedimentary noncalcareous
Metamorphic	Metavolvanic rocks
Metamorphic	Mica schist
Metamorphic	Migmatite
Metamorphic	Monzonite gneiss
Metamorphic	Mylonite
Metamorphic	Olivine marble
Metamorphic	Peridotite gneiss
Metamorphic	Phyllite
Metamorphic	Phyllonite
Metamorphic	Plagioclase gneiss
Metamorphic	Pyrophyllite schist
Metamorphic	Pyroxene gneiss
Metamorphic	Pyroxene hornfels
Metamorphic	Pyroxene schist
Metamorphic	Quartz diorite gneiss
Metamorphic	Quartz porphyry gneiss
Metamorphic	Quartz-mica schist
Metamorphic	Quartz-sericite schist
Metamorphic	Quartzite
Metamorphic	Quartzite gneiss
Metamorphic	Rhyolite gneiss
Metamorphic	Sandstone gneiss
Metamorphic	Schist
Metamorphic	Schistose quartzite
Metamorphic	Serpentine
Metamorphic	Serpentine marble
Metamorphic	Serpentine melange
Metamorphic	Sillimanite garnet schist
Metamorphic	Sillimanite gneiss

Primary lithology	Secondary lithology
Metamorphic	Sillimanite schist
Metamorphic	Silty slate
Metamorphic	Skarn
Metamorphic	Skarn gneiss
Metamorphic	Slate
Metamorphic	Soapstone
Metamorphic	Spotted slate
Metamorphic	Staurolite gneiss
Metamorphic	Staurolite schist
Metamorphic	Syenite gneiss
Metamorphic	Talc schist
Metamorphic	Tourmaline hornfels
Metamorphic	Tourmaline schist
Metamorphic	Tourmaline-mica schist
Metamorphic	Trachyte gneiss
Metamorphic	Tremolite hornfels
Metamorphic	Tremolite marble
Metamorphic	Ultramylonite
Metamorphic	Wollastonite hornfels
Metamorphic	Wollastonite marble
Sedimentary	Agglomerate
Sedimentary	Anhydrite
Sedimentary	Argillite
Sedimentary	Arkose
Sedimentary	Arkose argillaceous
Sedimentary	Arkose calcareous
Sedimentary	Arkose siliceous
Sedimentary	Asphalt
Sedimentary	Bentonite
Sedimentary	Breccia

Primary lithology	Secondary lithology
Sedimentary	Caliche
Sedimentary	Chalk
Sedimentary	Chert
Sedimentary	Chert oolitic
Sedimentary	Claystone
Sedimentary	Claystone siliceous
Sedimentary	Coal, anthracite
Sedimentary	Coal, bituminous
Sedimentary	Conglomerate
Sedimentary	Coquina
Sedimentary	Diatomite
Sedimentary	Dolomite
Sedimentary	Gilsonite
Sedimentary	Graywacke
Sedimentary	Graywacke calcareous
Sedimentary	Greensand
Sedimentary	Gypsum
Sedimentary	Halite
Sedimentary	Hematite
Sedimentary	Interbedded limestone and sandstone
Sedimentary	Interbedded limestone and shale
Sedimentary	Interbedded limestone and siltstone
Sedimentary	Interbedded sandstone and shale
Sedimentary	Interbedded sandstone and siltstone
Sedimentary	Ironstone
Sedimentary	Lignite
Sedimentary	Limestone
Sedimentary	Limestone arenaceous
Sedimentary	Limestone argillaceous
Sedimentary	Limestone bituminous

Primary lithology	Secondary lithology
Sedimentary	Limestone carbonaceous
Sedimentary	Limestone cherty
Sedimentary	Limestone clastic
Sedimentary	Limestone iron-rich
Sedimentary	Limestone oolitic
Sedimentary	Limestone organic
Sedimentary	Limestone phosphatic
Sedimentary	Limestone siliceous
Sedimentary	Limestone siliciclastic
Sedimentary	Limonite
Sedimentary	Marlstone
Sedimentary	Mudstone
Sedimentary	Mudstone siliceous
Sedimentary	Oolite calcareous
Sedimentary	Oolite iron-rich
Sedimentary	Oolite phosphatic
Sedimentary	Oolite siliceous
Sedimentary	Orthoquartzite
Sedimentary	Orthoquartzite feldspathic
Sedimentary	Orthoquartzite lithic
Sedimentary	Phosphorite
Sedimentary	Porcellanite
Sedimentary	Radiolarite
Sedimentary	Rock Salt
Sedimentary	Sandstone
Sedimentary	Sandstone argillaceous
Sedimentary	Sandstone argillaceous feldspathic
Sedimentary	Sandstone argillaceous lithic
Sedimentary	Sandstone argillaceous quartz
Sedimentary	Sandstone calcareous

Primary lithology	Secondary lithology
Sedimentary	Sandstone calcareous feldspathic
Sedimentary	Sandstone calcareous lithic
Sedimentary	Sandstone calcareous quartz
Sedimentary	Sandstone carbonaceous quartz
Sedimentary	Sandstone feldspathic
Sedimentary	Sandstone iron-rich
Sedimentary	Sandstone iron-rich quartz
Sedimentary	Sandstone lithic
Sedimentary	Sandstone quartz
Sedimentary	Shale
Sedimentary	Shale bituminous
Sedimentary	Shale calcareous
Sedimentary	Shale carbonaceous
Sedimentary	Shale iron-rich
Sedimentary	Shale phosphatic
Sedimentary	Shale siliceous
Sedimentary	Siderite
Sedimentary	Siltstone
Sedimentary	Siltstone calcareous
Sedimentary	Siltstone carbonaceous
Sedimentary	Siltstone iron-rich
Sedimentary	Subgraywacke
Sedimentary	Subgraywacke calcareous
Sedimentary	Travertine
Sedimentary	Tufa
Sedimentary	Tuff
Sedimentary	Volcanic breccia
Sedimentary	Volcaniclastic
Undifferentiated	Mixed extrusive and metamorphic
Undifferentiated	Mixed extrusive and sedimentary

Primary lithology	Secondary lithology
Undifferentiated	Mixed igneous (extrusive & intrusive)
Undifferentiated	Mixed igneous and metamorphic
Undifferentiated	Mixed igneous and sedimentary
Undifferentiated	Mixed intrusive and metamorphic
Undifferentiated	Mixed intrusive and sedimentary
Undifferentiated	Mixed metamorphic and sedimentary
Unconsolidated	Alluvium
Unconsolidated	Ash/loess mixture
Unconsolidated	Cinders
Unconsolidated	Colluvim
Unconsolidated	Cryoturbate
Unconsolidated	Diamicton
Unconsolidated	Diatomaceous earth
Unconsolidated	Eolian deposit
Unconsolidated	Glacial deposit
Unconsolidated	Glacial moraine deposit
Unconsolidated	Glacial till deposit
Unconsolidated	Glaciofluvial deposit
Unconsolidated	Glaciolacustrine deposit
Unconsolidated	Glaciomarine deposit
Unconsolidated	Greensand
Unconsolidated	Gypsum sand
Unconsolidated	Human cause/constructed
Unconsolidated	Lacustrine sediments
Unconsolidated	Lahar
Unconsolidated	Landslide deposit
Unconsolidated	Marine sediments
Unconsolidated	Marl
Unconsolidated	Mixed
Unconsolidated	Muck

