



Wet Meadow and Fen Mapping of Sequoia and Kings Canyon National Parks

A photo interpretation mapping project of wetland resources

Natural Resource Report NPS/SIEN/NRR—2015/968



ON THE COVER

Photo and aerial National Agriculture Imagery Program (NAIP) imagery (2010) of Shorty's Meadow in Kings Canyon National Park. Photo Credit: Plant Ecology Program, Sequoia and Kings Canyon National Parks

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Abstract

Meadows serve a variety of ecological functions including regulating water flow, recharging groundwater, and providing wildlife habitat; however, there has been relatively little historical monitoring of these important ecosystems. They are of particular interest within Sequoia and Kings Canyon National Parks (SEKI) due to current and historic anthropogenic use and influence, as well as the important ecological and hydrological functions they provide. The Wetland Mapping Project was a joint effort of the National Park Service Inventory & Monitoring Program, Sierra Nevada Network (SIEN) and the Plant Ecology Program of SEKI to identify and map all fens and wet meadows >0.5 ha within SEKI. The main goal of the project was to produce a comprehensive spatial dataset of all target wetlands (fens and wet meadows) within SEKI.

Wetland mapping was conducted by two technicians based on aerial imagery photo interpretation during the spring of 2013. Multiple years of true color and color infrared National Agriculture Imagery Program (NAIP) imagery were used to map and classify target wetlands based on color signature, texture, vegetation density, slope, and expert knowledge of park wetlands. Other key data that were used to inform mapping decisions included meadow survey data, the SEKI vegetation map, wetland mapping data from the SIEN Wetland Ecological Integrity pilot study, and the National Wetlands Inventory data. All mapping was done using Environmental Systems Research Institute (ESRI) ArcGIS 10.1 software with versioning that allowed the two technicians to work simultaneously on the same feature class. The project leads were then able to merge the technicians' edits into a master version. This allowed for each change made to the feature class to be reviewed by the project leads and reduced the quantity of conflicts and errors in the final version prior to posting the data in the parks' spatial data warehouse.

A total of 2,307 wetland polygons and 615 fen points of peat accumulating areas were created. Seventeen polygons represent fens, 260 represent fen-meadow complexes, and the remaining 2,030 represent wet meadows. Approximately 12% of the mapped wetlands in SEKI are thought to be peat accumulating. The total area of wet meadows, fen-meadow complexes, and fens mapped was 4,223 ha, which is 1.2% of the total acreage of the two parks. Overall classification accuracy was estimated to be 83% (90% CI = 78 – 89%) based on field assessments of 138 polygons that included both target wetlands mapped by this project as well as areas that were mapped as seasonal or perennial wetlands on the SEKI vegetation map, but were deemed to not meet the definition of a target wetland for this project. When these error rates are taken into account, the estimated area of fen and wet meadows in SEKI is 6,653 ha (1.9% of the total area of the parks). The products from this project will allow managers to better understand the distribution and current status of fens and wet meadows within SEKI. This information is already being used to aid several NPS planning and monitoring efforts including the SEKI Wilderness Stewardship Plan and the SIEN Wetland Ecological Monitoring Protocol.

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Acronyms

AA: Accuracy Assessment
AIS: Aerial Information Systems
BRD: Biological Resources Division, U.S. Geological Survey
CI: Confidence Interval
CIR: Color Infrared
CNPS: California Native Plant Society
DEM: Digital Elevation Model
Esri: Environmental Systems Research Institute
GIS: Geographic Information System
GPS: Global Positioning System
MMU: Minimum Mapping Unit
NAIP: National Agriculture Imagery Program
NC: Natural Color
NPS: National Park Service
NVCS: National Vegetation Classification System
NWI: National Wetlands Inventory
QA/QC: Quality Assurance/Quality Control
SDE: Spatial Database Engine
SEKI: Sequoia and Kings Canyon National Parks
SIEN: Sierra Nevada Network (Inventory & Monitoring Program)
SOP: Standard Operating Procedure
SQL: Structured Query Language
USDA: U.S. Department of Agriculture
USGS: U.S. Geological Survey
WEI: Wetlands Ecological Integrity (monitoring project)
WMFMP: Wet Meadow and Fen Mapping Project
YOSE: Yosemite National Park

Background and Objectives

Introduction

Baseline natural resource inventories are crucial for public lands managers to make stewardship decisions. Each National Park Service (NPS) unit completes a set of twelve basic natural resource inventories which include the location and characteristics of water features, soils, and vegetation (National Park Service 2009). However, some environments of interest are defined by the intersection of multiple environmental factors. Wetlands are an example of landscape features with distinctive hydrology, soils, and vegetation.

Lacustrine, riverine, and palustrine wetlands are all found in the Sierra Nevada and are a striking component of the landscape. Wet meadows and fens are distinctive and important subsets of palustrine wetlands defined by hydrology, vegetation, and soil characteristics (Weixelman et al. 2011). Wet meadows and fens play an important role in a variety of ecological functions including ground and surface water dynamics, carbon and nutrient cycling, and wildlife habitat. They are also subject to a host of stressors including climate change and anthropogenic use. Fens and wet meadows are of particular interest within the Sierra Nevada due to current and historic land use impacts, as well as the important ecological and hydrological functions they provide. This project sought to synthesize existing (vegetation, wetlands) and in-progress (soils) inventories by mapping and characterizing wet meadows and fens in Sequoia and Kings Canyon National Parks (SEKI).

Wet Meadows

Wet meadows are characterized by seasonally saturated soils but lack the perennial high water tables and peat soils of fens or the large seasonal and inter-annual water table fluctuations characteristic of marshes. However, wet meadows have significantly more organic matter than soils in surrounding forests. NatureServe places most Sierra Nevada wet meadows into the Temperate Pacific Subalpine-Montane Wet Meadow ecological system type (NatureServe 2008). Wet meadow vegetation may be composed of a diverse range of species including obligate and facultative wetland species.

Wet meadows frequently occur in stream valleys as part of larger wetland complexes but unlike riparian ecosystems are not characterized by high velocity surface flows or sediment deposition from fluvial processes. High water tables early in the summer are maintained in part by snowmelt though water tables may drop well below the soil surface in July and August, in contrast to fens where they typically remain within 20-40 cm of the soil surface (Cooper 1990, Chimner and Cooper 2003). Wet meadows can also be distinguished from dry meadows where the water table is often deeper than 2 m for much of the growing season, resulting in a different assemblage of species.

Fens

A fen is a wetland in which the production of organic matter is greater than the rate of decomposition due to anoxic conditions maintained by consistently high water tables; this allows for the development of organic soils (peat). In fens, peat accumulation is accompanied by a water table that typically remains within 20-40 cm of the soil surface throughout the growing season and is dominated by obligate wetland vascular plants and mosses (Weixelman et al. 2011). Wetland soils with an accumulation of 40 cm peat in the top 80 cm of the soil profile are classified as histosols in

the U.S. (Soil Survey Staff 1999). However, mountain wetlands in the Sierra Nevada and Rocky Mountains that contain as little as 20 cm of organic matter within the top 40 cm of the soil profile still display many of the ecological properties of fens including similar biota and hydrology (Driver 2010, Weixelman et al. 2011). Therefore, wetlands with at least 20 cm of peat within the top 40 cm in soil profiles were defined as fens in this project.

Fens have been found in three geomorphic settings in the southern Sierra Nevada: mound, slope discharge, and basin fens. Mound fens are created by strong upwellings of groundwater discharge, leading to mounded peat accumulation. Slope discharge fens are also created by springs and commonly occur on topographic breaks in a slope or at the toe of a slope. Basin fens occur along the margins of lakes or depressions and may develop floating mats of vegetation extending into the open water. Basin fens are more common in closed lake systems (Weixelman et al. 2011).

Fens are of interest because they support a characteristic flora including some rare species (Sikes et al. 2010). Furthermore, fens are an atmospheric carbon sink that develop over hundreds or thousands of years (Bartolome et al. 1990, Weixelman and Cooper 2009). In addition, fens regenerate very slowly due to low rates of peat accumulation (Amon et al. 2002, Weixelman and Cooper 2009) and may be particularly sensitive to environmental change.

Rationale and Justification

Wetlands are among the most significantly altered ecosystems in North America (Mitsch and Gosselink 2007). Anthropogenic impacts, including changes in hydrology due to channelization, ditching, flow regulation, pumping, fill placement, historical grazing by domestic livestock, atmospheric deposition of pollutants, and exotic species invasion, have drastically altered the structure and function of many wetlands (Patten 1998, Zedler and Kercher 2005, Mutch et al. 2008). In the Sierra Nevada, historic impacts to wet meadows and fens from livestock grazing have likely pushed species assemblages and ecosystem dynamics outside of their natural range of variability in some areas (Dull 1999). In addition, wet meadows and fens may be particularly vulnerable to forecasted changes in climate (Winter 2000, Weltzin et al. 2000, Poff et al. 2002, Baron et al. 2002, Weltzin et al. 2003).

Over the past decade, significant progress has been made in the mapping and assessment of Sierra Nevada meadows (and fens in particular), but these efforts have occurred largely outside of SEKI. The lack of a comprehensive and systematic assessment of wetlands within SEKI limits inferences that can be made about wet meadows and fens within these parks. The Wet Meadow and Fen Mapping Project (WMFMP) of the Sierra Nevada Network (SIEN) and the Plant Ecology Program of SEKI, described in this report aimed to identify and classify target wetlands (wet meadows and fens) within SEKI. The result of the project is a comprehensive map identifying and classifying all target wetlands within SEKI that can be used to evaluate their current condition and to monitor trends in the ecological integrity of these systems.

The products from this study have several research and management applications including informing sample design for the SIEN Wetland Ecological Integrity (WEI) monitoring program (Gage et al. 2009) and in park planning documents such as the SEKI Wilderness Stewardship Plan.

More broadly, the data will be of particular use to researchers interested in wetland habitats, regional carbon balance, ecological function of wetlands, and biogeographic and population studies of wetland-associated species.

In this report, we describe our methods for producing the WMFMP map and spatial database in order to document the process used and allow for the future reproduction of the wetland map if desired. We provide information on the decision rules used to map and classify individual target wetlands and background information on the data that were used to inform these decisions. We also document how the data have been archived and how they may be accessed. Finally, we present the summary results from the mapping project and discuss the accuracy assessment methodology used to validate the mapping and classification results.

Methods

The Wet Meadow and Fen Mapping Project relied on a variety of technical materials and existing datasets, as well as a defined set of mapping criteria and decision rules in order to meet project goals. The primary approach used to produce the WMFMP map was photo interpretation of aerial imagery. Aerial photography has been used to map wetlands for several decades (Committee on Characterization of Wetlands 1995). Mapping using aerial photography is useful for detecting wetland boundaries as the photo interpreter is able to view the wetland within the surrounding terrain. It is also possible to assess boundaries for areas that are difficult or impossible to access in the field. Still, there are limitations to the methodology; certain vegetation types can be difficult to interpret remotely when vegetation, soils, or hydrology are not distinct or exhibit seasonal or temporal variability. Ancillary data and prior mapping efforts are important aids that served to help technicians make critical distinctions when classifying potential wet meadows and fens for the purpose of this map.

Previous Mapping Efforts

In this section, we provide basic descriptions and relevant information about two related mapping projects in SEKI: the SEKI vegetation map (Aerial Information Systems and Environmental Systems Research Institute 2007) and the WEI pilot study (Gage et al. 2009). These two projects served as the main sources of historic data on wet meadow and fen vegetation location and classification in SEKI for the WMFMP.

SEKI Vegetation Map

To document the state of vegetation in national parks, the National Park Service, in conjunction with the Biological Resources Division of the U.S. Geological Survey (USGS), implemented a vegetation mapping program to develop a uniform hierarchical vegetation classification and mapping methodology at a national level. Between 2000 and 2007, a vegetation map of the entirety of both Sequoia and Kings Canyon National Parks was created by Aerial Information Systems (AIS) and Environmental Systems Research Institute (Esri). Specialists at AIS provided aerial photo interpretation and production of the SEKI vegetation map. Natural resource staff at SEKI conducted field sampling efforts to support development of the National Vegetation Classification System (NVCS), to provide feedback for the photo interpreters, and to assess the accuracy of the cartographic map products.

Project Materials

Aerial Imagery (Hardcopy Stereo-pair Diapositives). Color infrared aerial imagery from flights conducted in July 2000 and July 2001 was used as the basis for photo interpretation and attribute coding. The nominal scale for the imagery is 1:15840, and the 9"x9" photographs were organized using a flight line index for both sets of imagery.

Ancillary Data. Additional data that informed vegetation classification for the SEKI vegetation map included:

- Historic vegetation data (point and polygon features)

- Natural Resource Inventory Plots (1985-1996)
- Area descriptions of field trips taken during 2004 field season
- SEKI NVCS Plots 2000-2001
- SEKI Vegetation Map Accuracy Assessment Plots 2002

Mapping Criteria

Standard vegetation mapping criteria were used to ensure accuracy and maintain consistency of vegetation attributes such as type, height, and density (AIS 2007).

Minimum Mapping Unit. The minimum mapping unit (MMU) was 0.5 ha. The MMU is the minimum size of features that are mapped for a given map scale.

Aggregation. Aggregation of multiple vegetative classes was necessary when vegetation types fell below the resolution of the minimum mapping unit:

- Similar life forms were aggregated together (i.e. trees with trees, shrubs with shrubs, herbaceous with herbaceous).
- Wetland and upland vegetation aggregation was avoided if possible.
- Any unit below the MMU that was completely surrounded by another vegetation type was aggregated with the surrounding vegetation.

Density. Photo interpreters assessed total density of vegetation associated with the life form of the alliance being assigned to that polygon, quantifying the vegetation visible in aerial photography. Vegetation density was assigned in six classes (>60%, 40-60%, 25-40%, 10-25%, 2-10%, <2%).

The date that aerial photography is acquired influences the density assigned to vegetation types, especially for herbaceous dominated vegetation types:

Seasonality – Herbaceous density changes as the season progresses, and leaf on/off conditions affect the amount of herbaceous vegetation detectable in the understory as well as the ability to identify specific tree species.

Annual variability - Environmental conditions at the time of the photography (i.e. wet vs. drought years, flooding, etc.) affect the vegetation density.

Vegetation Classification. The assignment of vegetation polygons to alliance and association was based on NVCS criteria. AIS initially used the mapping classification developed for Yosemite National Park (YOSE) and modified it to fit conditions at SEKI. Using the plot data collected by the SEKI field sampling crews, AIS worked with park ecologists to create a final vegetation classification with an associated vegetation key and vegetation descriptions for each alliance and association within SEKI.

Use of the SEKI Vegetation Map in the WMFMP

Map units were filtered so that only units previously mapped as wet meadow vegetation were visible. These included the 6500 Willow-Meadow Unit, the 8000 Intermittently to Seasonally Flooded Meadow Unit, and the 9000 Semi-Permanently to Permanently Flooded Meadow Unit. Viewing these polygons helped photo interpreters to target areas previously mapped as meadow.

Photo interpreters identified additional areas of wet meadow and fen vegetation that had been mapped in other vegetation units besides those mentioned above. Other vegetation types where target wetland habitat was found included:

- 3022- Sierra Lodgepole Pine/Bog Blueberry Forest Mapping Unit
- 3048- Sierra Lodgepole Pine Mesic Forest Superassociation
- 6110 -Sierra Willow/Swamp Onion Seasonally Flooded Shrubland Alliance
- 6700- Willow spp. Talus Shrubland Mapping Unit

In some cases, meadow vegetation was included in these other vegetation units due to aggregation, whereas in other cases, there appears to be a difference in interpretation. Because only wet meadows, fens, and fen-meadow complexes were being mapped for this project, polygons did not need to be aggregated with other vegetation types or barren areas. This likely contributed to differences between meadow vegetation mapped in this project and in the SEKI vegetation map. When shrubs or trees represented a significant portion of the mapped meadow, an estimate of percent cover was included. Rocks and barren areas within a mapped meadow were excluded when possible: generally when they exceed an area of 150 square meters. Other differences in interpretation are attributable to advances in the working imagery available to the technicians (current imagery is much more detailed than what was used to create the original vegetation map for SEKI) and the ability to use several years' worth of imagery in both natural color and color infrared for the WMFMP.

If mapped vegetation units fit the definition of the target wetland types established for WMFMP, polygons were copied directly to the WMFMP map. Frequently, polygons were edited to include appropriate nearby areas or exclude areas that did not fit the target wetland definition. Reasons for exclusion of these polygons were typically: lack of apparent significant and lasting water source, low potential for significant soil development (often related to steep gradient), small size (many units were less than the MMU of 0.5 ha), sparseness of vegetation (<67% vegetative cover within the polygon), or narrowness (an average width of <15 m).

SIEN Wetland Ecological Integrity Pilot Study

A pilot study for the Wetlands Ecological Integrity Monitoring Protocol for the Sierra Nevada Network Inventory and Monitoring Program (Gage et al. 2009) identified wet meadow and fen features in selected watersheds in Yosemite and Sequoia and Kings Canyon National Parks. These features were mapped as a part of the original survey design for the SIEN WEI protocol. Mapping decisions were made and the feature class created by Colorado State University graduate student Jennifer Jones during the spring of 2007 for YOSE and 2008 for SEKI, prior to survey site selection. In total, 210 target wetland polygon features were identified within 15 Calwater subwatersheds

(CalWater 1999) in YOSE and 242 polygon features from within 21 Calwater subwatersheds in SEKI.

Mapping Criteria, Materials, and Methods

Minimum Mapping Unit. The minimum mapping unit (MMU) was 0.5 ha.

Classification. Sites were classified as fen, wet meadow, or fen-meadow complex based on visual color signature, vegetation texture, landscape context, and local knowledge of the area. Assignment of wetland type and boundaries was based on professional judgment of observed features in the imagery and spatial data. Locations of known wet meadows and fens in the area and at similar elevations were used as reference sites to compare color signatures and vegetation texture.

Data Sources. Imagery and data informing mapping decisions for SEKI included:

2005 National Agriculture Imagery Program (NAIP) imagery, 1:15840 scale aerial photographs interpreted using a stereoscope (2001), National Wetland Inventory (NWI) maps (U. S. Fish and Wildlife Service 2012), 30m resolution digital elevation model (DEM), digital raster graphics of 1:24000 topographic maps for the survey extent (U.S. Geological Survey 2005), and the SEKI vegetation map (National Park Service 2007; upland vegetation types were removed from the vegetation map so that only those areas indicated as containing a wetland vegetation type would be included during the delineation process).

Methods. Stereo-pair images were assessed in the entirety of each selected subwatershed. NWI-indicated wetlands and SEKI vegetation map wetland features with an area ≥ 0.5 ha were assessed and either a new feature was created to identify the site or the existing feature from the vegetation map was used. Boundaries differing in stereo imagery or in NAIP imagery were amended as needed. Only sites with an area ≥ 0.5 ha were retained in the final wetland polygon layer.

Use of the WEI Pilot Study in the WMFMP

While the initial mapping completed as part of the WEI pilot study identified and classified wet meadows and fens in a small subset of areas within SEKI, the goal of the WMFMP project was to perform this task at the park scale. Wetland delineations from the WEI pilot study were used to calibrate the interpretation of aerial imagery to identify and distinguish between fens, fen-meadow complexes, and wet meadows, as many of these sites were visited in the field to confirm their initial wetland type classification. Definitions of each of the target wetland types were developed based on information provided by the pilot study. The majority of features delineated in the WEI pilot study were incorporated into WMFMP without alterations to polygon line work.

Mapping Decision Rules and Criteria for the WMFMP

A set of decision rules was created to ensure accuracy and consistency between photo interpreters in including and excluding vegetation in the WMFMP. These criteria outline the ideal characteristics of the vegetation types of interest, and help the end user to understand the requirements for inclusion in the mapped vegetation communities. A detailed description and examples of the photo visual signature characteristics of each classification of wetland type are included in Appendix I.

Definition of wet meadow and fen vegetation. In general, color infrared reflectance of wet meadows and fens has a strong, bright red visual signature, sometimes interspersed with pink to orange to maroon, depending on the presence of water. All wet meadows and fens have a mostly smooth texture, although some areas can be coarser if larger forbs or shrubs (e.g., *Salix* spp.) are present.