Primary lithology	Secondary lithology
Unconsolidated	Organic deposits
Unconsolidated	Peat
Unconsolidated	Residuum
Unconsolidated	Talus deposit
Unconsolidated	Tephra (undifferentiated)
Unconsolidated	Transitional marine/continental deposits
Unconsolidated	Volcanic ash

Reference

U.S. Department of Agriculture (USDA), Forest Service. 2009. Site general: field guide. Washington, DC: U.S. Department of Agriculture, Forest Service, Rangeland Management Staff. 57 p.

Appendix 5. Plant Labels

(Cut along dashed lines)

Plant (or unknown #): ____________________ Collection # ____________________ Date: __________

Site Name: ____________________ Project/Unit: ____________________ Collector: ____________________

Perennial: Y or N Spreading: Y or N Height (m): __________ forb/graminoid/shrub/tree/other

Genus, Family, Comments: ____

Plant (or unknown #): ____________________ Collection # ____________________ Date: __________

Site Name: ____________________ Project/Unit: ____________________ Collector: ____________________

Perennial: Y or N Spreading: Y or N Height (m): __________ forb/graminoid/shrub/tree/other

Genus, Family, Comments: ____

Plant (or unknown #): ____________________ Collection # ____________________ Date: __________

Site Name: ____________________ Project/Unit: ____________________ Collector: ____________________

Perennial: Y or N Spreading: Y or N Height (m): __________ forb/graminoid/shrub/tree/other

Genus, Family, Comments: ____

Plant (or unknown #): ____________________ Collection # ____________________ Date: __________

Site Name: ____________________ Project/Unit: ____________________ Collector: ____________________

Perennial: Y or N Spreading: Y or N Height (m): __________ forb/graminoid/shrub/tree/other

Genus, Family, Comments: ____

Plant (or unknown #): ____________________ Collection # ____________________ Date: __________

Site Name: ____________________ Project/Unit: ____________________ Collector: ____________________

Perennial: Y or N Spreading: Y or N Height (m): __________ forb/graminoid/shrub/tree/other

Genus, Family, Comments: ____

Plant (or unknown #): ____________________ Collection # ____________________ Date: __________

Site Name: ____________________ Project/Unit: ____________________ Collector: ____________________

Perennial: Y or N Spreading: Y or N Height (m): __________ forb/graminoid/shrub/tree/other

Genus, Family, Comments: ____

Appendix 6. Measurement of Discharge at Springs and Wetlands

Introduction

Measurement of discharge at springs and wetlands, although similar to such measurements in streams, presents additional challenges. Each site is unique, so that a measurement method that may be appropriate at one site may not be appropriate at another site. The field investigator must evaluate each site and choose the appropriate method to use, and, if necessary, modify the method to adjust to conditions at the site. For example, if discharge at a spring or wetland site is diffuse or coming from several points, a channel might be dug to incorporate such diffuse flow into a single channel that can then be measured.

These instructions are modified from: Rantz et al. (1982). Additional information may be obtained from sources listed in the References section.

Purpose

This is a description of techniques for measurement of discharge at springs and in wetlands that have flowing waters. The situations and methodologies discussed include the following:

- Current meter
- Timed observation of floats
- Volumetric measurement
- Use of a calibrated portable weir plate
- Use of a calibrated portable Parshall flume
- Static head change procedure
- Visual estimate

Key Scientific Concepts, Considerations, and Assumptions

Measuring the discharge of some springs and wetlands can be challenging because the amount of discharge is small, waters are usually shallow and broadly and unevenly spread over a wide area, and areas with moving water are sometimes limited. Multiple observations are recommended to precisely quantify the hydrologic period or long-term discharge characteristics, because discharge changes diurnally, seasonally, and annually.

The way the flow (or discharge) is measured will vary depending on the site-specific factors, therefore, a variety of methods are presented. Table 6.1 lists the various instruments recommended for a range of discharge conditions.

Table 6.1.—Recommended methods to measure discharge based on flow (Stevens et al. 2006).

Discharge (metric)	Discharge (gal/min)	Instrument(s)
< 10 mL/s	< 0.16	Volumetric
10 to 100 mL/s	0.16 to 1.6	Weir, volumetric
0.1 to 1 L/s	1.6 to 16	Weir, flume
1 to 10 L/s	16 to 158	Weir, flume
10 to 100 L/s	158 to 1,585	Flume
0.1 to 1 m^3/s	1,585 to 15,850	Current meter
1 to 10 m^3/s	15,850 to 158,500	Current meter
> 10 m^3/s	> 158,500	Current meter

Note: Of all the instruments listed, the flume is the largest and most difficult to carry. Therefore, it should not be carried into the backcountry unless it is essential to obtain an accurate measurement or if the spring has a discharge magnitude making a flume the optimal instrument.

Hanging gardens and limnocrenes, in particular, present a challenge for measuring flow. Flow measurements at a hanging garden could be taken at the base of the wall where flow coalesces into a channel. If this is not possible, photo documentation of the wetted area of rock face is an option. For limnocrenes that do not have outflow, the static head change method is used. For limnocrenes that have an outflow, one of the other measurement techniques described in the following paragraphs would be appropriate.

If a single channel exists, the discharge measurement should be taken as close as possible to the spring orifice. If multiple channels exist, and if they all converge to a single channel, the discharge can be measured in the single channel as close as possible to the confluence of all the multiple channels. Alternatively, the flow at each orifice can be measured.

Accuracy of Discharge Measurements

Accuracy of a discharge measurement is dependent on many factors, including the equipment used, the location and characteristic of the measuring section, the number and spacing of measurements, the rate of change in stage, the measurement depth and velocity, presence of ice and/or debris, wind, and (especially) the experience of the person conducting the measurement (Turnipseed and Sauer 2010, p. 79). The accuracy is often evaluated qualitatively, taking all these factors into account.

See Rantz et al. (1982) and Turnipseed and Sauer (2010) for information on field equipment used for some of the methods described in the following section.

Procedure

Current Meter

A current meter is an instrument used to measure the velocity of flowing water at a specific point in a channel. Several types of current meters are now available. Selecting which meter to use at a site will depend on purpose, site conditions, and cost.