Dry meadows, especially in alpine and sub-alpine areas, have a lighter, pinker signature. They may be more interspersed with rock. Upland vegetation is typically less bright and less dense than wetland vegetation, although in some montane portions of the parks the signatures appear similar. Willow (*Salix* spp.) and other shrubs, as well as upland vegetation, may also display a strong red signature, but have a rougher texture than that of meadows. Photo interpreters considered hydrological, topographical, and landscape context to infer whether the water table likely remained high throughout the growing season.

Searching for the signature described above, photo interpreters also required mapped meadows to fit the minimum mapping unit of 0.5 ha, contain less than 33% of trees/shrubs/rocks within the meadow polygon, and have a minimum average polygon width of 15 meters. Details on each of these criteria are described below.

Classification of wetland type. Photo interpreters reviewed previous mapping efforts in SEKI to familiarize themselves with the common signatures visible in NAIP imagery that characterize fen and wet meadows in SEKI (Appendix I). They also reviewed known fen locations and boundaries to differentiate wet meadows, fen-meadow complexes, and fens. A hybrid fen-meadow complex wetland class was needed because fens and wet meadows could not be consistently mapped as separate classes as these wetland types are often interspersed within a single wetland due to small differences in topography and hydrology. Therefore, a third class, the fen-wet meadow complex was used. Several criteria were created to maintain consistency between the photo interpreters and throughout the entirety of the two parks. The decision rules are shown in Table 1 and examples of how these rules were applied are provided in Appendix II.

Table 1. Description of wetland-type classification definitions and color signatures.

Wetland type	Decision-rule	Signature characteristics
Wet Meadow	A wetland that does not contain a 25 m x 25 m area where peat depth is >20 cm	Color infrared reflectance yields bright orange to red signatures. The texture is always smooth but may be a bit coarser with presence of larger forbs such as <i>Veratrum californicum</i> , or interspersed <i>Salix</i> spp.
Fen-Meadow Complex	A wetland that includes at least one 25 m x 25 m area where peat depth is >20 cm and at least one 25 m x 25 m area where peat depth is <20 cm	A bright red meadow signature interspersed with the darker signature of standing water in color infrared imagery is used in mapping this category. Areas of meadow containing fen are a darker maroon color in the color infrared, indicating a mound or buildup often with abundant moss (e.g., <i>Sphagnum</i>) cover. Texture is smooth and often blotchy or mottled, indicating a change in the amount of standing water present.
Fen	A wetland that does not contain a 25 m x 25 m area where peat depth is <20 cm	Bright or dark red signature in color infrared imagery, a much darker redness than a wet meadow, but with more color consistency than in a fen-meadow complex. Brightness affected by presence of water. Texture is smooth, blotchy, or mottled.

Minimum mapping unit. To maintain consistency with the SEKI Vegetation Map, a minimum mapping unit of 0.5 ha was used. However, the SEKI Vegetation map included some meadow polygons smaller than 0.5 ha and, where minimal time was needed to attribute these polygons (i.e. the polygon very clearly fell into a fen, fen-meadow complex, or wet meadow class and needed little to no modification of line work), they were often included. New or edited features that were initially estimated to be >0.5 ha when the line work was being done but that did not end up meeting the MMU size were also included. Seventy-nine percent of the 2,307 polygons met the MMU criterion and were >0.5 ha and another 8% were between 0.4 and 0.5 ha.

Vegetation density. Wet meadow and fen vegetation had to meet a minimum density of 67% cover of the mapped area to be considered for inclusion in the feature class. This was an arbitrary cut-off based on the recognition that wet meadows and fens are dominated by dense herbaceous vegetation (AIS and Esri 2007) and cover below 67% was deemed to not meet this criterion. Often problematic in alpine areas, meadow vegetation interspersed with high rock cover was included if less than 33% rock cover was present. In forested areas and in meadow-willow matrices, meadows were mapped if a clear and continuous understory layer of meadow vegetation was visible throughout the area.

Slope. High-gradient, snowmelt-systems were not the target of the study, and were therefore excluded if there did not appear to be a persistent water source through much of the growing season or sufficient soil development to support wetland vegetation. Using the imagery available, it could be difficult to determine the water source for a particular meadow, especially those occurring in alpine and sub-alpine regions on steep slopes. High-gradient meadows were included when it was determined that they had a significant and consistent hydrological source such as a lake, stream, or spring, enough stability to permit soil development, and persistent greenness throughout the growing season.

Due to this requirement, many alpine and sub-alpine meadows on high-gradient slopes that were classified as meadow vegetation (PI codes 8000 and 9000) in the SEKI vegetation map were not included in the WMFMP map feature class.

Minimum polygon width. A minimum width was established for mapped meadow units to ensure that linear features less than 15 meters wide, which often represent ecotones, were excluded. Non-linear polygons may include small segments less than 15 meters wide if the narrow segment connects two areas that otherwise comply with the target wetland mapping criteria.

Photo Interpretation Mapping Procedures

This section describes the required materials, methods, and work flow pattern used to complete the Wet Meadow and Fen Mapping Project, and then describes the quality control procedures and timeline used to ensure high-quality data.

Project Materials

NAIP Imagery

National Agriculture Imagery Program digital aerial imagery (USDA Farm Service Agency 2014) was used as the primary basis for the vegetation photo interpretations and attribute coding. Imagery

was available in both natural color (NC) and color infrared (CIR) for 2005, 2009, 2010, and 2012. All imagery is at a 1 meter resolution, with the exception of the 2012 imagery which has a 0.3 meter resolution; this is equivalent to a scale of 1:2000 and 1:600, respectively. NAIP metadata did not contain capture dates for 2012 imagery, though it appears to have been captured mid-season for portions of Kings Canyon, and very early season for much of Sequoia National Park. The ability to access several years' worth of aerial imagery was indispensable in making wetland boundary and classification decisions, as shadows, snow, or poor image quality could obscure important landscape features in any given year. Each set of images had advantages and disadvantages for wetland classification that are described in Table 2.

Table 2. Qualities of multiple years of digital NAIP imagery.

Imagery	Advantages	Disadvantages
2005 NC	good color saturation	poorer resolution made it difficult to distinguish details
2005 CIR	none	infrared was too pale, therefore was not used
2009 NC	color contrast between vegetation types well defined, useful for fen delineation	under snow in some areas
2009 CIR	color contrast between vegetation types well defined, useful for fen delineation, detecting willow cover	under snow in some areas
2010 NC	good resolution, snow-free	poor registration in some areas (i.e. images did not line up with previously defined features and with other maps)
2010 CIR	good resolution, snow-free	poor registration in some areas (i.e. images did not line up with previously defined features and with other maps)
2012 NC	very detailed imagery, ability to distinguish finer details in the landscape;	under snow in many areas, early season photography meant herbaceous vegetation was not always captured
2012 CIR	high contrast, allowing for ability to see wetness and shrubbery	sometimes contrast inhibited visibility to see meadow fringes and made them appear smaller

Aerial imagery (Hard-copy stereo pairs)

The original hard copy aerial imagery stereo pairs used to produce the SEKI vegetation map were used occasionally to support mapping and classification decisions. Because the resolution is much lower (1:15840) than the NAIP imagery, photo interpreters looked to these data only when a decision could not be confidently made based on the other data sources at hand. Generalized flight line indexes were provided by the parks for both the July 2000 and July 2001 sets of imagery. These indexes were used for quick reference to photo locations and as a tool to display the status of mapping and automation tasks.

Ancillary Data

Several other data sources contributed meaningful information to the mapping process.

National Wetlands Inventory. NWI data depict locations of known or presumed wetland areas as mapped by the National Wetlands Inventory Project (U. S. Fish and Wildlife Service 2012). New wet meadow and fen features not associated with the SEKI vegetation map were often associated with the NWI layer.

15-minute Digital Raster Graphics. These provided topographic context for delineation.

SEKI Meadow Surveys. SEKI staff conducted field surveys that documented meadow hydrogeomorphic characteristics during the summer of 2012 (including classification according to Weixelman et al. 2013). Where peat accumulation was detected using soil probes, it was mapped and characterized as either a point feature or polygon depending on its size within the wetland. Searched areas that did not contain peat were also recorded. All these visited sites served as training locations for the photointerpreters.

SEKI Rivers/Streams feature class. These data display locations of rivers, streams, and springs and provided information to help understand hydrological influences.

Software

At the time of the mapping project, Esri's ArcGIS was the NPS standard software for working with spatial data. SEKI has a park-wide spatial data warehouse (geodatabase) that was set up through ArcSDE (Spatial Database Engine) and Microsoft SQL (Structured Query Language) Server. A versioned environment of the spatial data warehouse (Esri ArcGIS 10.1 with versioning) allowed the two technicians to work on the same feature class concurrently (Figure 1). Each worked on 'child' versions of a Quality Assurance/Quality Control (QA/QC) version that was created from the parent, or default, feature class in the warehouse. The project leads used the QA/QC version to merge the technicians' edits that were then rolled into the controlled 'parent' version. This allowed for each change made to the feature class to be reviewed by the project leads and reduced the amount of conflicts and errors in the versions prior to posting the data in the parks' spatial data warehouse.

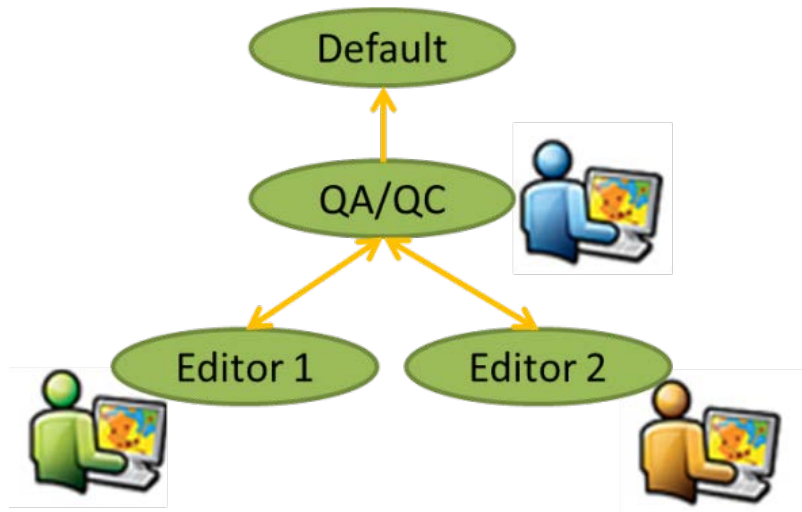


Figure 1. Esri ArcGIS 10.1 with versioning allows multiple editors to concurrently edit a feature. These versions are then merged into a QA/QC version before being added to the official feature class, thus reducing the potential for error.

Project Work Flow

To organize the work, Sequoia and Kings Canyon National Parks were broken down into work units by CalWater subwatersheds (CalWater 1999). An 8.5x11-inch map of each subwatershed with previously mapped meadow units over the 15-minute topographic base map was printed out, and technicians worked from north to south, one watershed at a time.

Two photo interpreters worked systematically within separate Calwater subwatersheds to perform an exhaustive search for target wetland vegetation. During this search they:

- Evaluated existing vegetation polygon features (8000, 9000, and 6500 units) for inclusion based on: signature, MMU size, herbaceous and woody vegetation density, width, and slope
- Copied and pasted polygon features from the SEKI vegetation map which met these mapping criteria
- Merged adjacent polygon features which all met the mapping criteria to create a single polygon
- Reshaped polygons to exclude areas not meeting mapping criteria, or to include areas that do meet these criteria and were previously excluded
- Created new polygons in areas where previously mapped polygons would require significant alteration to meet the mapping criteria
- Examined each polygon for potential fens, and indicated known or potential fens by creating a point feature in the FenPeat_pt feature class. This feature class included points for all identified peat areas regardless of size.
- Attributed each polygon feature with: wetland type, peat percentage, comments, confidence rating, mapping source, polygon author, and date (see descriptions of each field in Data Documentation and Deliverables section below)

- Searched and evaluated NAIP imagery for additional wet meadows and fens meeting mapping criteria; created new polygons and entered attributes when found

Quality Control Procedures

The project leads reviewed edits for consistency with project standards each time the editor versions were reconciled and posted to the QA/QC version, generally on a weekly basis. When the initial mapping was complete, technicians worked together to review each polygon and its attributes for accuracy and consistency and changes were recorded in a spreadsheet. Imagery of the entire mapped area was then searched a second time to scan for potential omissions. Several topology tools in ArcMap were used to check for duplicate or erroneous polygons, and a final check of topology was completed for the master geodatabase.

Timeline of the Mapping Effort at SEKI

The combined area for the two parks is 350,443 ha (865,964 acres). The mapping portion of WMFMP for SEKI took 12 weeks to complete, with two technicians working full-time on the project from February 19 to May 3, 2013 (Table 3). They were co-supervised by two Project Managers: The SIEN Ecologist and a SEKI Ecologist. The project also received support from the SEKI GIS Specialist, SIEN Logistics Technician, SIEN Program Manager, and several other NPS staff.

Table 3. Project timeline for Wet Meadow and Fen Mapping Project in Sequoia & Kings Canyon National Parks.

Dates	Time Required	Work Completed
12/2012 – 01/2013	8 weeks	Development of goals and methods
02/2013	1 week	Setting up Spatial Database Engine workspace; assembling files and equipment
02/19 – 02/21	1 week	Technicians hired and trained
02/22 – 02/26	1 week	Review of prior wetland delineations within SEKI
02/27 – 04/09	6 weeks	Mapping completed for all sub-watersheds of SEKI
04/10 – 04/24	2 weeks	Quality control review
04/22 – 05/03	2 weeks	Production of draft report

Data Documentation and Deliverables

Wet Meadow and Fen Feature Dataset

The purpose of this mapping project was to create a feature class that identifies all target wetlands greater than 0.5 ha within Sequoia and Kings Canyon National Parks, and classify them into wet meadow, fen-meadow complex, and fen. To accomplish this goal, two feature classes were created:

- A polygon feature class, SEKIgis.DBO.WetMeadowsFens_py, with boundaries of all wet meadows, fen-meadow complexes, and fens mapped based on their photo signature and with inferences from ancillary data
- A point feature class, SEKIgis.DBO.VEG_FenPeat_pt, with points that mark locations of known and photo-interpreted fen locations in the parks

A total of 2,307 wetland polygons and 615 fen points were created (Figure 2), of which 1,833 polygons (79%) were > 0.5 ha in size. Seventeen polygons represent fens, 260 represent fen-meadow complexes, and the remaining 2030 represent wet meadows. Fen habitat was almost always associated with vegetation previously mapped as wet meadows (PI codes 6500, 8000, or 9000), although several areas of peat accumulation were mapped in areas that were not mapped as meadow. Approximately 12% of the mapped wetlands in SEKI were thought to contain areas of peat accumulating habitat. A total of 51 (20%) of the fen and fen-meadow complex polygons had at least 50% of their area classified as peat-accumulating wetland. The total area mapped as wet meadows, fen-meadow complexes, and fens was 4,223 ha, which is 1.2% of the total area of SEKI.

Each polygon in the feature class delineating wetland boundaries, SEKIgis.DBO.WetMeadowsFens_py, is attributed with:

GlobalID: A unique random identifier for each point

Wetland Type: Wet meadow, Fen-Meadow Complex, or Fen

Peat Percentage: Estimate of the percentage of the area of the polygon that is peat accumulating habitat

Comments: Any clarifications related to wetland classification, confidence, or image interpretation

Confidence Rating: Indication of how confident the photo interpreter was in making the decision to map and attribute the polygon. Values are integers from 1-5, where 1 indicates up to 20% confident, 2 is 20-40% confident, 3 is 40-60% confident, 4 is 60-80% confident, and 5 is 80-100% confident

Mapping Source: Indicates primary imagery relied upon to draw wetland boundary

Polygon Author: Initials of photo interpreter

Date: Date the polygon feature was created

Each polygon in the feature class delineating locations interpreted to contain peat soils, SEKIgis.DBO.VEG_FenPeat_pt, is attributed with:

GlobalID: A unique random identifier for each point

Comments: Any clarifications related to wetland classification, confidence, or image interpretation

These feature classes are housed in the SEKI inpskihqgis3.sde geodatabase. Supporting documents are contained in the SIEN folders on a Sequoia and Kings Canyon National Parks shared network drive. Metadata for the two feature classes are given in Appendix III.

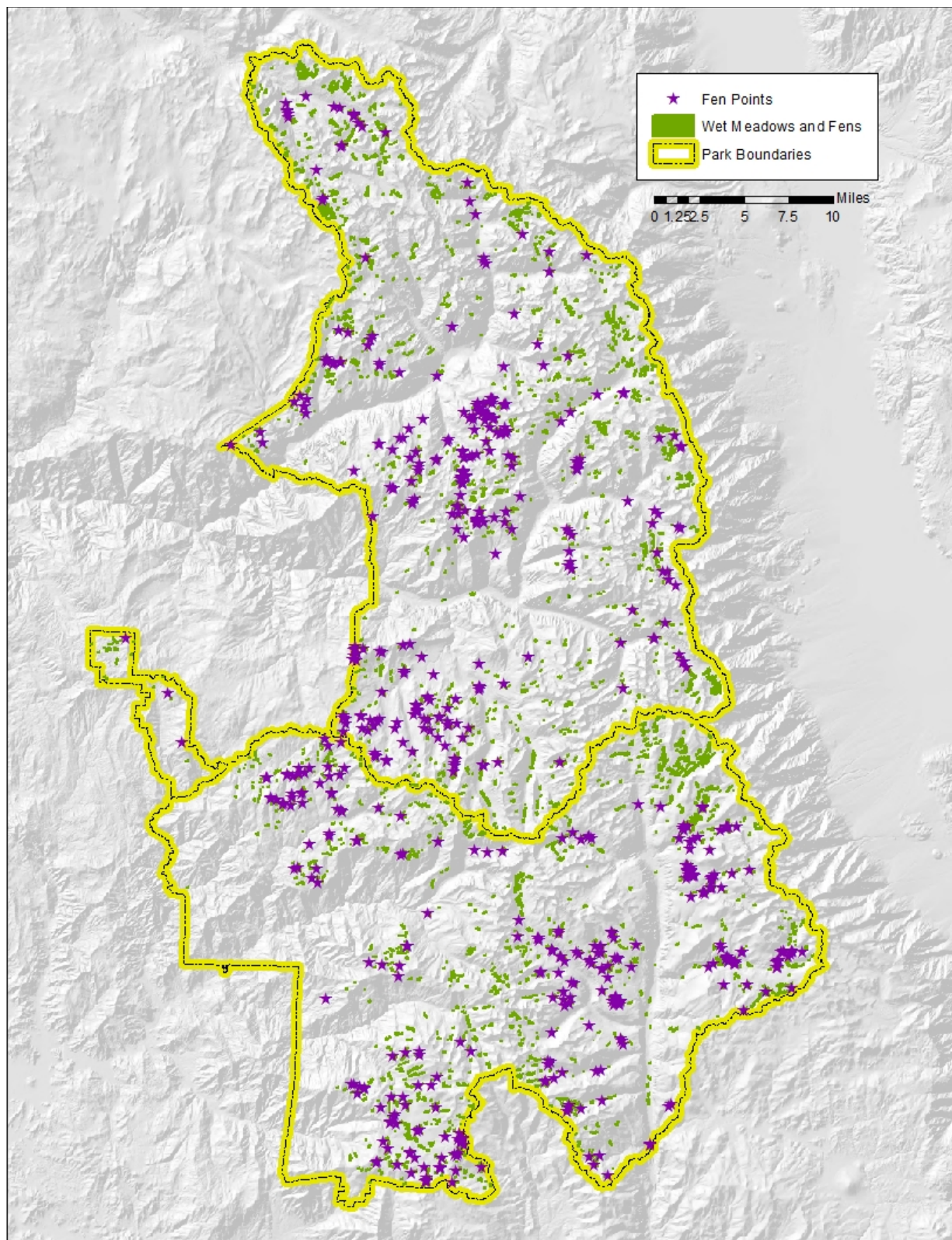


Figure 2. Overview map of locations of wet meadows and fens in Sequoia and Kings Canyon National Parks. A total of 2,307 features were mapped as wet meadow, fen-wet meadow, or fen, and included 615 distinct fen points.

Accuracy Assessment

An accuracy assessment estimates the extent and types of discrepancies between field observations and mapping classifications. Two types of accuracy assessment methods were used: an estimate of intra- and inter-photo interpreter variability and a validation of the map classification accuracy based on field site visits.