Historically, the U.S. Geological Survey (USGS) has used vertical-axis current meters (price current meter), which are mechanical devices that use spinning cups to measure the current velocity (Rantz et al. 1982 pp. 86–88). A smaller version (pygmy meter) is used at sites where water is shallow, such as a spring or wetland. Advancements in acoustic technology have led to important developments in the use of acoustic Doppler current profilers, acoustic Doppler velocimeters, and other emerging technologies for the measurement of discharge. These new instruments, based on acoustic Doppler theory, have the advantage of no moving parts, and in the case of the acoustic Doppler current profiler, quickly and easily provide three-dimensional stream-velocity profile data through much of the vertical water column. Additional information on current USGS stream-gaging procedures, including information on use of electronic field notebooks and personal digital assistants (PDAs), is available in Turnipseed and Sauer (2010).

Current meters are necessary in springs or in wide channels or high-discharge channels where flow cannot be routed into a weir or a flume. Measurement locations are selected in a straight reach where the streambed is free of large rocks, weeds, and protruding obstructions that create turbulence and where a flat streambed profile occurs to eliminate vertical components of velocity.

The cross-section of the channel is divided into partial sections, and the area and mean velocity of each section is measured separately. A partial section is a rectangular region where depth is equal to the depth measured at that location, and where width is equal to the sum of half the distances of adjacent verticals. At each vertical, the following observations are recorded on the data sheet: (1) the distance to a reference point on the bank along the tag line, (2) the depth of flow, and (3) the velocity as indicated by the current meter. The velocity should be measured at a depth that is 0.6 of the depth from the surface of water in the channel. The discharge of each partial section is calculated as the product of mean velocity times depth at the vertical times the sum of half the distances to adjacent verticals. The sum of the discharges of each partial section is the total discharge.

Measurements are made by wading in the stream with the current meter along the tag line. The person wading the channel should stand downstream of the velocity meter. Detailed procedures for use of current meters is documented in Rantz et al. (1982) and Turnipseed and Sauer (2010).

Accuracy of current meter measurements can be evaluated using methods described by Sauer and Meyer (1992). Their study indicated that accuracy can range from 2-percent measurement error under ideal measurement conditions to 20-percent measurement error under poor conditions. Under generally normal conditions, standard errors of measurement range from 3 to 6 percent.

Float Method

Floats are useful for measuring discharges at springs and wetlands, where water is shallow and velocities may be too small to accurately use a current meter. Floats can be almost any distinguishable article that floats, such as wooden disks; bottles partly filled with water, soil, or stones; or oranges. Floating ice cakes or distinguishable pieces of drift may be used if they are present in the stream. Fluorescent dye can also be used.

Two cross-sections are selected along a reach of straight channel for a float measurement. The cross-sections should be far enough apart so that the time the float takes to pass from one cross-section to the other can be measured accurately. A travel time of at least 20 seconds is recommended, but a shorter time may be used for streams with such high velocities that it is not possible to find a straight reach of channel having adequate length. The distance between the two sections is measured with a measuring tape, and recorded. The width and depth of each channel cross-section is measured with a tape measure and recorded. In making a float measurement, the float is introduced a short distance upstream from the upstream cross-section so that it will be traveling at the speed of the current when it reaches the upstream section. A stopwatch is used to time its travel between the end cross-sections of the reach. This procedure is repeated three to five times, as the float is placed at different locations across the channel at the upstream cross-section. The average velocity of the measurement is then calculated. An example field sheet for use with this method is shown in figure 6.1.

The velocity of the float is equal to the distance between the end cross-sections divided by the time of travel. The mean velocity in the vertical is equal to the float velocity multiplied by a coefficient whose value is dependent on the shape of the vertical-velocity profile of the stream, and on the depth of immersion of the float with respect to stream depth. Coefficients of 0.85 to 0.88 are commonly used to convert the velocity of a surface float to mean velocity in the vertical (Turnipseed and Sauer 2010, p. 85).

The procedure for computing the discharge is similar to that used in computing the discharge for a conventional current-meter measurement. Discharge is computed by multiplying the area of the channel by the mean vertical velocity.

Float measurements of discharge that are carefully made under favorable conditions may be accurate to within +/- 10 percent. Wind may adversely affect the accuracy of the computed discharge due to its effect on the velocity of the floats. If a nonuniform reach is selected, measurement results may be in error by as much as 25 percent.

Float method Reach length:		
Trial	Time elapsed	Velocity (reach length/time)
#1		
#2		
#3		
	Average velocity:	
	Average velocity x 0.85:	

Figure 6.1—Example field sheet for use with the float method.

Volumetric Measurement

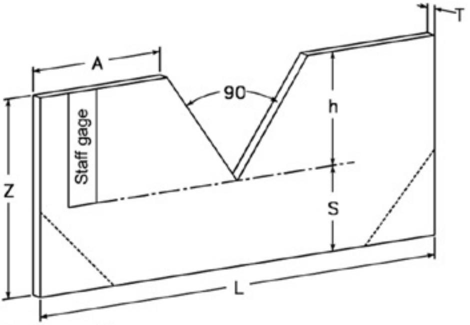
The volumetric measurement of discharge is the most accurate method of measuring small flows (less than a few gallons per minute). The time required to fill a container of known capacity, or the time required to partly fill a calibrated container to a known volume, is recorded. The only equipment required, other than the calibrated container, is a stopwatch.

Volumetric measurements are usually made where the flow is concentrated in a narrow stream, or can be so concentrated, so that all the flow may be diverted into a container. Examples of sites presenting the opportunity for volumetric measurement of discharge are a V-notch weir; a natural or artificial control where all the flow is confined to a notch; or a cross-section of natural channel where a temporary earthen dam can be built over a pipe of small diameter, through which the entire flow is directed.

Sometimes it is necessary to place a trough against the artificial control to carry the water from the control to the calibrated container. If a small temporary dam is built, the stage behind the dam should be allowed to stabilize before the measurement is begun. The measurement should be made three or four times to be certain no errors have been made and to be sure the results are consistent. Several calibrated containers of varying sizes should be taken to the field site.

Portable Weir Plate

A portable weir plate is useful for determining discharge when depths are too shallow and velocities too low for a reliable current-meter measurement of discharge. A 90-degree V-notch weir is particularly suitable because of its sensitivity at low flows. The USGS commonly uses three different sizes of weir plate; their recommended dimensions are given in figure 6.2.



Corners may be trimmed if desired.

Units in feet unless otherwise noted.

Weir	Z	h	S	L	A	T	Weight (lb)
Large	1.75	1.00	0.75	4.0	1.0	16 ga.	24
Medium	1.25	0.80	0.45	3.0	0.7	14 ga.	17
Small	0.75	0.47	0.28	2.0	0.53	10 ga.	8

Figure 6.2—Portable weir plate sizes.

The weir plate is made of galvanized sheet iron, using 10- to 16-gauge metal. The 90-degree V-notch that is cut in the plate is not beveled but is left with flat, even edges. A staff gauge, attached to the upstream side of the weir plate with its zero at the elevation of the bottom of the notch, is used to read the head on the weir. The staff gauge should be installed far enough from the notch to be outside the region of drawdown of water going through the notch. Drawdown becomes negligible at a distance from the vertex of the notch that is equal to twice the head on the notch. Consequently, if the weir plate has the dimensions recommended in figure 6.2, the staff gauge should be installed near one end of the plate.

To install the weir, the weir plate is pushed into the streambed. A pick or shovel may be necessary to remove stones or rocks that prevent even penetration of the plate. A carpenter's level is used to ensure that the top of the plate is horizontal and that the face of the plate is vertical. Soil or streambed material is packed around the weir plate to prevent leakage under and around it. It ordinarily requires only one person to make the installation.

A large weir plate of the dimensions shown in figure 10.1 can measure discharges in the range from 0.02 to 2.0 ft^3/s (0.00057 to 0.057 m^3/s) with an accuracy of +/- 3 percent, if the weir is not submerged. A weir is not submerged when air circulates freely around all sides of the nappe. The general equation for flow over a sharp-edged 90-degree V-notch weir is:

$$Q = C \times h^{5/2}$$

where

Q = discharge, in ft^3/s or m^3/s

h = static head above the bottom of the notch, in ft or m

C = coefficient of discharge

Each weir should be rated to determine C by volumetrically measuring the discharge corresponding to various values of head. In the absence of such a rating, a value of 2.47 may be used for C when British units are used, or 1.36 when metric units are used.

When the weir is installed, it will cause a pool to form on the upstream side of the plate. No readings of head on the notch should be recorded until the pool has risen to a stable elevation. The head should then be read at half-minute intervals for about 3 minutes, and the mean value of those readings should be used as the value for head in the equation to compute discharge. After the completion of the measurement, the weir plate is removed.

An online method for calculating discharge using a V-notch weir is available at http://www.lmnoeng.com/Weirs/vweir.htm.

Portable Parshall Flume

A portable Parshall flume is another device for determining discharge when depths are too shallow and velocities too low for a current-meter measurement of discharge. The portable flume used by the USGS is a modified form of the standard Parshall flume having a 3-inch (0.076 meter) throat. The modification consists, primarily, of the removal of the downstream diverging section of the standard flume. The purpose of the modification is to reduce the weight of the flume and to make it easier to install.

Because the portable Parshall flume has no downstream diverging section, it cannot be used for measuring flows when the submergence ratio exceeds 0.6. The submergence ratio is the ratio of the downstream head on the throat to the upstream head on the throat. Although a submergence ratio of 0.6 can be tolerated without affecting the rating of the portable flume, in practice the flume is usually installed so that the flow freely passes the throat without being slowed by ponding below the flume. That installation is usually accomplished by building up the streambed a couple of inches under the level converging floor of the flume. Figure 6.3 shows the plan and elevation of the portable Parshall flume. The gauge height or upstream head on the throat is read in the small stilling well that is hydraulically connected to the flow by a ⅜-inch hole. The rating for the flume is given in table 6.2.

When the flume is installed in the channel, the floor of the converging section is set in a level position by using the level bubble that is attached to one of the braces (fig. 6.3). A carpenter's level can be used for that purpose if the flume is not equipped with a level bubble. Soil or streambed material is then packed around the flume to prevent leakage under and around it. After the flume is installed, water will pool upstream from the structure. No gauge-height readings should be recorded until the pool has risen to a stable level. As with the portable weir, after stabilization of the pool level, gauge-height readings should be taken at 30-second intervals for about 3 minutes. The mean value of those readings is the gauge height used in table 10.3 to obtain the discharge. A carefully made measurement should have an accuracy of +/- 2 or 3 percent. After completion of the measurement, the portable flume is removed.

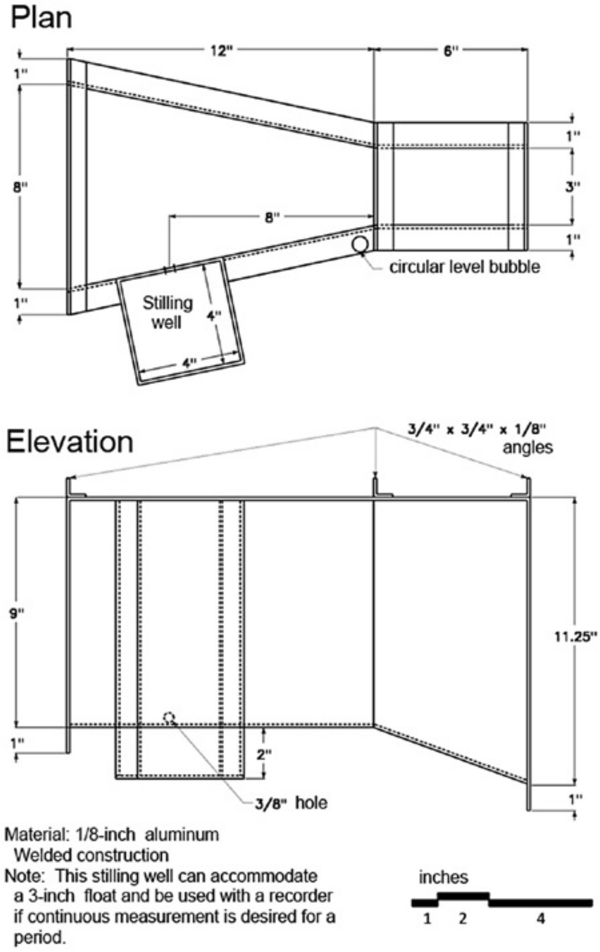


Figure 6.3— Working drawing of modified 3-inch Parshall flume.

Table 6.2—Rating table for 3-inch modified Parshall flume.

Gauge height (ft)	Discharge (ft^3/s)	Gauge height (ft)	Discharge (ft^3/s)	Gauge height (ft)	Discharge (ft^3/s)
0.01	0.0008	0.21	0.097	0.41	0.280
0.02	0.0024	0.22	0.104	0.42	0.290
0.03	0.0045	0.23	0.111	0.43	0.301
0.04	0.0070	0.24	0.119	0.44	0.312
0.05	0.010	0.25	0.127	0.45	0.323
0.06	0.013	0.26	0.135	0.46	0.334
0.07	0.017	0.27	0.144	0.47	0.345
0.08	0.021	0.28	0.153	0.48	0.357
0.09	0.025	0.29	0.162	0.49	0.368
0.10	0.030	0.30	0.170	0.50	0.380
0.11	0.035	0.31	0.179	0.51	0.392
0.12	0.040	0.32	0.188	0.52	0.404
0.13	0.045	0.33	0.198	0.53	0.417
0.14	0.051	0.34	0.208	0.54	0.430
0.15	0.057	0.35	0.218	0.55	0.443
0.16	0.063	0.36	0.228	0.56	0.456
0.17	0.069	0.37	0.238	0.57	0.470
0.18	0.076	0.38	0.248	0.58	0.483
0.19	0.083	0.39	0.259	0.59	0.497
0.20	0.090	0.40	0.269		

The Static Head Change Procedure

This method may be used for a relative comparison value for change in elevation of standing pools or limnocrenes with no outflow. A staff gauge is placed in the standing pool and relative gauge elevation recorded, or efforts are made to locate and record an existing fixed point in or near the standing pool and the vertical distance to the pool surface recorded. Periodic measurements of changes in the static head on the staff gauge or fixed point are recorded.