Observer Variability

Photo interpreter variability was estimated by repeated mapping of selected watersheds. To assess the variability between technicians and within individuals, technicians completed a re-mapping of eight selected watersheds in four distinct regions: two in Sequoia and two in Kings Canyon. Watersheds were subjectively chosen to span alpine, subalpine, and montane vegetation zones. Each technician re-mapped two watersheds they had done themselves and two done by the other technician.

Observer Variability Results

Within the eight selected watersheds 241 wetland polygons were mapped in the original mapping effort and 234 were mapped during the QC process (Table 4). Wetlands were assigned to the same wetland type >90% of the time. In general, map agreement was stronger in watersheds that were re-mapped by the same person compared to watersheds that were re-mapped by the alternate technician (Table 5).

Table 4a: Summary of initial mapping (1st) and remapping (2st) for the number of wet meadows (WM), fen-wet meadow complexes (F-WM), fens (F), total number of features, and total target wetland area in the eight watersheds used to assess agreement within photointerpreter (PI).

	<u>WM</u>		<u>F-WM</u>		<u>E</u>		<u>Total features</u>		<u>Total area (ha)</u>	
Within PI	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Laurel Creek	28	24	4	3	0	0	32	27	54.7	54.2
Whitney Creek	30	31	3	4	1	1	34	36	68.9	76.3
Lost Canyon	24	23	4	5	1	4	29	32	44.9	46.4
Wallace Creek	19	23	5	3	0	0	24	26	46.4	44.2
Total	101	101	16	15	2	5	119	121	214.9	221.1

Table 4b: Summary of initial mapping (1st) and remapping (2nd) for the number of wet meadows (WM), fen-wet meadow complexes (F-WM), fens (F), total number of features, and total target wetland area in the eight watersheds used to assess agreement between photointerpreter (PI).

	WM		F-WM		F		Total features		Total area (ha)	
Between PI	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
Lwr. Sugarloaf Creek	20	23	12	4	0	0	32	27	61.8	54.4
McGee Canyon	28	27	2	1	0	0	30	28	62.9	49
Goddard Canyon	22	16	1	1	0	0	23	17	52.2	29.9
Upr Sugarloaf Creek	27	27	9	13	1	1	37	41	60.7	70.5
Total	97	93	24	19	1	1	122	113	237.6	203.8

Table 5: Summary of error rates (percent agreement) encountered between mapping technicians (repeating work done by the other technician) and by the same person over time (repeating previous work). “Features” indicates percent agreement for the number of wetlands mapped in each watershed. “Total Area” indicates percent agreement for the total area mapped in each watershed, and “Avg.Area” indicates the percent agreement for the average wetland feature size mapped in each watershed.

Re-mapping by:	Features	Total Area	Avg. Area
Original technician	90%	95%	90%
Alternate technician	85%	77%	88%

Field Accuracy Assessment of the WMFMP

The field-based method of accuracy assessment for the WMFMP was executed in the summer of 2013. The accuracy assessment results provide an understanding of what types of classification errors were most common during mapping and their potential causes. The design and methods employed for the field-based accuracy assessment component of this project draw heavily on recommendations from the NPS Vegetation Inventory Thematic Accuracy Assessment Procedures Report (Lea and Curtis 2010).

Sampling Design

Field crews were assigned a sample of wetland features to visit in order to verify the location, extent, and classification assigned to them during the photointerpretation component of the project. Target meadows are those wetlands that were included in the WMFMP feature class and include all meadows that met the definitions for wet meadow, fen-meadow complex, or fen. To evaluate the possibility that features were excluded from the WMFMP that should have been included, polygon features from the SEKI vegetation map that were classified as 8000 (Intermittently to Seasonally Flooded Meadow Unit) and 9000 (Semi-Permanently to Permanently Flooded Meadow Unit) that were not included in the WMFMP polygon layer were included for sampling as “non-target” features. Sites whose classification was already known from previous field visits (e.g., J. Jones pilot study or SEKI 2012 meadow survey) were excluded from the accuracy assessment. Also targeted in the accuracy assessment were sites selected as part of the WEI long-term monitoring project. The

field crews were provided with the location and boundaries of the features to be assessed, but not the wetland type they had been assigned during the mapping process (Figure 3).

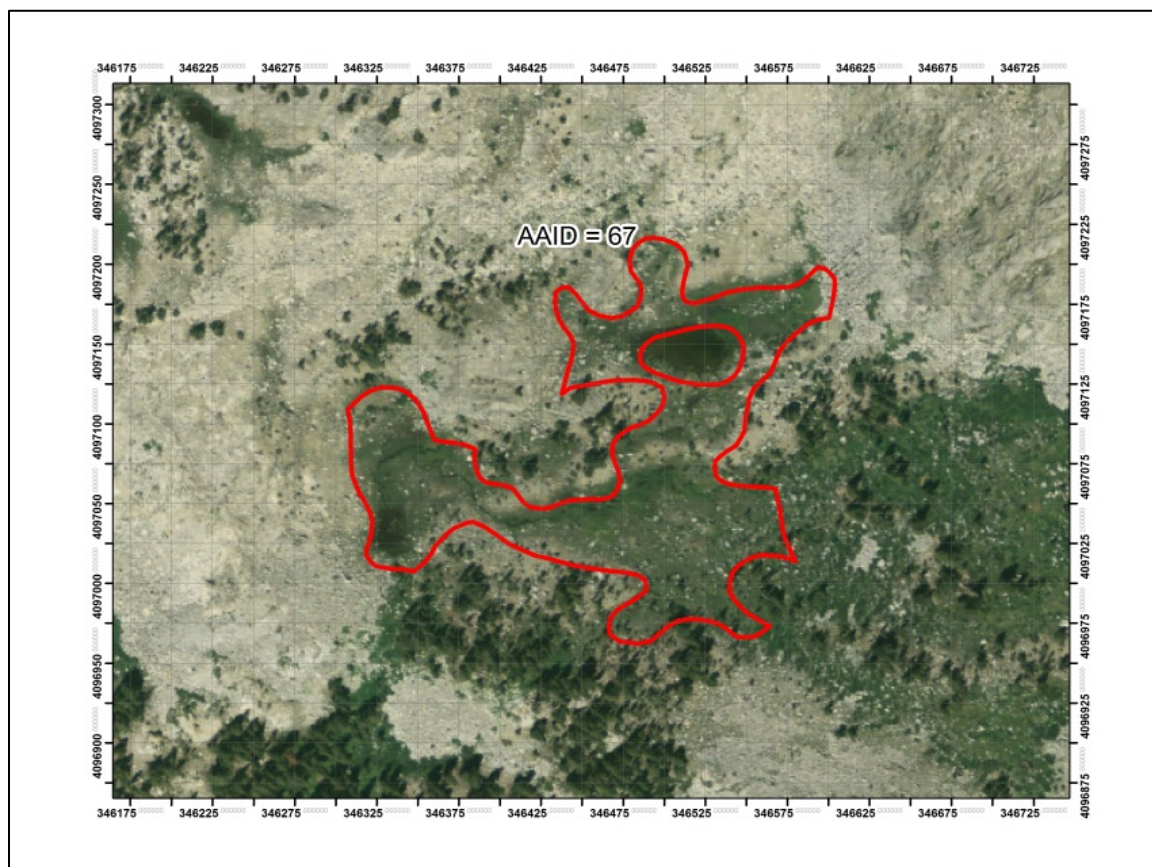


Figure 3. Example of map used by field observers to locate individual polygons in relation to landscape features and determine site boundaries. Imagery was labeled with an accuracy assessment identification number, polygon boundaries, and a UTM coordinate grid.

Site Selection Criteria

Sample Size. The goal for sample sizes for each map class was 30 individual observations following NPS accuracy assessment procedures (Lea and Curtis 2010). This standard has been used by NPS Vegetation Inventory projects for map classes that occupy greater than 50 ha of total area as it provides a balance between precision and cost.

Spatial Criteria. The minimum mapping unit for Accuracy Assessment polygons was 0.5 ha, and 15 meters wide, to align with the spatial criteria used in photointerpretation.

Adjustments for Access Costs. Sequoia and Kings Canyon National Parks include over 800,000 ha of land, 97% of which is roadless wilderness. Because of the difficulty of accessing portions of the parks, the sampling design was adjusted to increase the chance of meeting sample size goals. A filter was applied to the random sample draw so that sites were selected from subwatersheds with existing sampling and monitoring obligations of the SEKI Plant Ecology Program in 2013. In addition to the sites chosen randomly from pre-determined areas within the parks, observers made assessments of

opportunity at sites they visited as a part of other field work (Table 6). Although randomly selected sites within the parks were not evenly distributed spatially, meadows and fen-meadow complexes from each of the montane, subalpine, and alpine zones within both parks were represented (Figure 4). Many of the more accessible areas that were not surveyed as a part of the accuracy assessment had been assessed for their hydrogeomorphic qualities and peat-accumulating ecosystems in 2012 by the SEKI Plant Ecology Program as part of a stock camp and meadow assessment survey. These sites were not used in the accuracy assessment but were used instead to train technicians making wetland classification decisions during the mapping process.

Table 6. Distribution of accuracy assessment sites per wetland mapping class.

Mapped wetland class	Randomly selected	Opportunistic	Total observations
Wet meadow	25	50	75
Fen or Fen- meadow complex	10	29	39
Non-target	24	0	24
Totals	59	79	138

Aggregation of Fen and Fen-Meadow Complex Classes. Out of 2,307 mapped polygon features, only 17 were mapped as fen. Of those, only two met the minimum mapping unit requirement of being greater than 0.5 ha. Because these 17 sites were scattered across the parks, it would have been infeasible to obtain the recommended sample size of 5 features (Lea and Curtis 2010) with the available resources. Therefore, the fen class was aggregated to the fen-meadow complex class for the purpose of the accuracy assessment. No polygons of the fen class ended up being selected as a part of the random sample. Field technicians could, however, classify a polygon as fen if it fit the criteria instead of a fen-meadow complex.

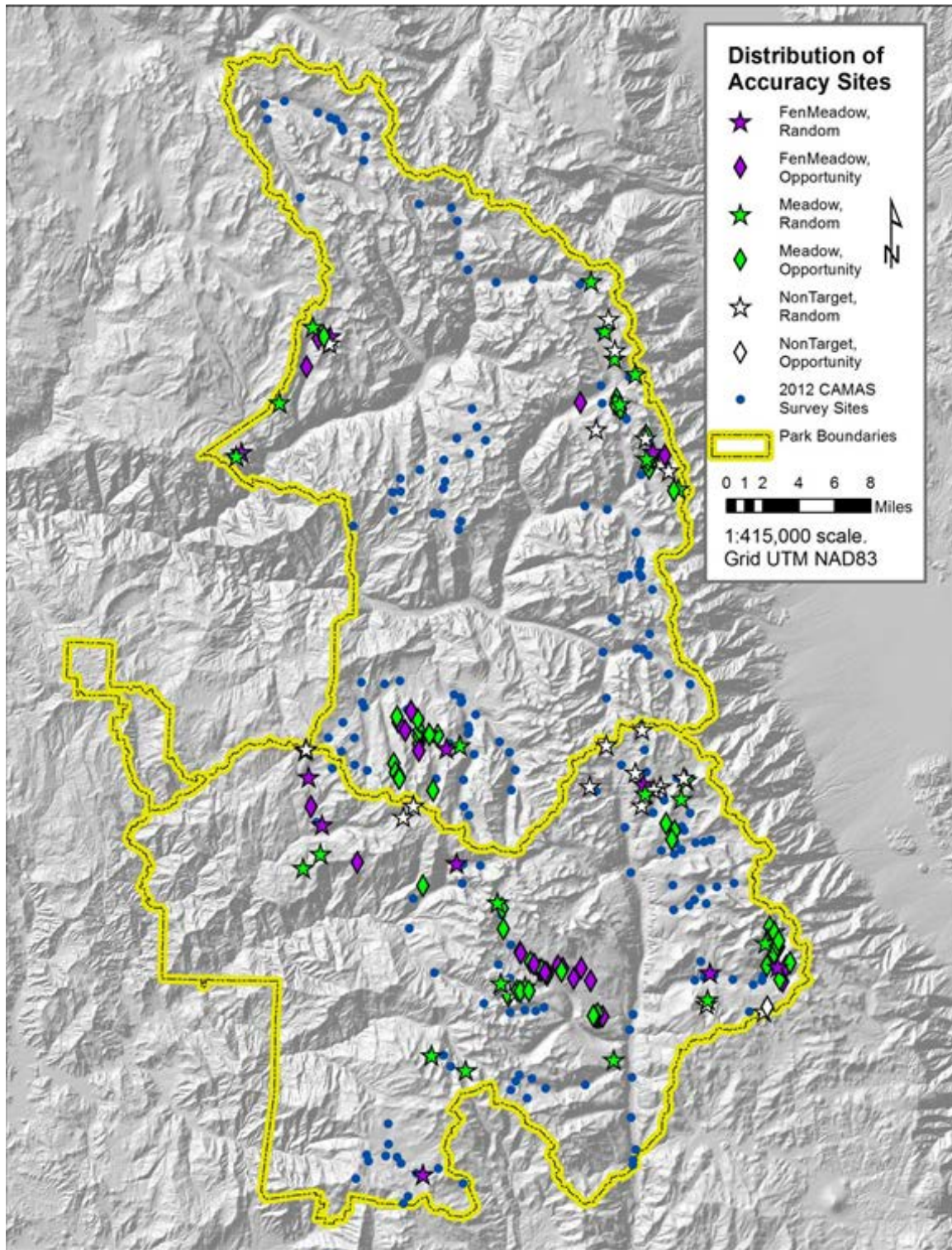


Figure 4. Locations of sites visited and surveyed as a part of the accuracy assessment component of the WMFMP. Symbols and colors indicate the field classification of each site. Symbol shape indicates the status as a random or opportunistic site. Blue dots (camp and meadow assessment survey sites [CAMAS]) show areas which were surveyed in 2012 and used to train technicians making photointerpretation determinations.

Field Methodology

A description of the methods used by the field crews to assess the accuracy of the meadow classification is provided in Appendix IV. SOP1: *Wet Meadows and Fens Feature Class Accuracy Assessment Field Methods*. Method 3 from the NPS thematic accuracy assessment procedures (Lea and Curtis 2010) was employed in this project. This methodology uses qualified and trained, but non-expert, technicians as field observers, who also collect supplemental data to support the map class assignment they choose. An expert uses the supplemental data to review and evaluate the field calls in the office; the expert can assign a class that will supersede the field call. Two experts who participated in vegetation classification and mapping were available to collect field observations. They were joined by three qualified and trained field observers. At the end of the field season the two experts reviewed field assessments for every observation and re-evaluated those that appeared questionable without knowing the mapped classification. In a handful of cases field assessments were changed based on comments and other supplementary data.

Field observers were proficient in identifying the plant species that characterize montane, sub-alpine, and alpine meadows of the Sierra Nevada. When unable to make a confident identification, they collected vouchers of unknown dominant species. They were trained in estimating distance and area in the field to assess whether wetland boundaries met the established spatial criteria. They calibrated herbaceous cover estimates and trained in the use of the soil probe to do peat detection at the beginning of the season. For safety purposes technicians usually worked in teams of two or three, but occasionally worked alone. A few sites that were hazardous to access were not sampled. Observers navigated to sites using topographic maps and either a Trimble Juno or Garmin Global Positioning System (GPS) unit. They also were equipped with maps that included aerial imagery and polygon boundaries to help them determine site boundaries using their surroundings (Figure 3).

Determination of Mapping Classification in the Field

Upon reaching a selected site, observers surveyed the entirety of the site, paying close attention to hydrological influences, dominant plant species, and potential peat-accumulating areas. The presence or absence of peat soils was assessed using a soil probe, which indicated likelihood of peat when it could be inserted smoothly, often in a wet area. The presence of sand, gravel, or larger rocks in the soil creates a gritty sound or prevents the soil probe from penetrating deep into the earth.

If peat was present and appeared to meet the minimum conditions to be considered a fen (at least 20 cm of organic soil in the top 40 cm), observers collected a point or created a polygon if peat extent was $>25 \text{ m}^2$ and collected supplementary data about the fen as part of a parallel effort to document and characterize these features. They did this regardless of whether the extent of the fen would classify the polygon as a fen-meadow complex. Additional information that was collected included hydrological indicators (i.e. soil moisture, presence/absence of groundwater features, streams, and pools), estimated percent cover of hydrogeomorphic types (Weixelman et al. 2013), herbaceous canopy cover, soil indicators (presence/absence and extent of peat accumulation, and/or fine-textured organic soils), and dominant plant species. After collecting these data, observers would make a determination as to whether the polygon should be classified as fen, wet meadow, fen-meadow complex, or non-target. Observers took detailed supplementary notes when appropriate and photos

for documentation purposes. Data were recorded on paper datasheets as well as into GPS units and a point was taken to ensure that the area being assessed corresponded with the correct accuracy assessment polygon ID number.

Field Accuracy Assessment Results

Data were collected for 138 accuracy assessment sites and included geospatial references, wetland type, as well as supplemental information and photographs for each location. The sample contingency table (Table 7) is a summary of the data which compares the classification of sampled polygons during the mapping process with their classification based on field observations. The rows represent the Sample Data (Map Classes) and the row total is the number of accuracy assessment observations for that class. The columns represent the reference data, or observed classifications recorded in the field. The values in the shaded diagonal cells indicate the number of occurrences when field and mapping classifications agree.

Two types of accuracy were calculated: user's and producer's accuracy. User's accuracy determines the percentage of correct predictions based on the map; i.e., if a wet meadow is selected by looking at the map, this is the likelihood that when one arrives at that site it is indeed a wet meadow. Producer's accuracy is the calculated number of correct predictions based on references; i.e., if an area is known to be a wet meadow, this is the probability that it has been mapped correctly. Overall accuracy, in contrast, is calculated as percentage of polygons where the field classification matched the initial assigned mapping class.

Table 7a. Sample contingency tables comparing mapped and observed wetland type classifications from the 59 random accuracy assessment sites. Shaded cells, also marked with an asterisk, indicate the number of polygons where the field classification matched the initial assigned mapping class.

Sample Data (Map Classes)	Fen-Meadow	Meadow	Non-Target	Total	Users' Accuracy
Fen-Meadow or Fen	9*	1	0	10	90.0%
Meadow	5	20*	0	25	80.0%
Nontarget	0	2	22*	24	91.7%
Column Total	14	23	22	59	
Producers' Accuracy	64.2%	87.0%	100%		Overall Accuracy: 86.4%

* Indicate the number of polygons where the field classification matched the initial assigned mapping class.

Table 7b. Sample contingency tables comparing mapped and observed wetland type classifications from the 138 opportunistic accuracy assessment sites. Shaded cells, also marked with an asterisk, indicate the number of polygons where the field classification matched the initial assigned mapping class.

Sample Data (Map Classes)	Fen-Meadow	Meadow	Non- Target	Total	Users' Accuracy
Fen-Meadow or Fen	27*	12	0	39	69.2%
Meadow	13	61*	1	75	81.3%
Non-Target	0	2	22*	24	91.7%
Column Total	40	75	23	138	
Producers' Accuracy	67.5%	81.3%	95.7%		Overall Accuracy: 79.7%

* Indicate the number of polygons where the field classification matched the initial assigned mapping class.

While guidance previously used by the NPS Vegetation Inventory advised to calculate accuracy from the sample contingency table, it is now recognized that it is appropriate only for users' accuracies. Inaccurate results will result for producers' and overall accuracy, as the sample contingency table does not account for unequal probability sampling due to the unequal weighting of map classes (Lea and Curtis 2010). The population contingency table calculates accuracy using values that are the proportion of the target area, rather than a raw count (Table 8). It includes an estimate of the true area for each map class, as well as overall accuracy. Overall accuracy is the proportion of the total area that is correctly mapped. In any test of this nature there may be agreement between sample and reference data due only to chance. The calculation of the Kappa statistic accounts for this. A Kappa statistic of 1 occurs when there is perfect agreement, and a Kappa of 0 is when the results are the same as if it were left to chance.

Table 8. Population contingency table. Observation values indicate the proportion of the total target area assigned to each map class. Estimated True Area is the estimated total area of each map class after accounting for the probability that it was mapped correctly. Users', Producers' and Overall Accuracy are point estimates of class accuracy.