Visual Estimate

Site conditions, such as dense vegetation cover, steep or flat slope, diffuse discharge into a marshy area, and limited or dangerous access sometimes do not allow for a direct measurement of discharge by the techniques listed previously. Typically, the visual estimate method is used along with a gross estimate of flow velocity with a float but is only recommended as a last resort. Discharge class is estimated based on those listed in table 10.1. Photographs should be taken to record the surface area wetted or covered by water and observations recorded on a datasheet. Also, it should be noted if another method could be recommended to measure discharge for future site visits.

Documentation and Data Management

The name, serial number (if available), accuracy of the instrument used to measure discharge, and any other important observations should be recorded. Important observations may include the markers of any recent high discharges, such as high water marks, oriented vegetation, or debris on or above the channel or floodplain.

All computation sheets for discharge calculations should be neat and legible. Errors or modifications should be indicated by a single line drawn through them (no erasures or blackouts). These computations should be checked by an independent reviewer. Copies of computation sheets should be kept in project files and archived according to required procedures. Electronic copies of computations should be archived in the appropriate database.

Additional Information

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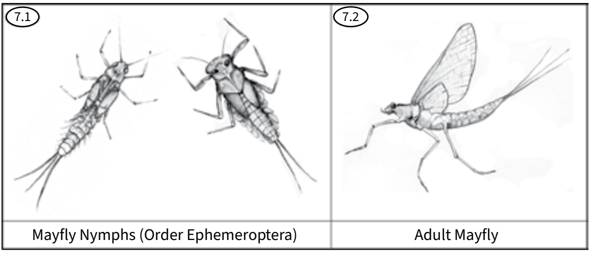
Appendix 7. Identification of Freshwater Invertebrates

This appendix has representative drawings of groups of aquatic macroinvertebrates important in springs and other groundwater-dependent ecosystems. A substantial amount of training is needed to identify many macroinvertebrate species, but identifying most groups (such as order or family) and many nonnative species may be accomplished with minimal training.

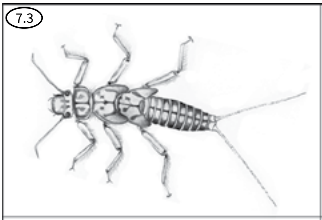
These descriptions and illustrations can facilitate identification of important taxa in the field. Useful references that provide more detail include “A Guide to Common Freshwater Invertebrates of North America” (Voshell 2002) and “Aquatic Entomology: The Fisherman’s and Ecologist’s Illustrated Guide to Insects and Their Relatives” (McCafferty 1981). At the end of this appendix is a “Key to Macroinvertebrate Life in the River,” developed by the University of Wisconsin, in an easy-to-use flowchart format.

The following illustrations, other than those in the “Key to Macroinvertebrate Life in the River,” were drawn by Luke Boehnke.

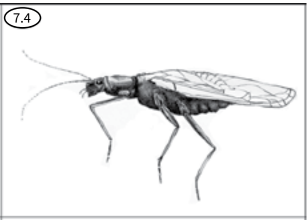
All three insect orders described in figures 7.1 to 7.6 leave the water to mate as winged adults. Large swarms of mating mayflies and caddisflies often occur when all the individuals of a single species emerge at the same time. The females of all three groups fly upstream and drop their eggs onto the water or dive into the stream to attach them to rocks or leaves.



Figures 7.1–7.2.—Mayflies are insects that spend most of their lives in streams, emerging briefly as adults to mate and lay eggs. Many species have gills that are visible along the abdomen. Most mayflies have three tails, but some have only two tails. Mayfly diversity declines as aquatic conditions are degraded; mayflies are particularly sensitive to mine waste (size: 6 to 25 millimeters).

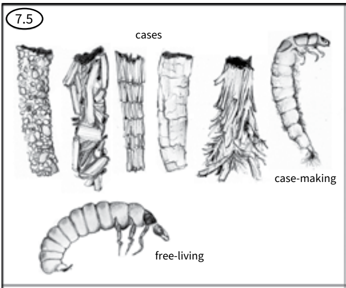


Stonefly Nymph (Order Plecoptera)

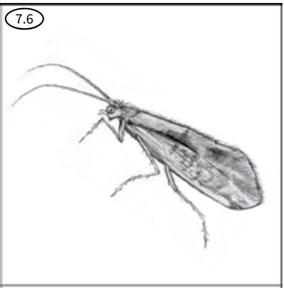


Adult Stonefly

Figures 7.3–7.4.—Stonefly nymphs are almost always found in flowing water. Some stoneflies feed on other invertebrates while other taxa eat dead organic matter and prefer coarse substrate. Stoneflies look similar to mayflies but are stockier, have two claws (rather than one) on each foot, and have two tails instead of the usual three in mayflies. There are no gills on the abdomen. Diversity of these animals declines rapidly at the first sign of human disturbance (size: 12 to 40 millimeters).

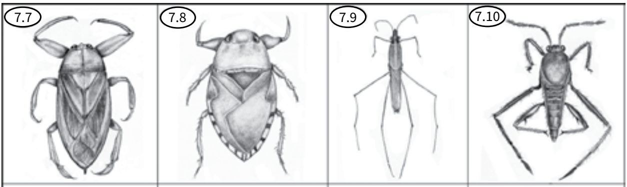


Caddisfly Larvae (Order Trichoptera)



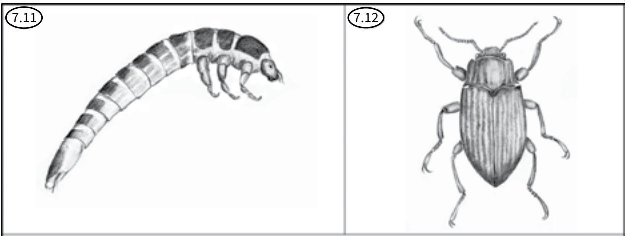
Adult Caddisfly

Figures 7.5–7.6.—Caddisflies are insects that emerge to mate as winged adults. They use silk to build cases from gravel, twigs, needles, or sand. The larva is caterpillar-like with three pairs of legs, two claws at the posterior (rear) end of the abdomen, and a tendency to curl up slightly. They may be found in a stick, rock, or leaf case, with the head sticking out. Different species build distinct cases or chambers, often on or under rocks. Free-living caddisfly larvae do not build cases; many are predators and need to move quickly to capture other animals for food. Some caddisflies are very sensitive to human disturbance, but others are tolerant (size: 12 to 40 millimeters).



Belostomatidae	Naucoridae	Gerridae	Veliidae
Adult True Bugs (Order Hemiptera)			

Figures 7.7–7.10.—These four families of true bugs commonly occur in western North American springs. True bug larvae look similar to the adults. They can be distinguished from other aquatic insects by the following combination of characteristics: mouthparts are an elongated beak that folds back under the head when not feeding, wingpads are present on the thorax, three pairs of segmented legs with two claws on some of them, and no gills are present.



Riffle Beetle (Order Coleoptera, Family Elmidae)—Larvae and Adult

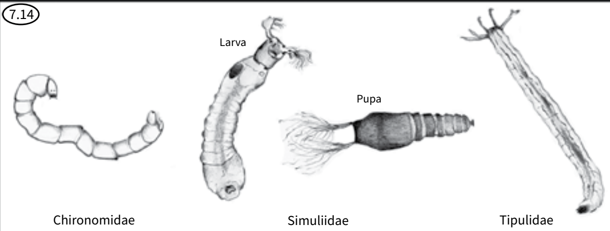
Figures 7.11–7.12.—Riffle beetle larvae are specially adapted to cling to smooth rocks in fast-flowing water (riffles). After emergence, adults fly for a short time but return to water to feed in the same habitat as the larvae. Both larvae and adults are rather small and tend to drift to the bottom of a sample. Many beetle families occur in aquatic habitats, but comparatively few crenobiontic species exist. In the Western United States, most crenobiontic riffle beetles are in two genera, *Stenelmis* and *Microcylloepus.* Differentiating between these genera is difficult in the field because individuals are small (less than 3 millimeters long) and difficult to examine without magnification. They are easy to see in samples, however. Riffle beetles are black or dark brown with long, spindly legs. They move slowly by crawling, and they have weak swimming ability (size: less than 3 millimeters).

7.13

Long-Toed Water Beetle (Order Coleoptera, Family Dryopidae)

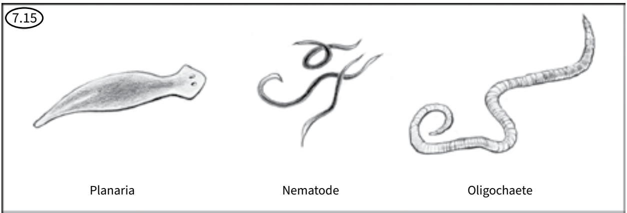
Figure 7.13.—Long-toed water beetles are common in riffles and on woody debris or rocks. Adults use long, sharp claws to cling to debris and sometimes they crawl on the bottom or along the shore. The body is dull gray or brown and often covered with fine hairs, and the head is mostly withdrawn into the thorax (size: 4 to 8 millimeters).

7.14



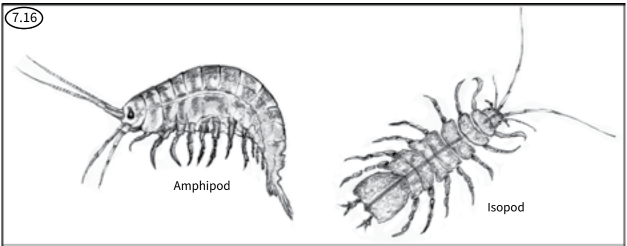
Fly Larvae (Order Diptera)

Figure 7.14.—Many species of true flies exist, but in springs, there are three main groups or families. Midge larvae (or chironomids) are very small (up to 6 millimeters), often C-shaped, with a segmented body and a spastic squirming movement. They are often whitish to clear, but occasionally bright red. Midge larvae have distinct heads with two small prolegs in the front of the body and are often attached to debris by their tiny legs. Blackfly larvae (or simuliids) are dumbbell shaped and soft (up to 6 millimeters). The body is larger at the rear end, similar to the shape of a bowling pin. The distinct head contains fan-like mouth brushes. Blackfly larvae often curl into a U-shape when held in your hand. They attach themselves to the stable substrate such as rocks, large wood, or rooted vegetation. Crane fly larvae (or tipulids) are large (8 to 60 millimeters) with a fleshy, worm-like, segmented body with finger-like projections (gills) at the back end. They occur in a variety of colors (clear, white, brown, and green) and bury themselves in soft sediment.



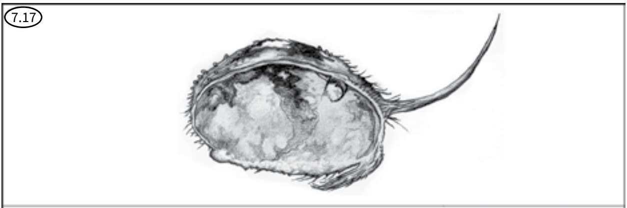
Aquatic Worms (Phylum Turbellaria, Nematoda, Annelida)

Figure 7.15.—Flatworms (e.g., *Planaria*), roundworms (nematodes), and freshwater segmented worms (oligochaetes, leeches, earthworms) are properly called worms, but should not be confused with the soft-bodied larvae of flies. Nematodes and oligochaetes are long, thin, and writhe like snakes, while planarians glide. These animals do not have legs.



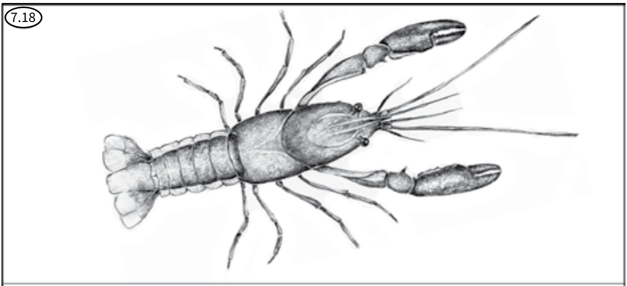
Amphipod and Isopod (Subphylum Crustacea)

Figure 7.16.—Amphipods (or scuds) occur in many springs and are usually very numerous. They are comparatively large (up to 10 millimeters long), active, and easy to identify in a macroinvertebrate sample. Amphipods are very fast swimmers that look like shrimp. They have many appendages that give them a fuzzy appearance. Amphipods can be common in very degraded sites. Isopods (or sowbugs) are usually found creeping through leaf litter. They have a flat, segmented body (6 to 20 millimeters) with an “armored” appearance and seven pairs of legs. Unlike amphipods, isopods are flattened top to bottom.