Sample Data (Observations Selected within Map Class)	Fen- Meadow	Meadow	Non- Target	Row Total	Map Class Area (ha)	Users' Accuracy with 90% Confidence Interval
Fen-Meadow or Fen	0.1010	0.0449	0.0000	0.1458	970.2	69.2% (55.8%-82.7%)
Meadow	0.0848	0.3977	0.0065	0.4890	3253.0	81.3% (73.3%-89.4%)
Non-Target	0.0000	0.0304	0.3348	0.3652	2429.6	91.7% (80.3%-100.0%)
Column Total	0.1857	0.4730	0.3413	1.000	6652.8	Overall Accuracy (with 90% Confidence Interval): 83.3% (78.1% - 88.6%)
Estimated True Area (ha)	1235.5	3146.7	2270.5			
Producers' Accuracy with 90% Confidence Interval	54.4% (51.4%- 57.3%)	84.1% (81.0%- 87.2%)	98.1% (95.8%- 100.0%)			
						Point Estimate, Overall Accuracy: Kappa Statistic (with 90% Confidence Interval): 66% (56% – 76%)

Overall Accuracy. Overall accuracy was estimated at 83.2% (90% CI = 77.9-89.2%). This surpasses the minimum mapping standard of 80% accuracy (AIS 2007).

Estimated Acreages. The mapped area of fen-meadow complex (including fen), meadow, and non-target polygons was 970 ha, 3,253 ha, and 2,430 ha, respectively. When adjusted based upon the proportion of correctly mapped areas, it is estimated that there are 1,236 ha of fen-meadow complex and fen and 3,147 ha of wet meadow in SEKI. There are an estimated additional 2,271 ha of wetlands mapped as 8000 – Intermittently to Seasonally Flooded Meadow Unit or 9000 – Semi-Permanently to Permanently Flooded Meadow Unit that would not meet the definition of a target wetland for this project.

Accuracy Assessment Products

Accompanying the WMFMP mapping products is the accuracy assessment feature class containing useful baseline information about visited sites including:

- Accuracy Assessment polygon ID number
- Place name
- Observer initials
- Observation date
- Hydrological indicators: soil surface condition (dry, moist, saturated, inundated), presence/absence of hydrological indicators including groundwater features, perennial streams, seasonal streams, and pools

- Hydrogeomorphic types: observers could record up to five hydrogeomorphic types to classify hydrological regimes in the meadow system, as well as an estimated percent of each type. Hydrogeomorphic types include: slope, basin, or mounding peatland, lacustrine fringe meadow vegetation, seasonal or perennial depressional pools, discharge slopes, low-, mid-, or high-grade riparian systems, and low-, mid-, or high-grade subsurface flow regimes
- Presence/absence and depth of peat accumulating and non-peat accumulating areas: Indicates whether there is at least 25m x 25 m of peat accumulating or non-peat accumulating areas
- Fen ID numbers: each fen mapped was given a unique ID name
- Presence/absence of organic, fine textured soils: This indicates whether the soils were consistent with those found in Sierra Nevada meadows
- Herbaceous canopy cover (%): an estimate of herbaceous cover using a course-grained scale; ocular estimate used to determine whether vegetation in the polygon meets the 2/3 rule established to eliminate sites which consist of too much rock, tree, or shrub cover
- Dominant species: at least two were recorded. Additional dominants are occasionally included in the comments in meadows with diverse cover.
- Field classification: After filling out worksheet, observers decided upon their classification of the polygon: meadow, fen –meadow complex, fen, or non-target vegetation.
- Size criteria: Whether or not the polygon appears in the field to meet the MMU of 0.5 ha, and the minimum average width of 15 m.
- Comments

This feature class is stored in the SIEN folders on a shared Sequoia & Kings Canyon National Parks network drive.

Sources of Error in the Accuracy Assessment

Missed Sites. Due to lack of time and resources, sampling had to be limited to areas of the parks where existing work was already planned in 2013. However, within these areas, a random sample of meadows was selected for accuracy assessment. During each field tour, observers received a list of sites to assess, which were ranked into three classes based on their sampling priority during fieldwork. The highest priority sites for sampling were the randomly selected sites. The goal was to sample at least 30 from each map class. Once 30 sites from a particular map class had been visited, additional sites from that map class were ranked as medium priority. Lowest priority sites were the opportunistic samples from locations coincident with work for another program. Because of the difficult terrain and limited time, not all highest priority sites could be visited to achieve the desired sample size from each map class. However, observations were made at an additional 79 opportunistic sites, increasing the total number of sites to 138. No bias was detected in the opportunistic sites in terms of classification error rates or spatial patterns on the landscape compared to the randomly selected sites.

Lack of Soil Cores. Because the project did not take soil cores or dig soil pits, estimates of the extent of peat accumulation are not definitive. Particularly, in the later part of the season when even some

peat-accumulating areas have less moisture content, it can be hard to detect the presence of peat. Some lacustrine-fringe and depressional-type areas contain a very high clay content, which can also lead to a less definitive signal, as the soil probe can penetrate deeply and clay does not make as distinct a sound compared to larger mineral deposits. However, the residue left on the soil probe was often indicative of clay soils and was easily observed in the field.

Misclassified Features. A review of misclassified polygons contributed to an understanding of the underlying reasons for the discrepancies between how a polygon was classified during mapping, and how it was subsequently classified in the field. The most likely errors were the potential for omissions or erroneous inclusions of fens.

Not mapped (Non-Target), Classified as Wet Meadow. This was observed in two cases:

Polygon 194: This feature was likely excluded due to its width and size. It is only slightly larger (0.63 ha) than the MMU, and only marginally meets the width requirements established during the mapping process. The presence of large forbs in this montane meadow also creates a less smooth photo signature, which can be indicative of shrubs or other non-meadow vegetation. In the field, the vegetation and hydrology agreed with our requirements for a wet meadow. There was discussion in the field about whether the feature met the width requirements.

Polygon 216: This feature was likely excluded as it appears in the imagery to have low vegetative cover and be too dry for a wet meadow classification. The photo signature is intermediate between a wet and dry meadow. Field assessment confirmed that vegetation density is on the low end for a wet meadow. However, the presence of two large perennial pools, a stream bordering the meadow, and sufficient meadow vegetation prompted field technicians to classify this feature as a wet meadow.

Mapped as Wet Meadow, Classified as Non-Target. This situation occurred once. In aerial imagery, the photo signature of this polygon is very similar to neighboring meadows of the Siberian Outpost area of Sequoia National Park. It is closest to the signature of the drier portions of that meadow, but appears as though it could be classified as wet meadow. In the field, cover was found to be sparse, and although a facultative wetland species (*Calamagrostis muiriana*) was found to be dominant, the upland species *Carex filifolia* was second most abundant. Due to the dryness of the year, it is possible that vegetation would appear more mesic in another year in which there was more precipitation.

Mapped as Wet Meadow, Classified as Fen-Meadow Complex. In 13 observations, a fen-meadow complex was mapped as a meadow. In five of these instances, a fen point was placed in the polygon, indicating that the photo interpreter perceived that a fen may be present in the meadow, but assumed that the amount of area with peat accumulation would not be large enough to meet the criteria for a fen-meadow complex. Of the remaining eight, no fen point was created, although in one case the polygon author included the comment, "May contain fen." In another case, the fen mapped in the field was only marginally large enough for the polygon to be categorized as a fen-meadow complex and is only marginally wide enough for inclusion in this classification. These errors are consistent

with earlier observations that some of the fens that were mapped in the field in 2012 during meadow surveys were not at all visible or barely discernible using available imagery (Figure 5).

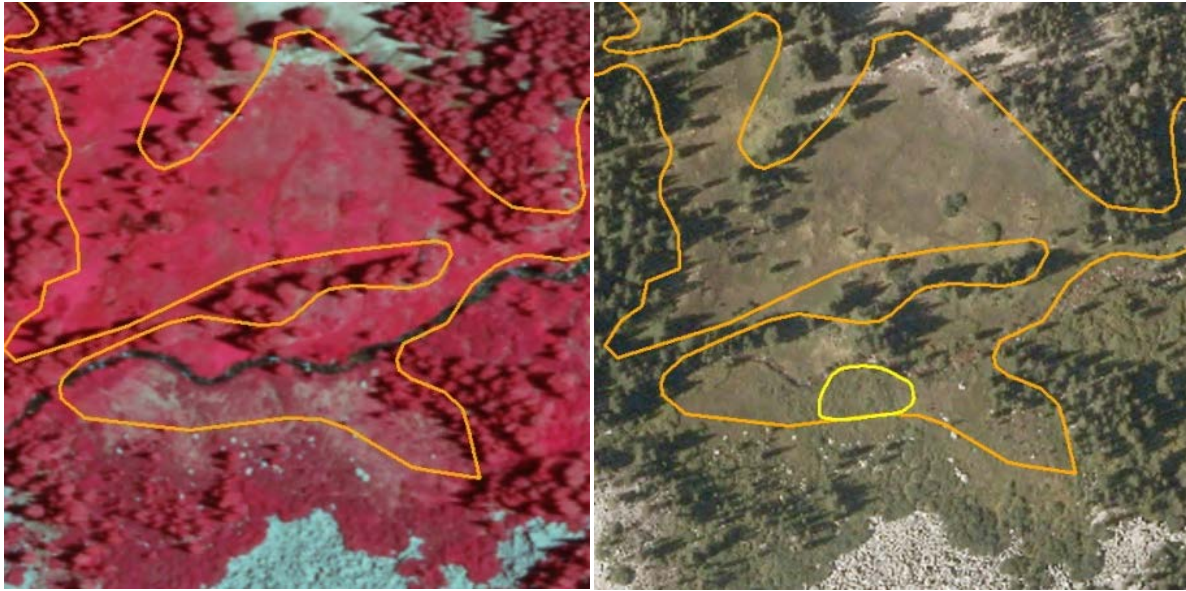


Figure 5. Color infrared (left) and natural color imagery (right) of a fen. The fen in the example above outlined in yellow in the image on the right was delineated in the field in 2012, though none of the NAIP imagery distinctly indicates its presence.

Mapped as Fen-Meadow Complex, Classified as Wet Meadow. There were 12 observations where a wet meadow was mapped as a fen-meadow complex. One observation had an area of peat accumulation, but it did not meet the 25x25m criterion. In reviewing aerial photos, several of these misclassified polygons have a signature that is consistent with observed fens. Only field observations confirmed that the soil did not have enough organic content to be considered peat accumulating.

Summary

The main goal of the Wet Meadow and Fen Mapping Project was to identify and map all fens and wet meadows >0.5 ha within SEKI. Multiple years of aerial imagery were used to map and classify target wetlands based on color signature, texture, vegetation density, slope, and expert knowledge of park wetlands. A total of 2,307 wetland polygons and 615 fen points were created. These data provide a detailed spatially explicit representation of important wetland habitat throughout SEKI that was unknown prior to this project. Based on these results, approximately 12% of the mapped wetlands in SEKI are thought to be peat accumulating and the total estimated area of wet meadows, fen-meadow complexes, and fens within the parks is 6,653 ha (1.9% of the total acreage of the two parks). Overall classification accuracy was estimated to be 83% (90% CI = 78 – 89%). The most common errors in the map were misclassifications of fen-wet meadow complexes as wet meadows or vice versa. However, non-target habitat was rarely misclassified as a target wetland type.

Informed management of meadows requires an understanding of where they occur, their current condition, and key drivers of past and future ecosystem change. The products from the WMFMP will allow managers to better understand the distribution and current status of fens and wet meadows within SEKI. These products can be used by multiple user groups including researchers, resource managers, and the public to address multiple goals including investigating questions related to resource stewardship and restoration, long-term planning and management, research related to wet meadow and fen condition, distribution, and function. The products of the WMFMP are already being used to aid several NPS planning and monitoring efforts including the SEKI Wilderness Stewardship Plan and the SIEN Wetland Ecological Integrity Monitoring Protocol.

A secondary goal of this report was to thoroughly document the procedures and decision criteria used to generate the wetland polygon and fen point feature classes so that the methods would be repeatable. Repeated mapping has been a widely used approach to evaluate change in wetland extent and condition over the landscape (Miller and Rogan 2007, Dahl 2011). While this map represents a snapshot in time of the current spatial extent of wet meadows and fens in SEKI, the mapping process could be repeated in the future to evaluate changes in wetland extent and classification.



SEKI Plant Ecology Program crew members conduct field accuracy assessments for the wetland mapping project. NPS photo, 2013.

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Appendix I. Descriptions and Examples of Target Wetland Mapping Classes

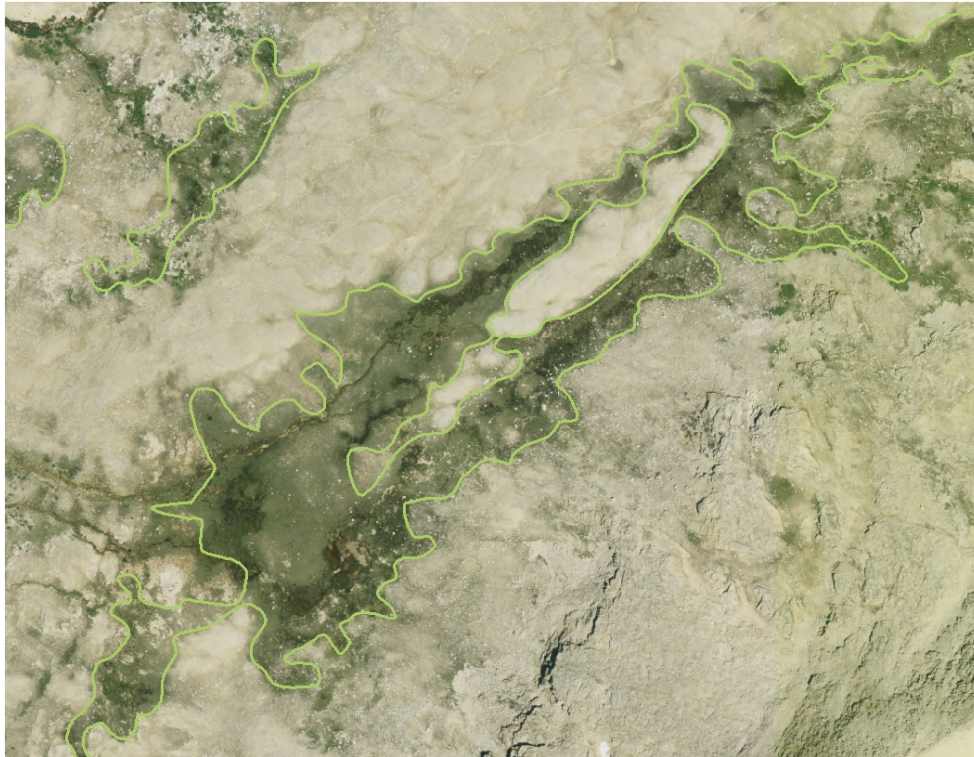
This appendix supplements the Wet Meadow and Fen Mapping of Sequoia and Kings Canyon National Parks report by providing descriptions of each of the target wetland mapping classes (wet meadow, fen-meadow complex, fen) and their photo interpretation signatures. Examples of each mapping class are shown in natural color and color infrared National Agriculture Imagery Program (NAIP) imagery.

Wet meadow

Wet meadows typically occur on small to moderate slopes and landscape concavities of varying aspect at montane, sub-alpine, and alpine elevations. Vegetation is a dense herbaceous composition of graminoids and forb species, although a sparse shrub or tree layer may be present. Hydrology is palustrine, riverine, or lacustrine. Wet meadows frequently have standing water present at the early part of the growing season which may or may not persist through the end of the growing season. Unlike fens, wet meadows lack perennially high water tables, which may drop to a meter or more below the soil surface in July and August.

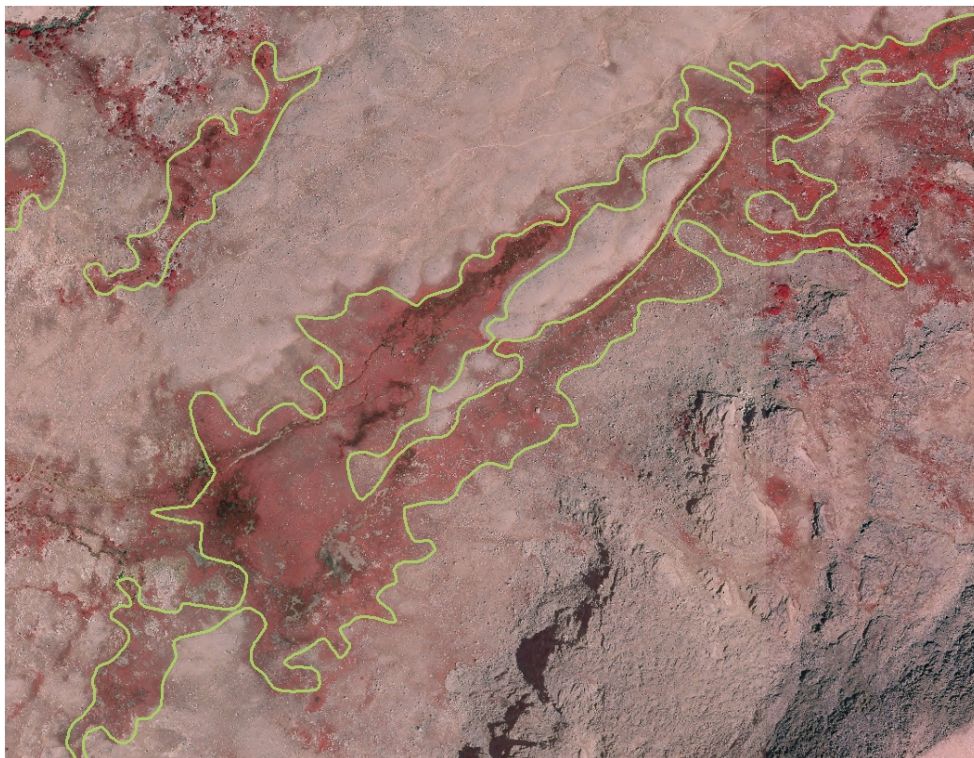
Photo Interpretation Signature

Wet meadows display a photo signature that varies depending on wetness, species composition, and elevation. Color infrared reflectance (CIR) is high and yields bright orange to red signatures. Higher elevation (alpine and subalpine) wet meadows can tend towards a pinkish hue in drier or shallower soils. The texture is always smooth but may be a bit coarser with presence of larger forbs such as *Veratrum californicum*.



*Wet Meadow,
Alpine: Tyndall*

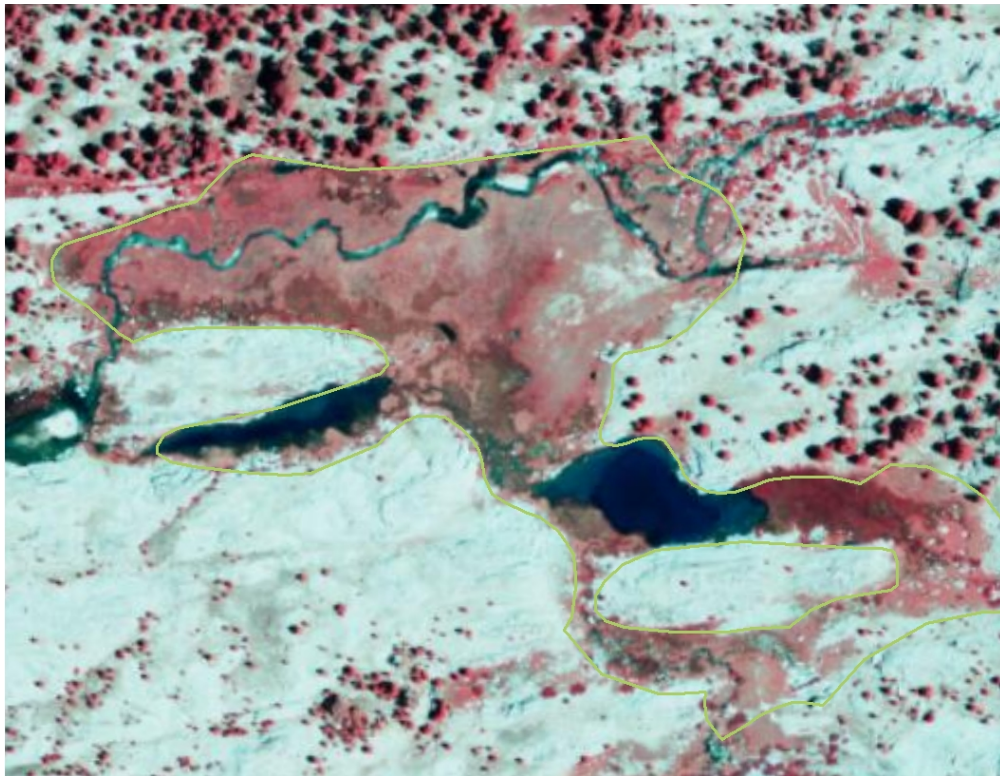
Vegetation mapped
as wet meadow is
included within
green line.