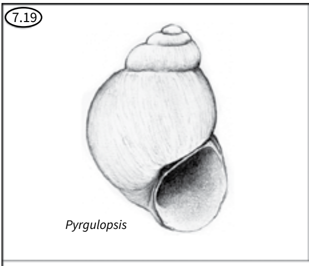
Ostracod (Subphylum Crustacea, Class Ostracoda)

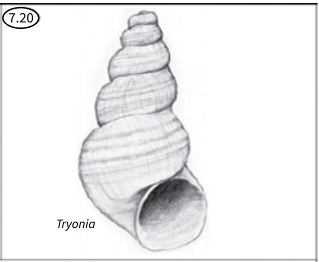
Figure 7.17.—Ostracods (seed shrimp) are the oldest known microfauna and have been extensively used in paleoclimate studies. They are small (usually less than 2 millimeters long), flattened animals with a calcitic shell and an external morphology that is similar to a plant seed. They are brown to pale olive green or gray, active, and are usually easy to see in a sample because they constantly move. Ostracods may occur in the water column or on the substrate, and they are usually abundant in springs.



Crayfish (Subphylum Crustacea, Order Decapoda)

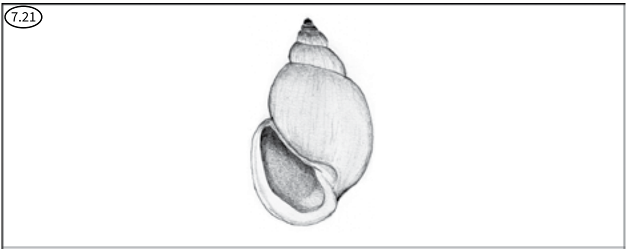
Figure 7.18.—Crayfish generally occur only in large springs that do not dry. In some places, nonnative crayfish have been introduced into springs, with often dramatic negative effects on native plants and animals.





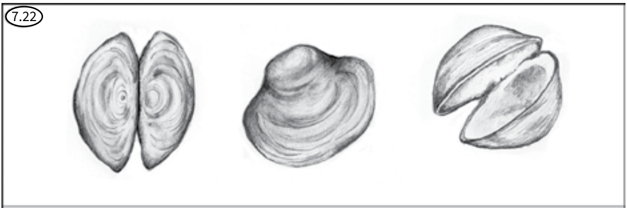
Springsnails (Phylum Mollusca, Class Gastropoda, Family Hydrobiide)

Figures 7.19–7.20.—Springsnails are small, black or brown crenobiontic species that have an operculum (lid) and a shell that opens on the right. Most species in southern U.S. deserts are in the genera *Pyrgulopsis* or *Tryonia,* which occur in two general body forms. Most *Pyrgulopsis* species are round and slightly inflated, while most *Tryonia* species are elongated. *Pyrgulopsis* species generally occur on gravel and cobble substrates and on watercress in areas with higher water velocity. *Tryonia* species are usually found in slow currents with fine substrates (size: less than 5 millimeters).



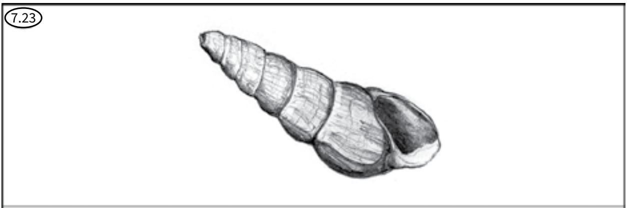
Physid Snail (Phylum Mollusca, Class Gastropoda, Family Physidae)

Figure 7.21.—Physid snails are found in springs and, although some are introduced, many are native and likely endemic. There is no operculum, and the shell opens on the left (size: 5 to 20 millimeters).



Fingernail Clams (Phylum Mollusca, Class Bivalvia, Family Sphaeriidae)

Figure 7.22.—Fingernail clams are small and usually bury themselves in habitats with fine sediment and low current velocity. They may be tan colored, but they are usually white and often translucent. Magnification is needed to differentiate species, which precludes field identification of species. When present, they are usually common and comparatively easy to find (size: 2 to 5 millimeters wide).



Red-rimmed Melania (Phylum Mollusca, Class Gastropoda, Family Thiaridae)

Figure 7.23.—Red-rimmed melania *(Melanoides tuberculata)* is a mollusk that was introduced into North America from Asia by the aquarium trade and has become widespread throughout the Western United States. It is parthenogenic (reproduces asexually) and can survive long periods out of water. It can be easily transplanted, is tolerant of harsh conditions, and prefers warm, slow water and fine substrates. Red-rimmed melania is easy to identify by its distinctive shape and color. It is long and conical, with body whorls terminating at a sharp point. Its shell is slightly sculptured, and its coloration is an attractive and distinct mottled, reticulated mixture of tan and brown. Because these mollusks are easily transported, care should be taken to completely clean and inspect field gear to ensure they are not carried and introduced into other springs (size: up to 25 millimeters).

References

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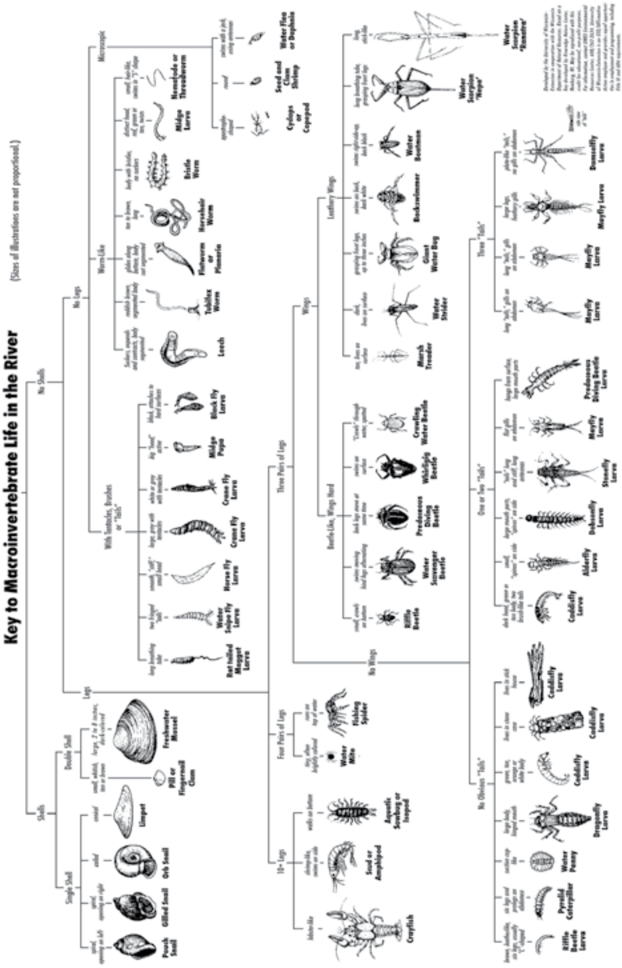
Voshell, J.R., 2002. A guide to common freshwater invertebrates of North America. Blacksburg, VA: McDonald and Woodward Publishing. 442 p.