*Wet Meadow,
Subalpine:
Wright Lakes*

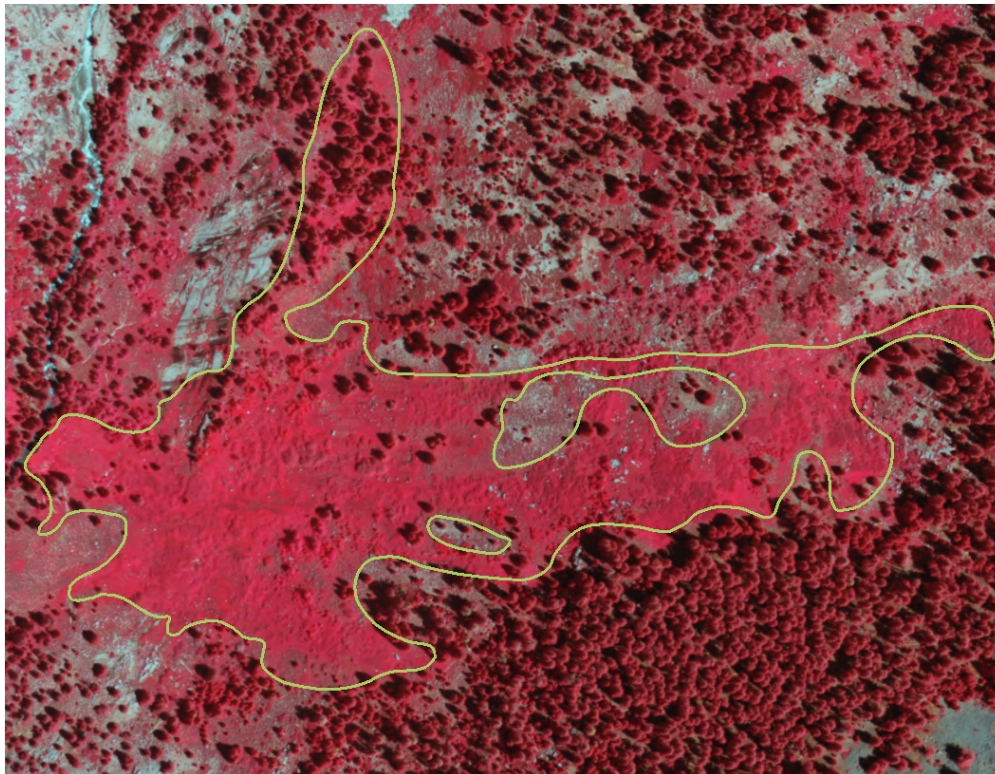
Vegetation mapped as wet meadow is included in green line. Large rocky areas are excluded.





*Wet Meadow,
Montane: Blue
Canyon*

Vegetation mapped as wet meadow is included in green line. Large rocky areas are excluded. Upper finger includes a percentage of trees but meadow vegetation is apparent in the understory.



Fen-Meadow Complex

Fen-meadow complexes typically occur on low to moderate slopes and landscape concavities of varying aspect at montane and sub-alpine elevations. Vegetation is typically a dense herbaceous composition of graminoids and forb species, although a sparse shrub or tree layer may be present. Meadow hydrology is palustrine, riverine, or lacustrine. At least some spring-fed areas are necessary to create slope or mound fens, although basin fens are dependent on lacustrine systems or seasonally to perennially flooded depressions. Fen-meadow complexes often have standing water that persists through the end of the growing season in at least parts of the complex.

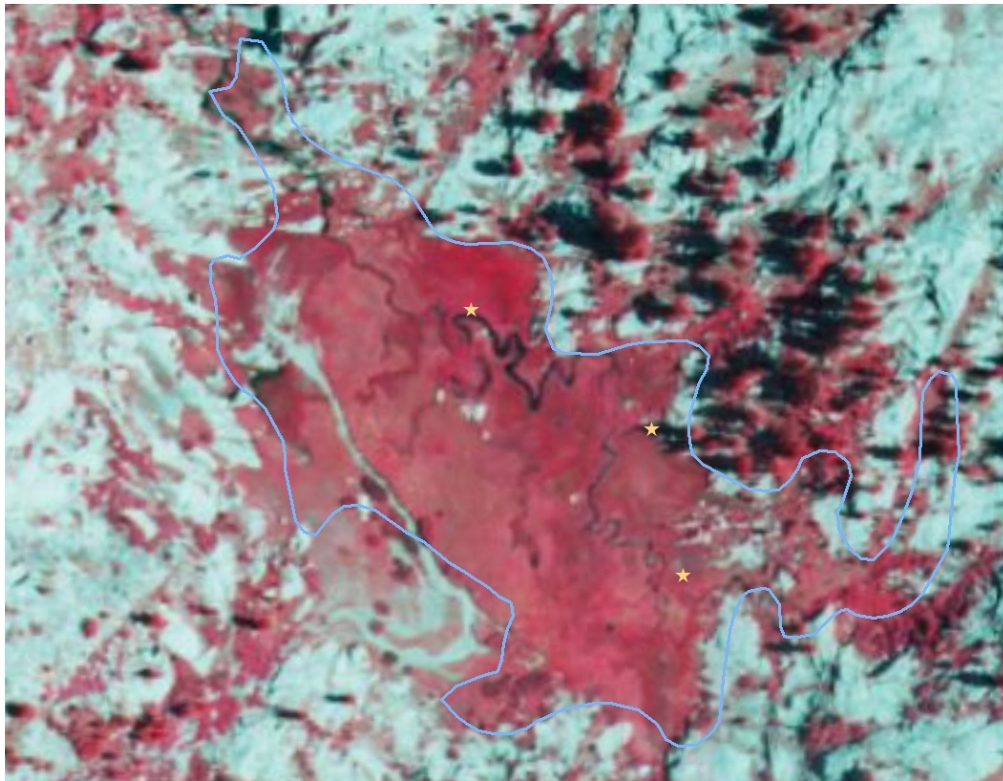
Photo Interpretation Signature

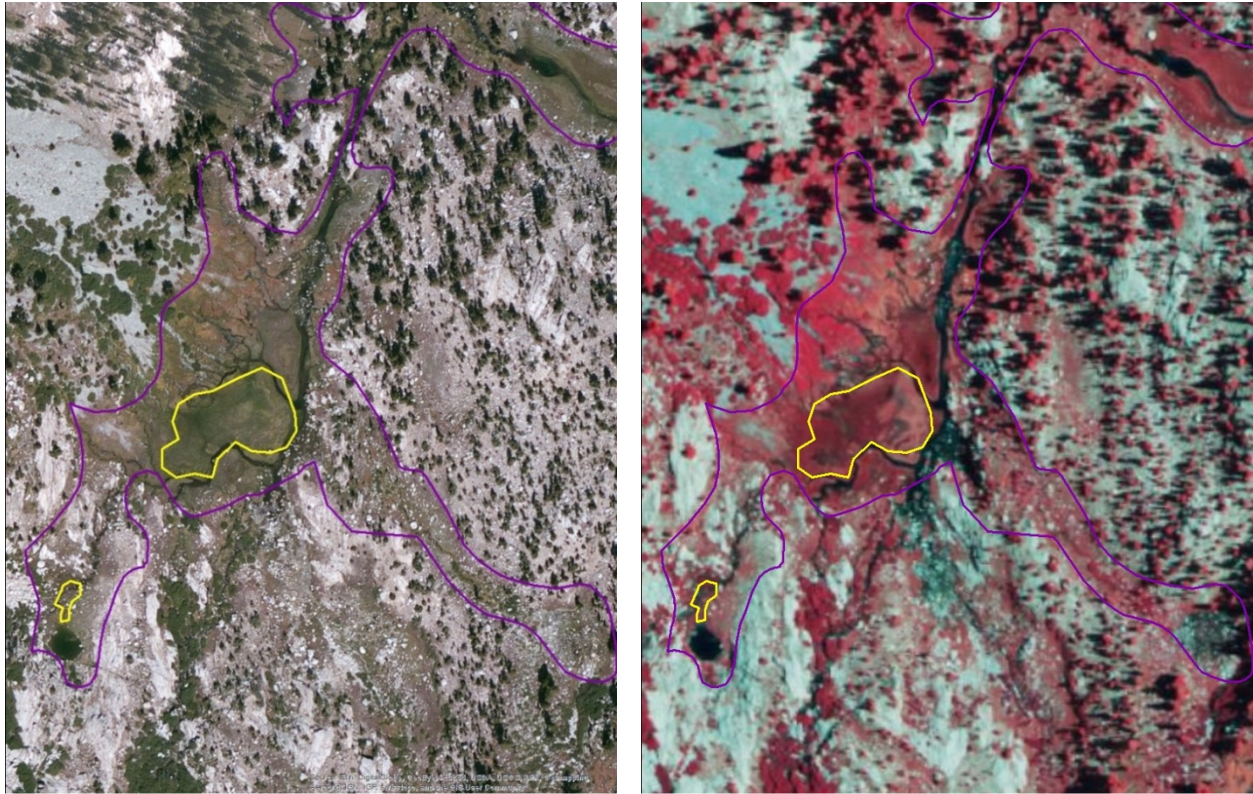
Fen-meadow complexes display a photo signature that varies depending on fen type (slope discharge, mound, or basin), wetness, species composition, and elevation. These signatures often appear the most varied and complex. The presence of standing water either interspersed with or as a part of a bright red meadow signature in color infrared imagery is used in mapping this category. Water signature may affect the brightness of the actual vegetation's reflectance. Areas of the meadow containing fen are usually a darker maroon color in the color infrared, and oftentimes blotchy or mottled, indicating a change in the amount of standing water present. Stands of *Eleocharis* stand out as darker than surrounding vegetation in true-color imagery, and monocultures of *Carex utriculata* or *C. vesicaria* in depressional fens often are evident and show up as a darker depressional with water at surface level. The presence of *Sphagnum* often shows up as lighter markings in wet areas, while other mosses such as *Drepanocladus* may create darker signatures.



*Fen-Meadow
Complex,
Subalpine:
Granite Pass*

Vegetation mapped as fen-meadow complex is included in blue line. Yellow stars mark presence of fens. Darker (in true color) or brighter (in CIR) color on the right side indicates higher water content.





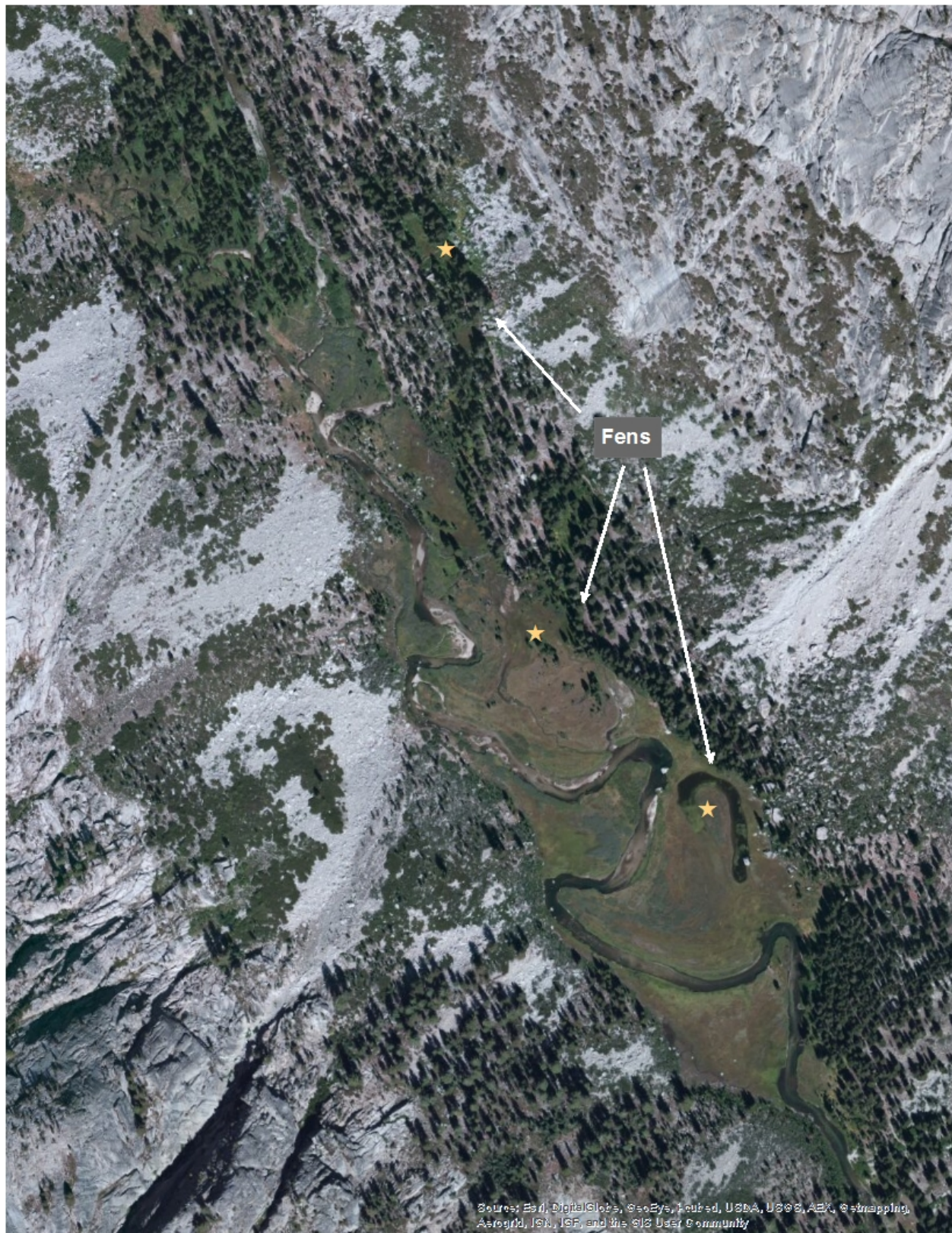
Above: Fen-Meadow Complex, Subalpine: McGee

Vegetation mapped as fen-meadow complex is included in the purple line. Yellow lines mark fen delineations made in the field in 2012.

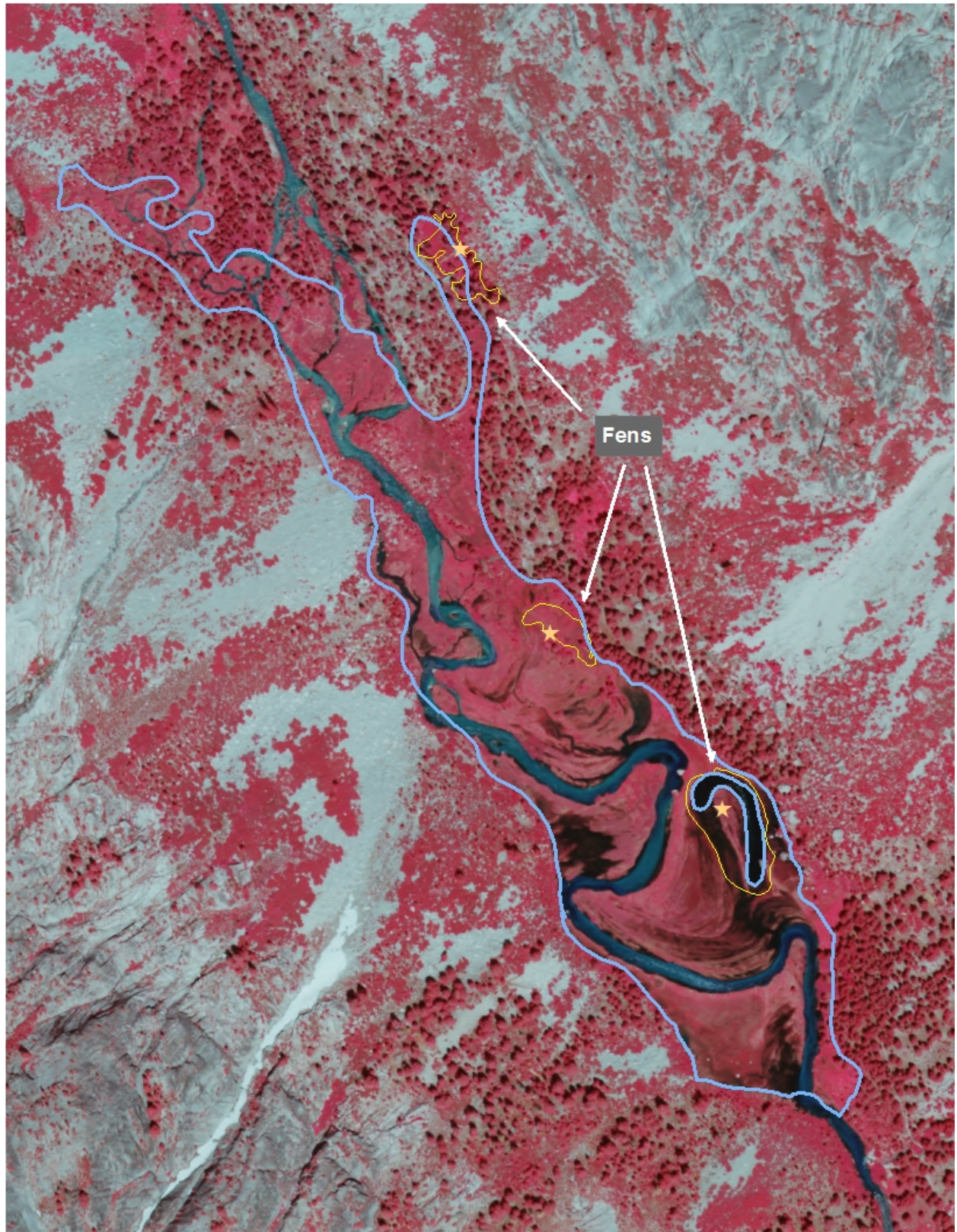
Next Two Pages: Fen-Meadow Complex, Montane, Grouse Meadow

The natural color image on the following page does not include any boundaries, allowing the observer to view shifts in vegetation patterns at fen and meadow edges; yellow stars indicate fen locations. The CIR image shows meadow boundaries in a blue line so that the viewer can see photointerpreters' decisions in marginal areas. Yellow lines also show delineations made in the field in 2012 so the viewer can see the extent of the known fens.

Fen/Meadow Complex, Montane: Grouse Meadow



Fen/Meadow Complex, Montane: Grouse Meadow

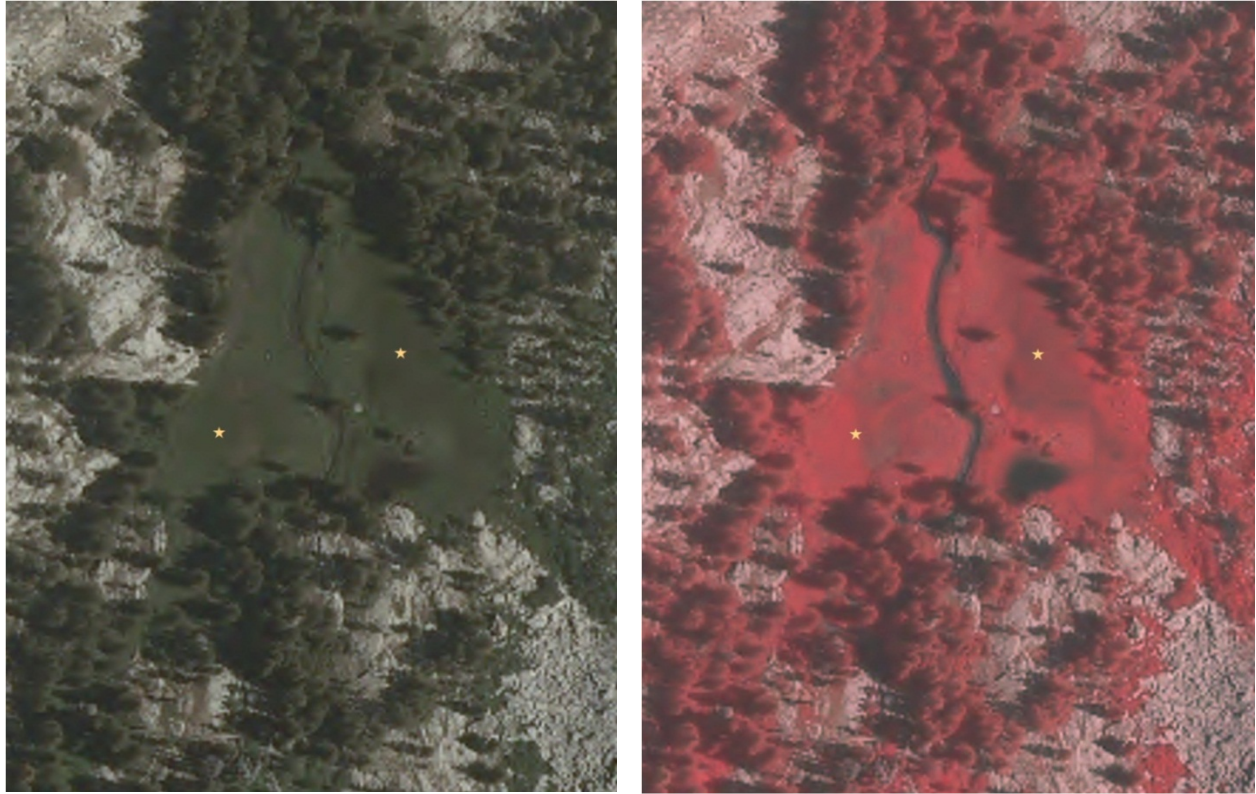


Fen

Fens typically occur on gentle slopes and landscape concavities of varying aspects at montane and sub-alpine elevations. Vegetation is typically a dense herbaceous composition of graminoids and forb species. In a few cases, trees and shrubs occur in fens. Hydrology is typically palustrine or lacustrine. Slope and mound fens are dependent on the presence of springs, but basin fens often occur in association with lacustrine systems or seasonally to perennially flooded depressions. Fens often have standing water that persists through the end of the growing season. The water table typically remains within ~20-40 cm of the soil surface.

Photo Interpretation Signature

The photo signature that fens display varies depending on fen type (slope discharge, mound, or basin), wetness, species composition, and elevation. The presence of standing water creates a bright or dark red signature in color infrared imagery. Water signature may affect the brightness of the actual vegetation's reflectance. Texture of a fen is always smooth, and oftentimes blotchy or mottled. Stands of *Eleocharis* stand out as darker than surrounding vegetation in true-color imagery, and monocultures of *Carex utriculata* or *C. vesicaria* in depressional fens often are evident by showing up as a darker depressional with water at surface level. The presence of *Sphagnum* often shows up as lighter markings in evidently wet areas, while other mosses such as *Drepanocladus* may create darker signatures.

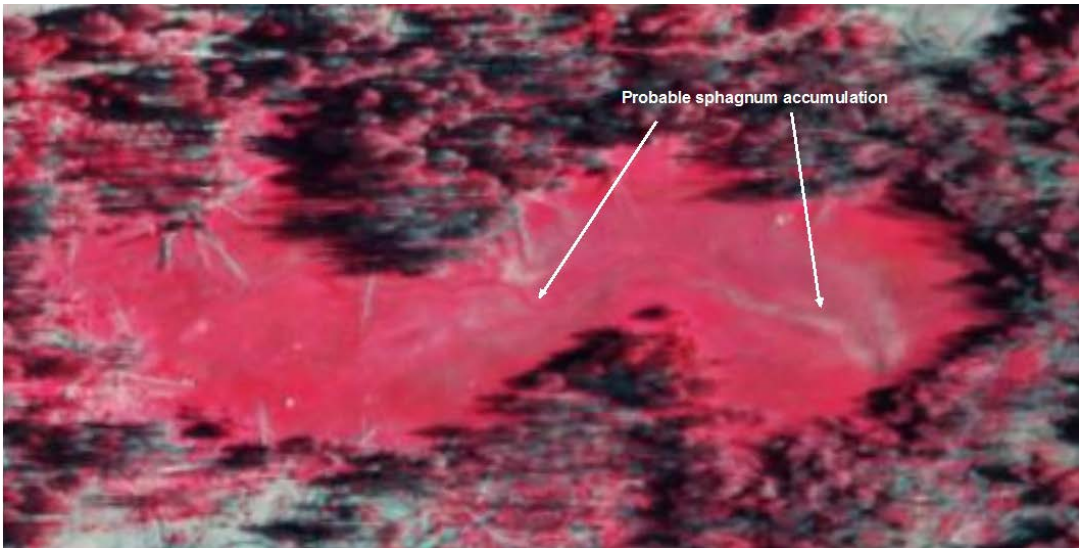
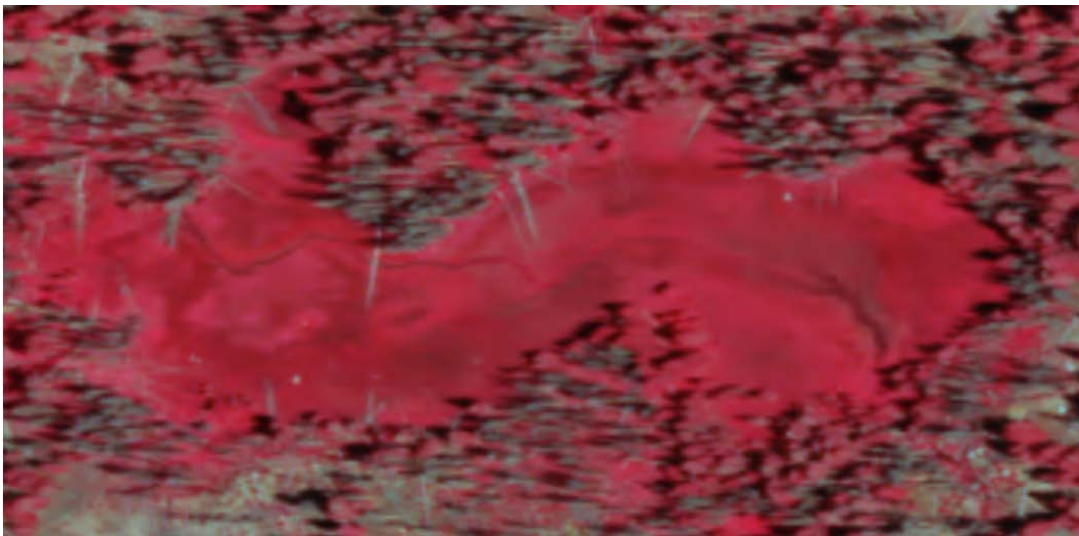


Above: *Fen, Subalpine: Upper Sugarloaf*

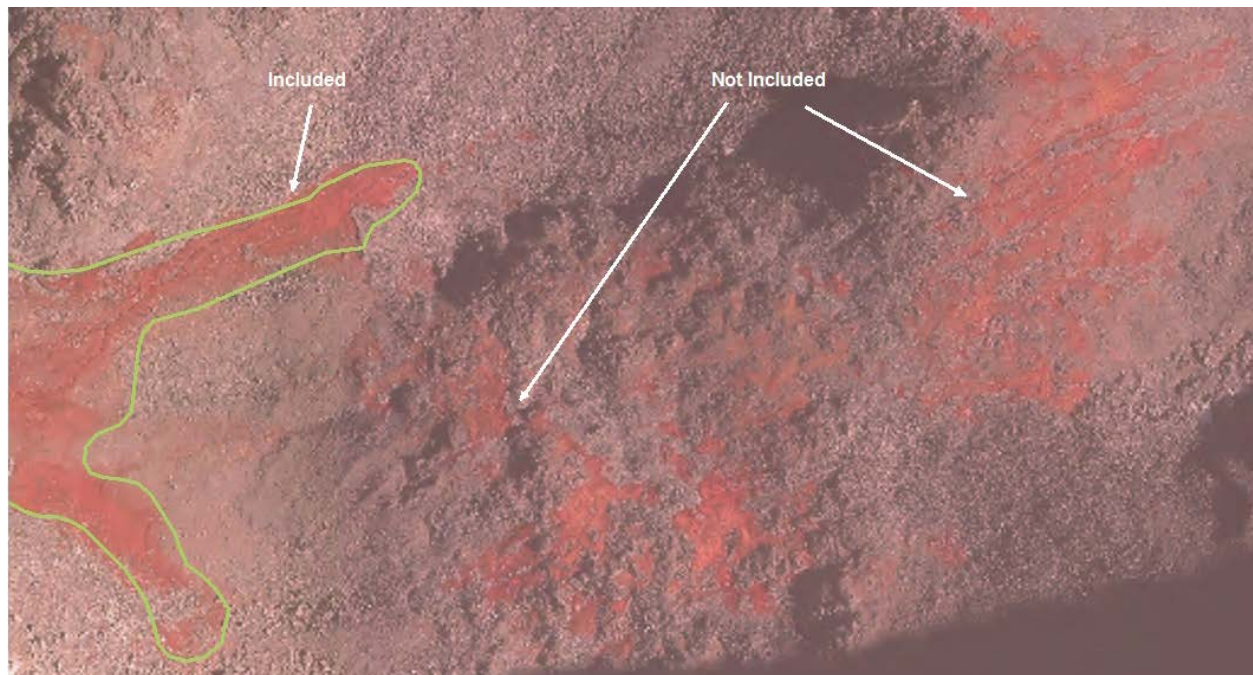
Mapped fens are indicated by yellow stars. The majority of both sides of the creek show a darker or slightly mottled signature indicative of standing water. The lighter reddish-gray on the left side of the CIR image may be *Sphagnum*. The brighter red bordering the creek is likely buildup of organic matter and/or presence of larger *Carex* species.

Next Page: *Fen, Montane, Rattlesnake Creek*

In this example it is possible to see how water and vegetation patterns appear in different imagery in a montane fen. The natural color image (top) appears mostly smooth with some variability on the left side. The 2009 CIR image (center) reveals some interesting variations in species composition, including some mounding in the left-center of the image, indicating peat accumulation. The right side of the image in the 2012 CIR image (bottom) suggests *Sphagnum* buildup by the pink-grey lines that follow the flow of the water.

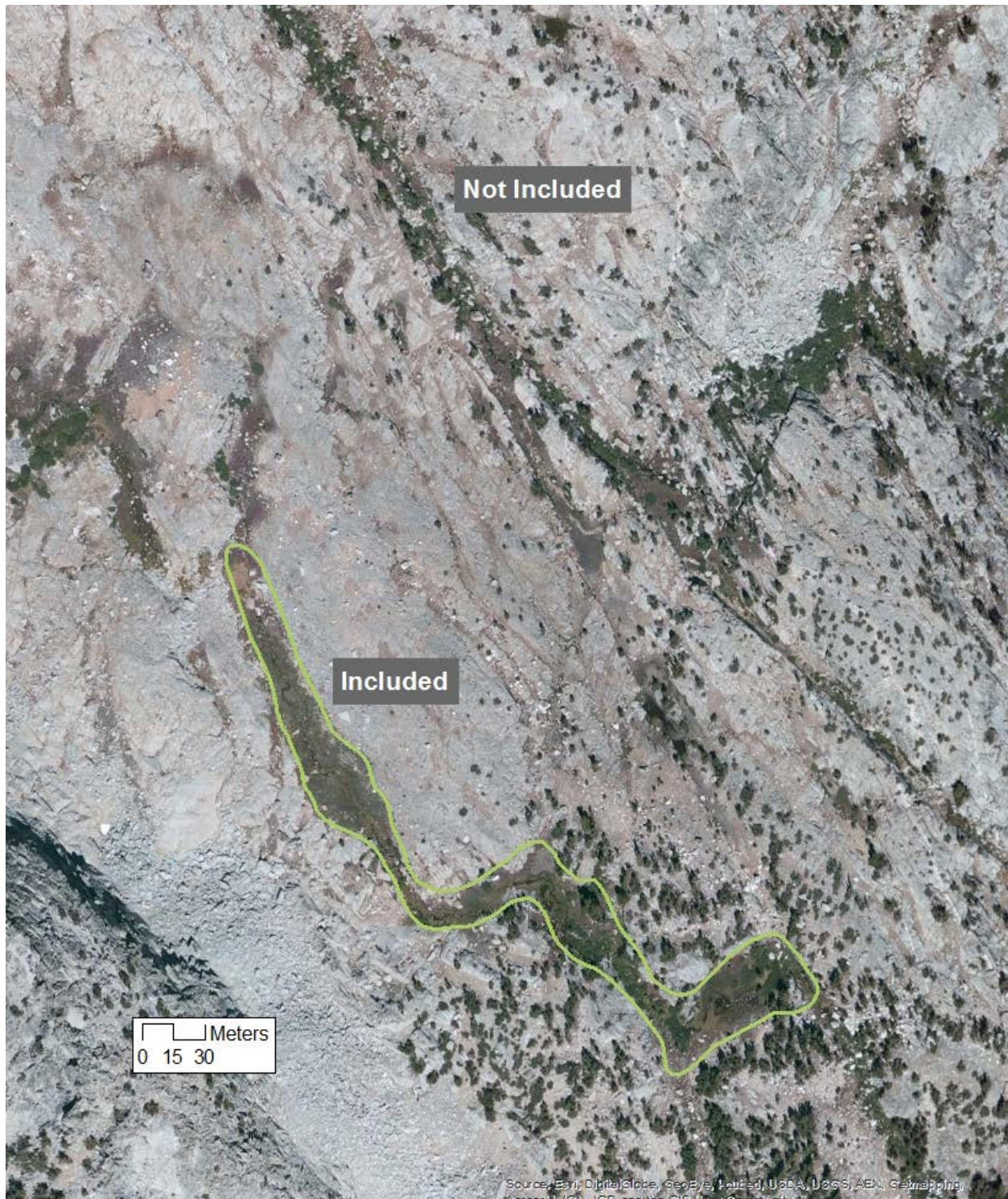


Appendix II. Examples of Mapping Decision Rules



Methods: Alpine: Snowmelt driven vegetation

Snowmelt driven vegetation on the right displays the target signature, but lacks a watershed and soil development which would support wet meadow status. The included area on the left is just within the vegetation density and wetness parameters of the project.



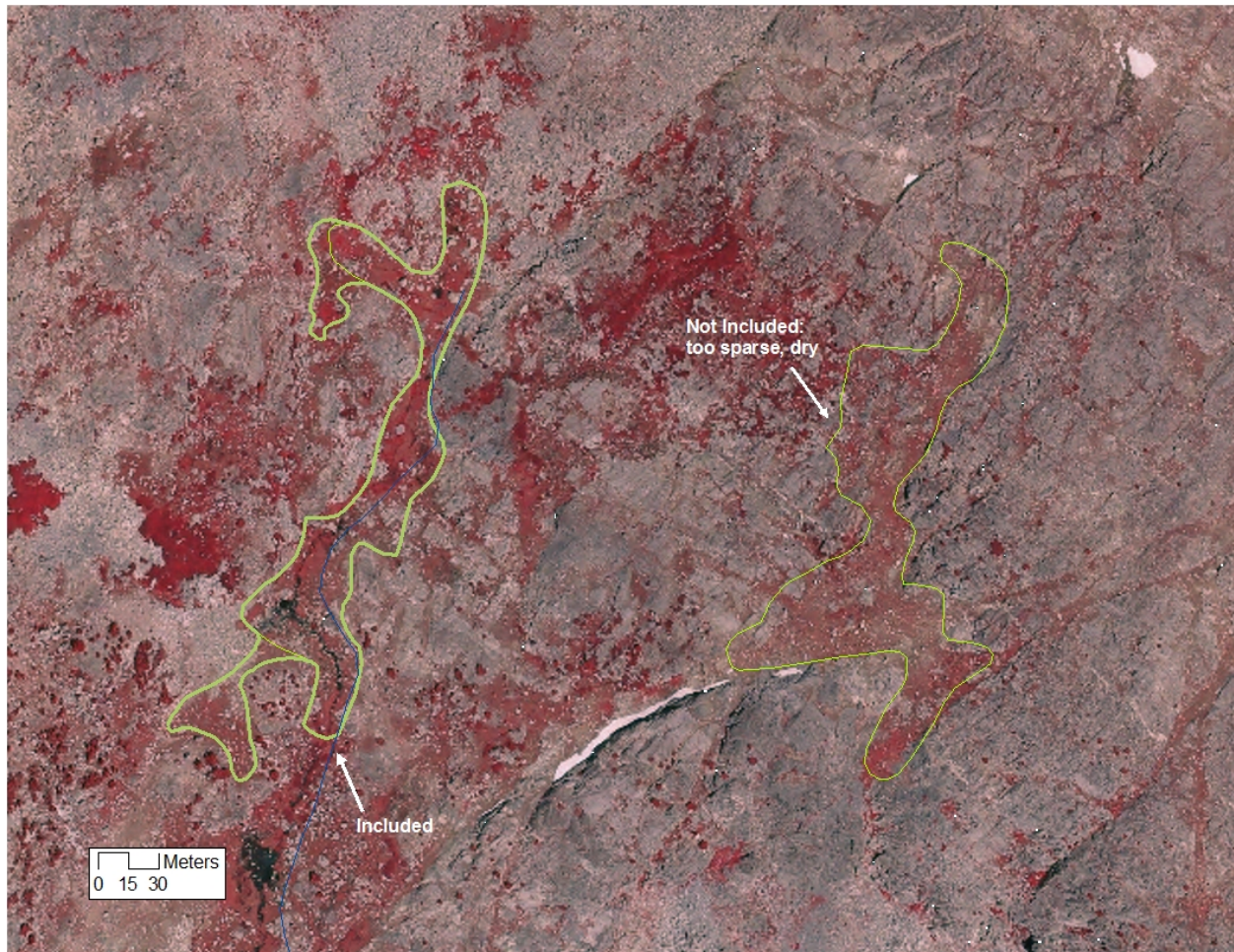
Methods: Alpine/Subalpine, 15-meter rule

Meadow vegetation occurring in strips less than 15 meters wide was not included. The strip on the upper part of this image has discontinuous vegetation patches and on average is just under 15 meters wide, and was therefore not included. The lower strip has more continuous meadow vegetation that is at least 15 meters wide, and consequently it was mapped.



Methods: Alpine/Subalpine: Vegetation density

Meadow vegetation in this instance was considered too sparse to be included. More than 1/3 of the area that would be mapped appears as rock or bare ground, and not much soil development is detectable. Vegetation such as this was consistently mapped in the SEKI vegetation map as meadow, but excluded in the context of this project.



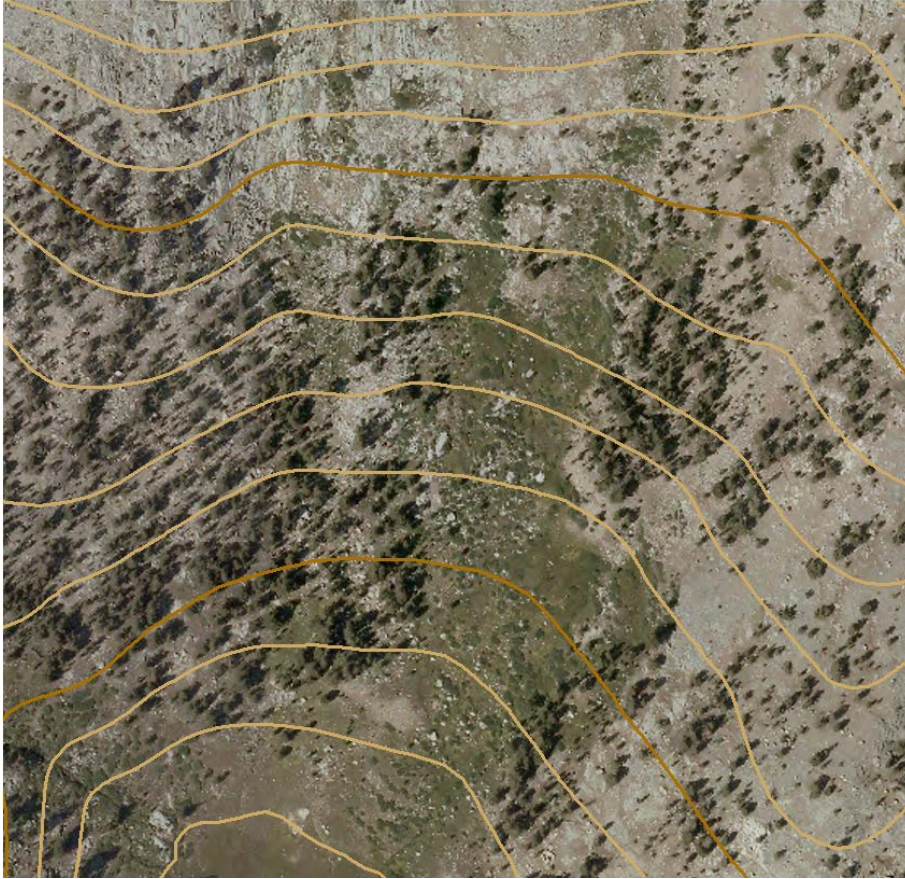
Methods: Alpine/Subalpine: Vegetation density

Many areas, particularly in the alpine and subalpine, were on the cusp of inclusion or exclusion. In this image, the outline on the left shows what was included in the map: the vegetation meets density requirements, and the headwaters of a stream are visible. The lighter outline on the right was included in the SEKI vegetation map as meadow, but was too rocky and sparse to meet the criteria of a target wetland for this project. Other dense and bright red areas in the above image are mostly shrubs.