The following “Key to Macroinvertebrate Life in the River” was developed by the University of Wisconsin.



Appendix 8. Dichotomous Key to Terrestrial Spring Types

Numbers guide the user stepwise through the options in the key. All springs can have more than one spring type, and all spring types can be perennial or ephemeral (i.e., secondarily hypocrene). (Adapted from Stevens et al. (2021), used by permission of Springs Stewardship Institute, and John Wiley & Sons).

Step	Description	Spring type
1	Groundwater expression of flow is subterranean, emerging within a cave (a water passage, often through limestone or basalt), before emerging into the atmosphere or subaqueously into a surface pool or channel. Lentic (standing or slow-moving), lotic (fast-moving), or both flow conditions can exist.	Cave spring
	Groundwater expression of flow emerges or emerged in a subaerial setting (in direct contact with the atmosphere), including within a sandstone alcove or subaqueously (beneath a body of water), but not from within a cave. Lentic, lotic, or both flow conditions can exist.	2
2	Groundwater is not expressed at the time of visit (the springs ecosystem is not flowing; the soil may be dry or moist, but not saturated).	3
	Groundwater is expressed at the time of visit; saturation, seepage, and/or flow are actively expressed (water, saturated soil, or both are evident); Lentic, lotic, or both flow conditions can exist.	5
3	Evidence of prehistoric groundwater presence and/or flow exists (e.g., paleotravertine, paleosols, fossil springs-dependent species), but no evidence of contemporary flow or aquatic, wetland, or riparian vegetation.	Paleospring
	Not as above.	4
4	Soil is dry or moist but is not saturated by groundwater. Groundwater is expressed solely through wetland or obligate riparian vegetation.	Hypocrene spring

Step	Description	Spring type
	Groundwater is expressed through saturated soil, or as standing or flowing water. Lentic, lotic, or both flow conditions can exist.	5
5	Groundwater is expressed, but discharge is primarily lentic (standing or slow-moving), and flow downstream from the spring's ecosystem may be absent or very limited.	6
	Groundwater is expressed; discharge is primarily lotic (fast-moving) and flows actively within and/or downstream, away from the spring's ecosystem.	11
6	Groundwater is expressed as a patch of shallow standing water or saturated fine sediment or soil, usually strongly dominated by hydric soils and emergent herbaceous wetland vegetation, but sometimes can include woodland or forest vegetation (e.g., palm oases, swamp forests). The slope is usually low (<16°). These sites are colloquially called wet meadows or ciénegas and include some GDE fens. Lotic flow conditions prevail.	7
	Subaqueous flow creates an open, lentic body of water, typically more than a few square meters in area, not dominated by emergent wetland vegetation, and with or without outflow.	8
7	A wet meadow with seepage emerging from the margin of an active surface flow-dominated channel or floodplain, and subject to regular flood scour by the stream channel into which it feeds.	Helocrene spring; secondarily rheocrene
	A wet meadow with seepage emerging outside and away from an active surface flow-dominated channel or floodplain, and not subject to regular flood scour by a stream.	Helocrene spring
8	The groundwater table surface is exposed as a pool with standing water, without a focused inflow source and with no outflow. Lotic flow conditions exist. Many prairie pothole springs are classified as this spring type.	Exposure spring

Step	Description	Spring type
	A pool is formed by one or more focused, usually subaqueous, inflow sources; generally with outflow, if not frozen.	9
9	Spring's source is surrounded by, and has contributed to the formation of, a mound composed of chemical precipitate (e.g., travertine), ice, or organic matter. Both lentic and lotic flow conditions can occur.	10
	Spring source forms an open pool which is not surrounded by a spring-created mineral, ice, or organic mound, often with a focused outflow channel. Lentic flow conditions prevail, but lotic flow may occur in the outflow channel.	Limnocrene spring
10	Spring's source is surrounded by, and/ or emerges from a mound composed of carbonate (including travertine) or other chemical precipitate. Both lentic and lotic flow conditions can occur.	Mound-form spring (carbonate)
	Spring source is surrounded by, and/or emerges from a mound composed of ice in an ice-dominated landscape. Flow may be seasonal, and both lentic and lotic flow conditions can occur. Also colloquially called pingos or aufeis springs.	Mound-form spring (ice)
	Spring source is surrounded by, and/or emerges from a mound composed of organic matter, such as decomposing vegetation or peat. Lentic flow conditions generally prevail. Some GDE fens are classified as this springs type.	Mound-form spring (organic)
11	Spring's flow emerges explosively and periodically, either by geothermally derived or gas-derived pressure. Lotic flow conditions generally prevail. This springs type includes geothermal geysers and "coke-bottle" (CO_2 gas-driven) geysers.	Geyser
	Spring flow emerges nonexplosively, but by the action of gravity.	12

Step	Description	Spring type
12	Artesian flow emerges from one or more focused points and rises 10 cm or more above ground level due to gravity-driven head pressure. After the flow falls to the ground, lentic or lotic flow conditions may prevail. Colloquially called artesian springs.	Fountain
	Spring's flow may emerge from a focused point, but without substantial artesian rise above ground level.	13
13	Spring's flow emerges from a bedrock cliff and not within an established surface flow channel (although a surface flow channel may exist on top of the cliff, directly above the source).	14
	Not as above.	15
14	Focused lotic flow emerges from a bedrock cliff and immediately cascades, usually as a madicolous sheet of whitewater flow, down the cliff face.	Gushet
	Flow emerges along a horizontal geologic contact, typically dripping along a seepage front and often creating a wet backwall. This spring type includes unvegetated or vegetated seepage patches on near vertical or overhung bedrock walls. Both lentic and lotic flow conditions can occur.	Hanging garden
15	Flow emerges from a surface flow-dominated channel bed. Upstream of the spring source, the channel may be a perennial stream, or it may be dry. Lotic flow conditions generally prevail. These springs are subject to channel flood scour.	Rheocrene spring
	Flow emerges from a nonbedrock dominated slope that does not have a surface flow channel upslope of the spring's source. Sources may emerge within an upland habitat or a floodplain, but not within the bed of a surface flow channel. In some cases, these springs may emerge from the base of a cliff, but not from the cliff itself. Lotic flow conditions generally prevail.	16

Step	Description	Spring type
16	Flow emerges from a 16–60° slope in an uplands habitat, not associated with a flood-plain or channel that is subject to regular surface flow stream flood scouring.	Hillslope spring
	Flow emerges from the bank or terrace of an active riparian channel or floodplain and the source is subject to regular flood scour by the stream into which it feeds.	Hillslope spring; secondarily rheocrene