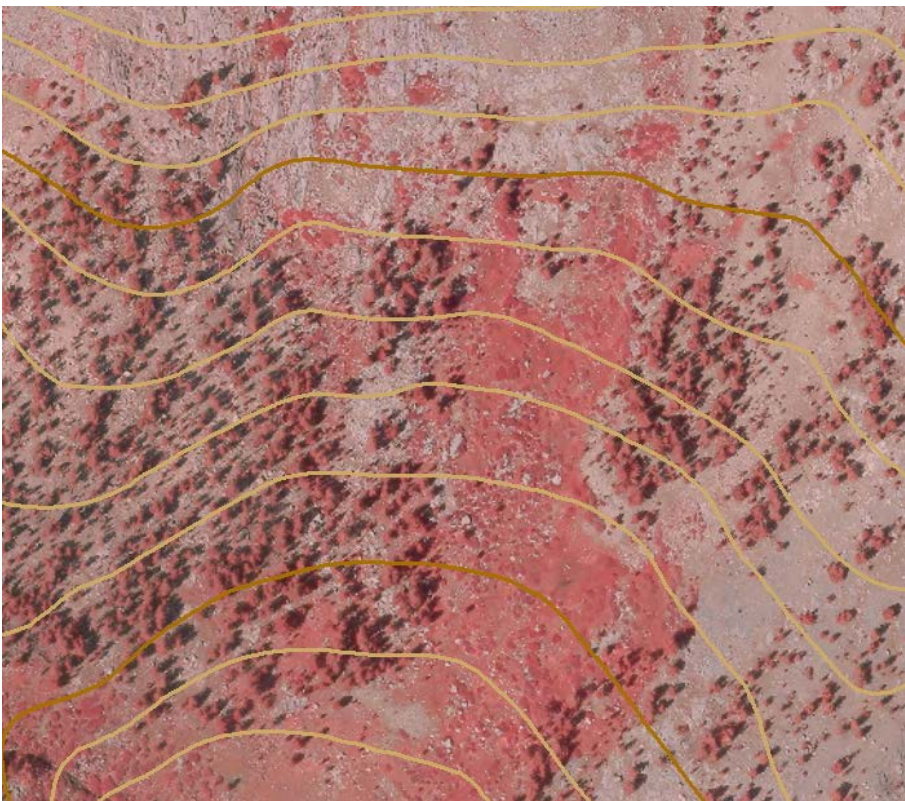
Methods: Subalpine: Streamside vegetation

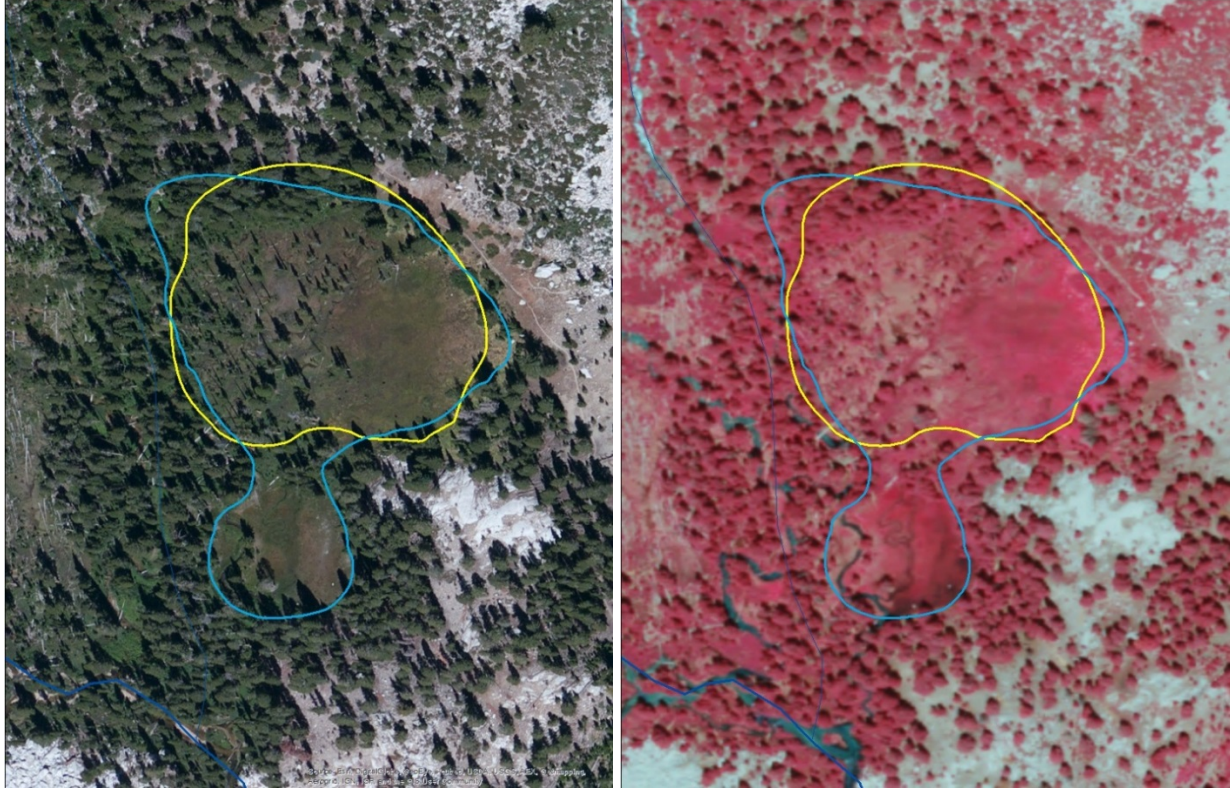
In the SEKI vegetation map, streamside vegetation had been included in some meadow vegetation classes. Only riparian vegetation that is a part of meadows that are an average of greater than 15 m wide were included in the Wet Meadow and Fen Mapping Project. The area that had been mapped in the SEKI vegetation map as meadow vegetation was excluded in this instance because of the amount of rock and shrubs (resulting in a lowered density of meadow vegetation), in addition to being narrow.



Methods:
Alpine/Subalpine:
Spring-fed Steep Slope

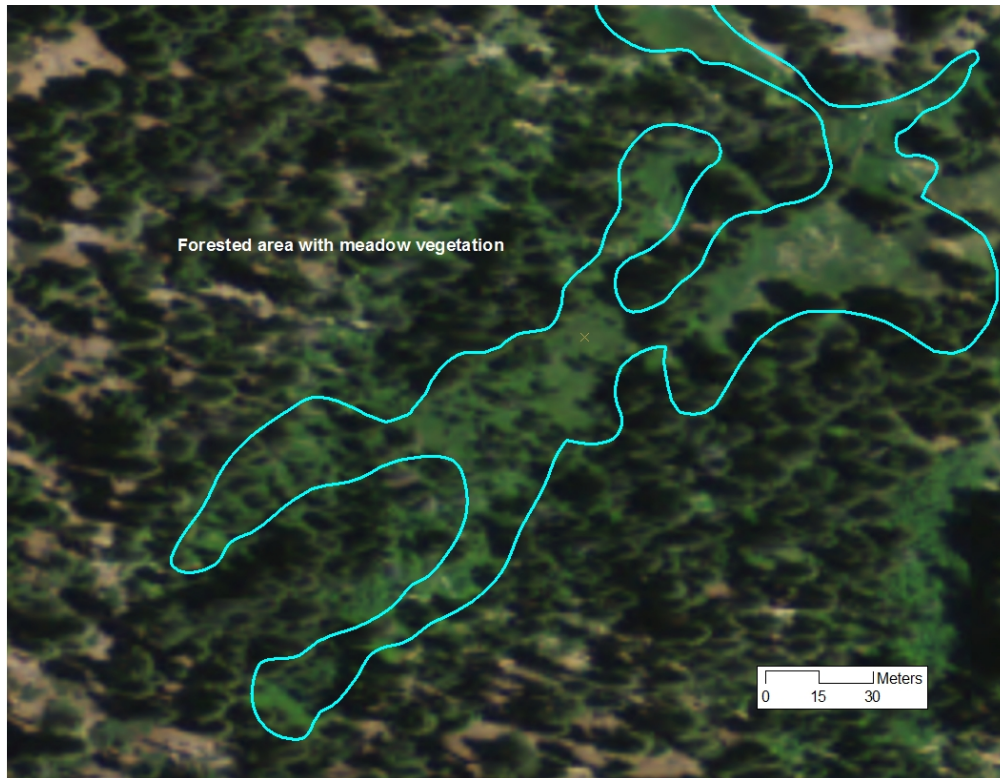
High-gradient meadows with good signature likely due to spring activity such as this were included owing to their apparently consistent water source. Brown lines are 40 foot contour lines, indicating the steepness of the slope in this example.





Methods: Montane: Forested Fen

The majority of fens in SEKI are characterized by a dense herbaceous layer or occasionally have a shrub overstory (such as willow). However, a tree overstory has been observed in some fens. In this example, the blue line indicates the extent of the fen-meadow complex, and the yellow line shows the extent of the fen, as mapped in the field in 2012. Notable in the color infrared image is the signature of *Sphagnum* with an overstory of lodgepole pine (*Pinus contorta* ssp. *murrayana*).

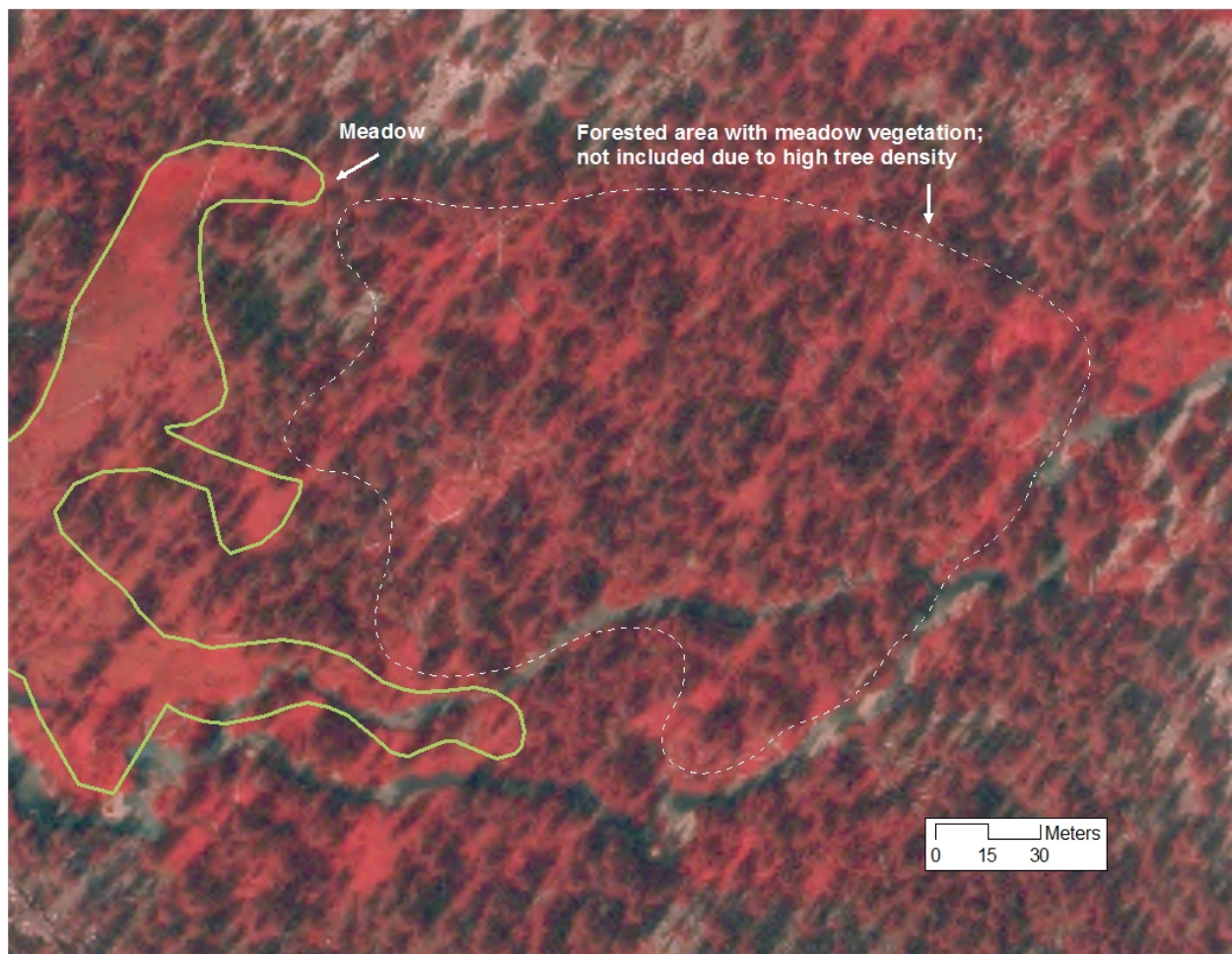


Methods:
Montane:
Acceptable tree density

These two examples show small meadows in forested areas. The above example is interspersed with trees but the vegetation throughout the understory is clearly meadow vegetation.

The meadow in the example below includes scattered trees in the center; they are included because of the evident meadow understory and low tree density.





Methods: Montane: Unacceptable tree density

Included meadow vegetation on the left is outlined in green. The area indicated by the white dotted line is treed with a combination of meadow vegetation and shrubs. While it may have meadow vegetation in the understory, this area was considered to be too densely forested to be included as the non-herbaceous cover was estimated to be $>67\%$.



Methods: Inclusion of vegetation from non-meadow mapping units in the SEKI vegetation map:
3022- Sierra Lodgepole/Bog Blueberry Forest Mapping Unit

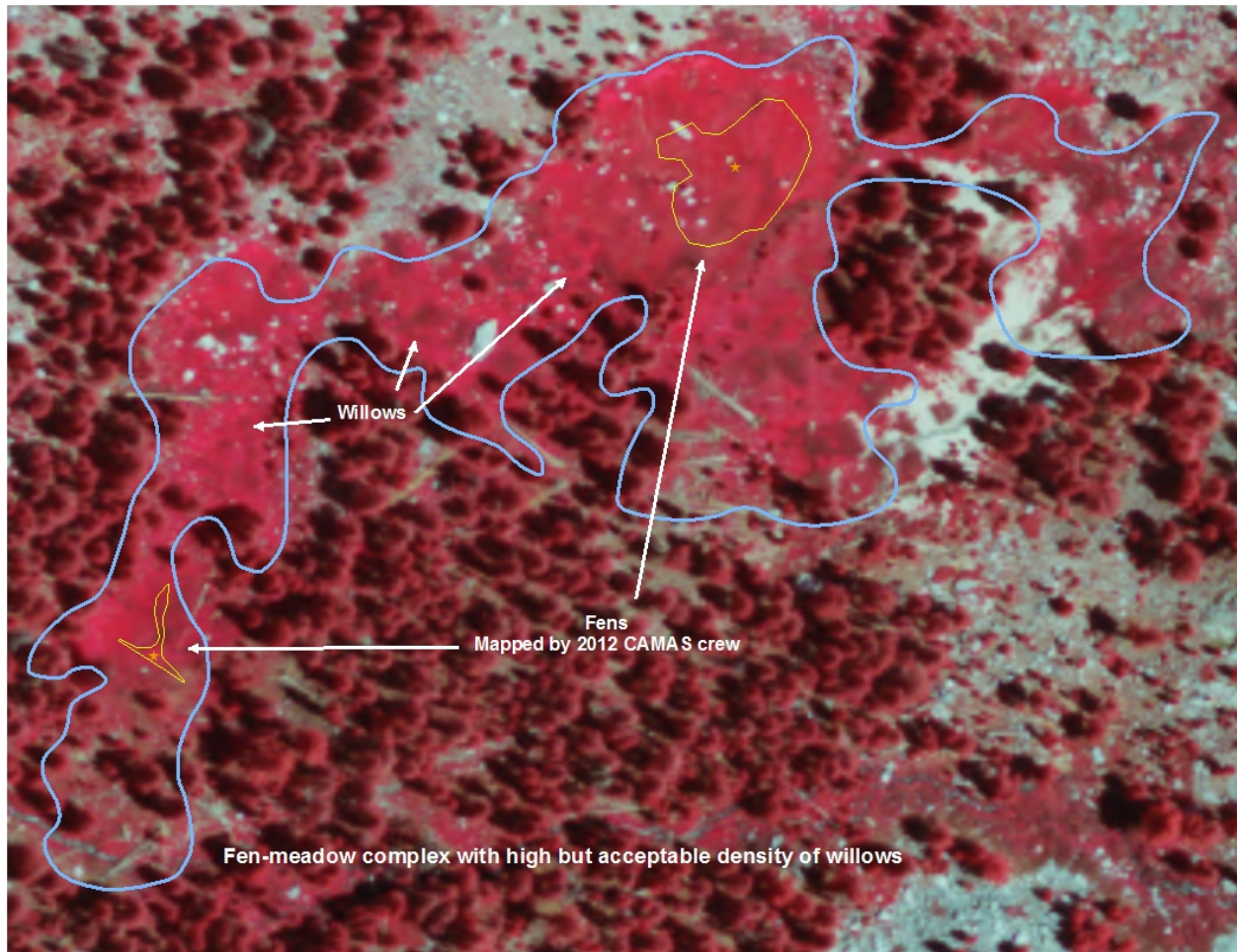
Included meadow vegetation outlined in green. Areas originally mapped in the 3022 unit are outlined in blue. There is considerable overlap.



Methods: Inclusion of vegetation from non-meadow mapping units in the SEKI vegetation map: 6110 -Sierra Willow/Swamp Onion Seasonally Flooded Shrubland

Both of these are examples of vegetation that was mapped in the 6110 unit, but that were found to meet the visual signature and other criteria of the Wet Meadow and Fen Mapping Project.

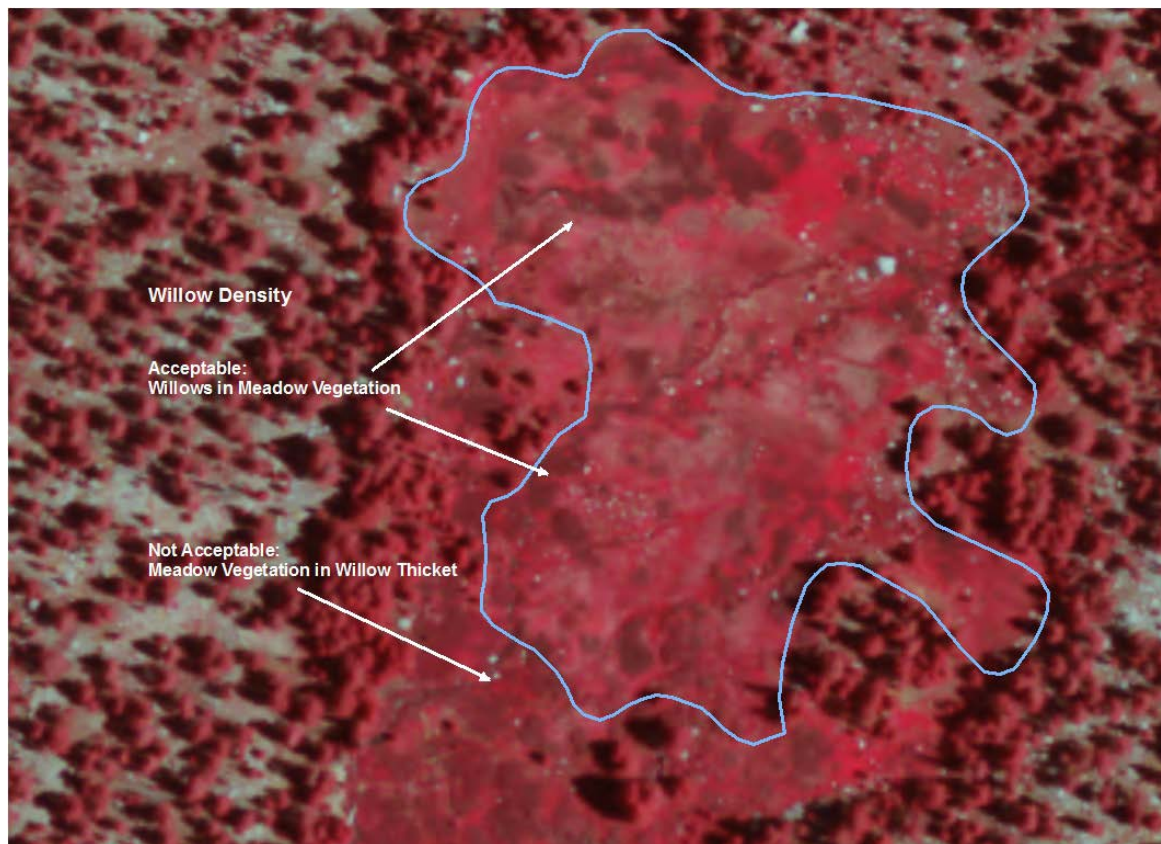
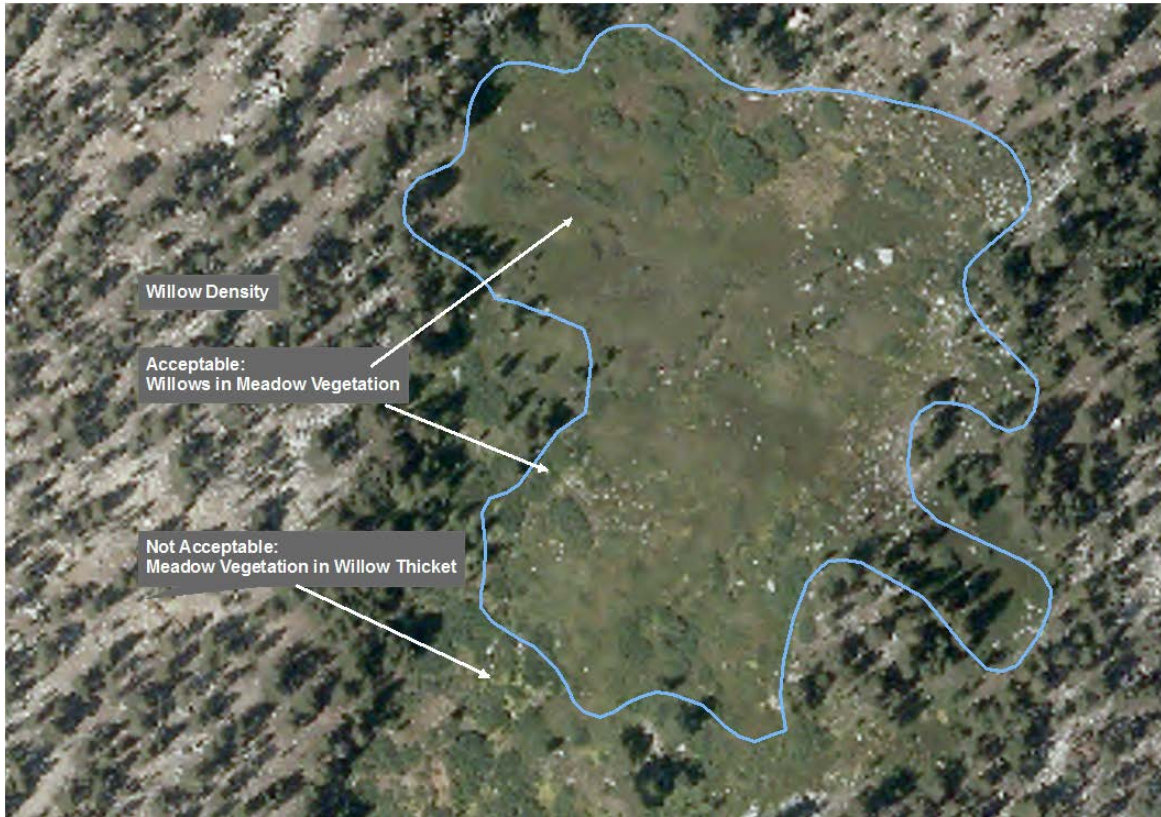


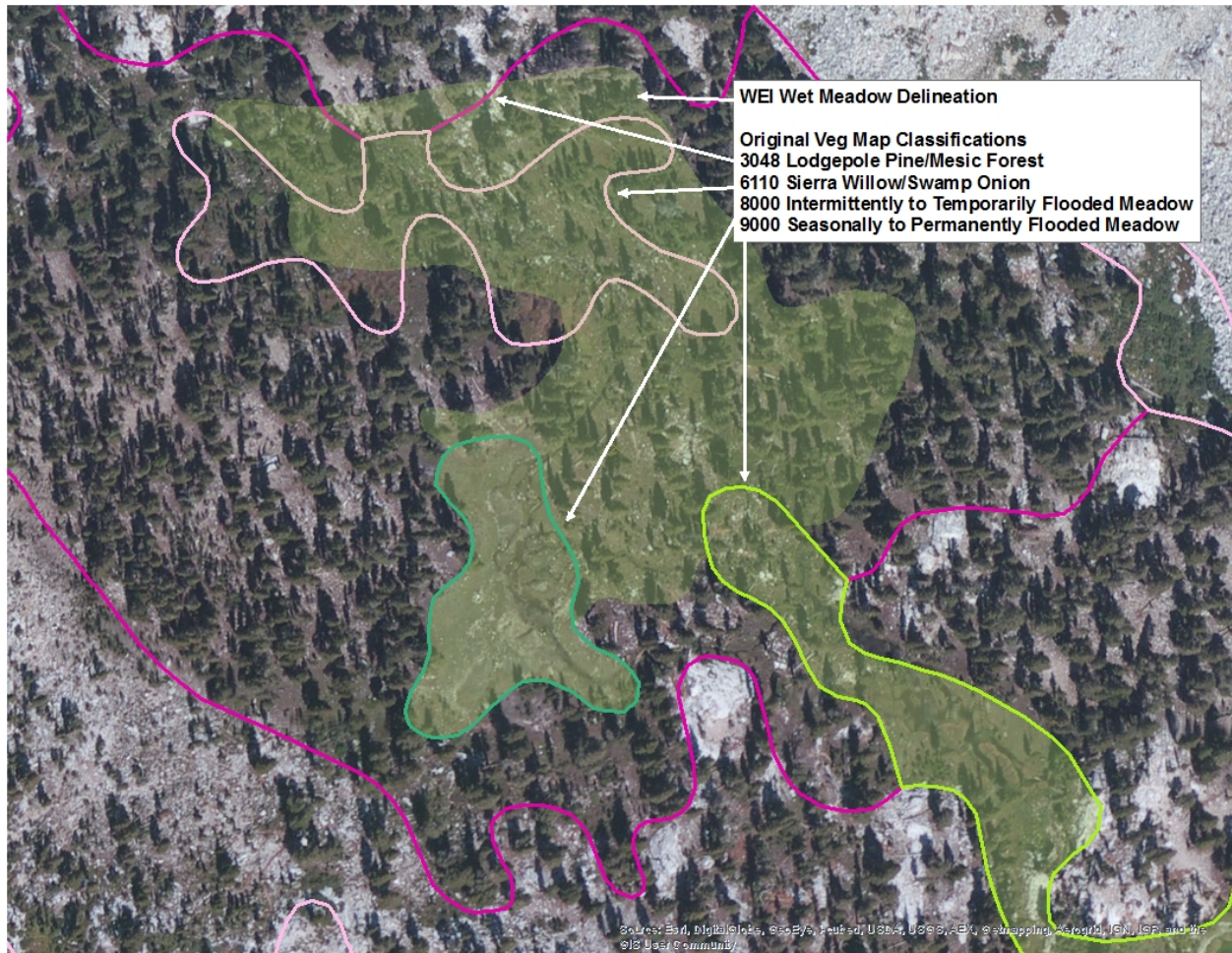


Methods: Inclusion of vegetation from non-meadow mapping units in the SEKI vegetation map:
 6500- Willow spp./Meadow Shrubland mapping unit

Above: Fens were delineated in the field in 2012 in this meadow, which was originally included in the 6500 Willow spp./Meadow Shrubland mapping unit in the SEKI vegetation map. Willows appear darker in irregular patterns in parts of the meadow. While there is moderate willow cover, the density of meadow vegetation on its own and interspersed with the *Salix* is sufficient to consider it a meadow; because there are known fens, this is classified as a fen-meadow complex.

Next page: Shrub vegetation is sparse enough with meadow vegetation understory, as shown in the mapped meadow (inside the blue line); in the bottom portion of the image the willows become a thicket, and this is excluded.





Methods: Inclusion of vegetation from non-meadow mapping units in the SEKI vegetation map:
 3048 – Sierra Lodgepole Pine Mesic Forest Unit

This is a good example of how aggregation affected the SEKI vegetation map differently than the Wet Meadow and Fen Mapping Project (WMFMP) since the latter was not attempting to classify the entire landscape, but rather was searching for a particular feature within a landscape. The transparent green represents the mapped feature in the WMFMP map. The other lines indicate different units used in the SEKI vegetation map. While trees occur, and this was largely considered part of the 3048 Sierra Lodgepole Pine Mesic Forest Unit, they are at a sufficiently low density to be included.



Methods: Inclusion of vegetation from non-meadow mapping units in the SEKI vegetation map:
6700 – Willow spp. / Talus Shrubland

The brown outline above was originally included in the 6700 Willow spp. Talus Shrubland unit. While some areas mapped above fall distinctly within that definition, a significant portion supports wet meadow vegetation and has been mapped as such in the current wet meadow and fen mapping project.

Appendix III. Wet Meadow and Fen Mapping Project Feature Class Metadata

SEKlgis.DBO.WetMeadowsFens_py

SDE Feature Class

Tags

National Park Service, Vegetation, Plants, Biota, Wetlands, Fens, Meadows, Groundwater, Sequoia National Park, Kings Canyon National Park, SEKI

Summary

Wetland classification, wet meadows and fens, wetland ecological integrity

Description

The Wet Meadows and Fens Feature Class of Sequoia and Kings Canyon National Parks was produced over a three month period (late February through early May 2013) to identify and classify all target wetlands (wet meadows and fens) >0.5 hectare in the parks. Over 2300 polygons represent wetlands in three classes: wet meadows, fen-meadow complexes, and fens. Classifications are as follows: a wet meadow is a wetland that does not include any peat accumulation or may contain up to a 25x25 square meter area of peat accumulation; a fen-meadow complex is a wetland that includes at least at 25x25 square meter area of peat-accumulating and non-peat-accumulating soil; a fen contains less than 25x25 square meter area of non-peat-accumulating soil. Overall spatial accuracy of the resulting map products is equivalent to 1:24000 National Map Accuracy Standards. Mapped polygons are based on photo interpretation of Natural Color and Color Infrared NAIP aerial photography from 2005, 2009, 2010, and 2012. Ancillary data informing mapping decisions included: the SEKI Vegetation map, 15-minute Digital Raster Graphics (USGS), the National Wetlands Inventory Wetland Layer, the SEKI Rivers and Streams Layer, and 2012 spatial data depicting known fen locations produced by the SEKI Plant Ecology program. Supporting documentation for the feature class (report, accuracy assessment) are located in the SEKI network at: J:\sien\monitoring_projects\wetlands\projects\WEI_delineation_project. The project was a collaboration between the SEKI Plant Ecology Program, SEKI GIS Staff, and the SIEN Inventory and Monitoring Program; photo interpretation was performed by two technicians under contract.

Credits

National Parks Service – Sequoia and Kings Canyon National Parks

Use limitations

Any person using the information presented here should fully understand the data collection and compilation procedures, as described in these metadata and associated documentation, before beginning analysis. The burden for determining fitness for use lies entirely with the user. For purposes of publication or dissemination, citations should be given to the National Park Service. This data should not be used for navigational purposes.

Extent

West -118.993847 **East** -118.243620

North 37.230271 **South** 36.301942

SEKlgis.DBO.VEG_FenPeat_pt

SDE Feature Class

Tags

National Park Service, Vegetation, Plants, Biota, Wetlands, Fens, Meadows, Groundwater, Sequoia National Park, Kings Canyon National Park, SEKI

Summary

Wetland classification, fens, wetland ecological integrity

Description

The Wet Meadows and Fens Feature Class of Sequoia and Kings Canyon National Parks was produced over a three month period (late February through early May 2013) to identify locations of fens within park boundaries. More than 600 fen points identify locations where fens are known or presumed to occur. Overall spatial accuracy of the resulting map products is equivalent to 1:24000 National Map Accuracy Standards. Mapped polygons are based on photo interpretation of Natural Color and Color Infrared NAIP aerial photography from 2005, 2009, 2010, and 2012. Ancillary data informing mapping decisions included: SEKI Vegetation Map, 15-minute Digital Raster Graphics (USGS), the National Wetlands Inventory Wetland Layer, the SEKI Rivers and Streams Layer, and 2012 spatial data depicting known fen locations produced by the SEKI Plant Ecology program. Supporting documentation for the feature class (report, accuracy assessment) are located in the SEKI network at: J:\sien\monitoring_projects\wetlands\projects\WEI_delineation_project. The project was a collaboration between the SEKI Plant Ecology Program, SEKI GIS Staff, and the SIEN Inventory and Monitoring Program; photo interpretation was performed by two technicians under contract.

Credits

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Use limitations

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Extent

West -118.957839 **East** -118.250777

North 37.201896 **South** 36.308257

Scale Range

There is no scale range for this item.

Appendix IV. Accuracy Assessment Standard Operating Procedure

SOP 01. Wet Meadows and Fens Feature Class Accuracy Assessment Field Methods

Change History

Previous Version	Revision Date	Author	New Version	Changes Made	Reason for Change

Introduction

This SOP provides step-by-step instructions for field classification of mapped vegetation polygons used to assess the accuracy of the Wet Meadows and Fens feature class created in 2013. In order to assess the accuracy of the map, a selection of mapped polygons will be assigned to a mapping class in the field and compared to the mapped feature. In addition, polygons mapped as wet meadow vegetation in the SEKI vegetation map (2001) which were not included in the Wet Meadows and Fens feature class will be assessed in order to determine whether they were correctly excluded.

Polygons will be selected for assessment and provided to field crews with identifying information excluded. Results will be reported by an identifying number.

Polygons will be classified as meadow, fen-meadow complex, fen, or non-target vegetation following the definitions used in the Wet Meadows and Fens mapping report. This will be accomplished by determining the extent of and fen habitat and documenting the presence of any peat accumulating wetlands. The following definitions will be used in classifications:

Wet meadow: herbaceous vegetation with a water table within 2 m of the surface that does not accumulate peat or that contains peat accumulating areas that are less than 25 m by 25 m in size. In the case of multiple discrete fens, areas are to be evaluated individually, not cumulatively.

Fen-Meadow complex: a wetland that includes at least a 25 m by 25 m continuous area of peat-accumulating soil in addition to an area of non-peat accumulating soil which is at least 25 m by 25 m in size. In case of multiple discrete fens, areas are evaluated individually, not cumulatively.

Fen: a peat-accumulating wetland containing less than a 25 m by 25 m continuous area of non-peat-accumulating soil.

Non-target vegetation: water table is greater than 2 m deep during part of the growing season, soils lack the characteristics of wet meadows or fens, and plants are characteristic of upland habitats or ecotones between wet meadows and uplands. Wet meadow and fens may

also be classified as “non-target vegetation” if vegetative canopy cover is less than 67%, or if the vegetation is dominated by woody species (i.e. willows) without a continuous herbaceous wetland understory.

Equipment

- Accuracy assessment maps with polygons to be evaluated
- Paper data forms
- Pencils
- Clip board
- Moss and vascular plant ID guides
- Moss envelopes and plant press
- 48” Fiberglass tile probe with 5/8” diameter pointed steel tip
- Camera
- GPS (Trimble Juno SB with appropriate data dictionary or Garmin)

Steps

1. **Walk the assessment polygon** with particular attention to very wet areas. Form a mental model of water sources and the seasonality of these water sources.
2. **Identify whether the polygon contains wet meadow or fen habitat** based on the three criteria: soils, hydrology, and vegetation.
 - 2.1 Determine if the polygon has sufficient soil development to support a wet meadow plant community.
 - 2.2 Determine if there is evidence that the water table remains within 2 m of the soil surface throughout the growing season- look for springs, permanent channels, depressional features, etc.
 - 2.3 Determine whether the polygon is dominated by wetland or upland plant species.
3. **Identify the presence of fens** based on the three criteria: soils, hydrology, and vegetation
 - 3.1. Fen soils contain 20 cm of organic horizons in the top 40 cm. Relatively thin mineral strata may be present, but organic horizons dominate. Organic soils resemble decomposing roots and leaves (fibric) or may feel slippery (hemic and sapric). Peat accumulation can cause the wetland to appear to have a domed surface. The surface of a fen may feel spongy under foot.
 - 3.2. Fen water tables are within 20 cm of the surface throughout the growing season. The soil surface should be at least damp throughout, and pools and active small channels are likely to be present. Fens are most common at springs and seeps on low slopes, but may also form on midslopes and in basins.
 - 3.3. Fen vegetation is made up of peat forming species adapted to very wet conditions. Dense moss cover is characteristic of many fens; indicator species such as *Sphagnum* help differentiate wet meadows from fens. Vascular species of *Carex* and other graminoids may form dense sods. Woody species (especially Ericaceous species) may be abundant, especially on hummocks. Trees are usually confined to hummocks or drier areas in the fen, although they may form a major part of the vegetation in some fens.

4. **Map any fens located within the polygon** based on the methodology described in Frenzel and Haultain (2015) Appendix A.2 using three criteria (soils, hydrology, and vegetation) as a guide. Include important hydrological features (such as springs and seeps) which are crucial to the existence of the fen even if soils don't meet fen criteria.
5. **Record polygon attributes**
 - 5.1. Record the polygon ID number from the map
 - 5.2. Record the closest place name
 - 5.3. Record the initials of the persons making the evaluation
 - 5.4. Record the date
 - 5.5. Record **hydrological** indicators:
 - 5.5.1. What soil surface condition best characterizes the polygon
 - 5.5.1.1. Dry at surface
 - 5.5.1.2. Moist at surface
 - 5.5.1.3. Saturated at surface
 - 5.5.1.4. Inundated at surface
 - 5.5.2. Are the following features present (YES/NO/UNKNOWN for each)
 - 5.5.2.1. Springs/seeps/other groundwater feature
 - 5.5.2.2. Perennial streams
 - 5.5.2.3. Seasonal streams
 - 5.5.2.4. Pools
 - 5.5.3. Hydrogeomorphic classification of the polygon according to Weixelman et al. (2011): identify up to five hydrogeomorphic meadow types contained within polygon by percentage, including a "non-meadow" type if none of the hydrogeomorphic types are present.
 - 5.5.3.1. Type 1, % of polygon
 - 5.5.3.2. Type 2, % of polygon
 - 5.5.3.3. Type 3, % of polygon
 - 5.5.3.4. Type 4, % of polygon
 - 5.5.3.5. Type 5, % of polygon
 - 5.6. Record **soil characteristic** indicators:
 - 5.6.1. Is there a peat accumulating area (at least 20 cm of peat within the top 40 cm of the soil) at least 25 m by 25 m in size (YES/NO/UNKNOWN)
 - 5.6.2. Record feature identifiers for mapped peat accumulating areas
 - 5.6.3. Is there a non-peat accumulating area at least 25 m by 25 m in size (YES/NO/UNKNOWN)
 - 5.6.4. Are the non-peat accumulating areas characterized by fine textured soils with dark surface horizons (YES/NO/UNKNOWN)
 - 5.7. Record **vegetation** data:
 - 5.7.1. Is there greater than 33% rock and non-vegetated or woody cover when considered at a coarse scale?

- 5.7.2. Record the vegetation dominants in polygon. May include non-vascular plants.
- 5.8. **Classify** the polygon using the key to mapping classification given below.
- 5.9. **Spatial criteria:** is the wet meadow and fen vegetation >15 m wide on average and >0.5 ha in size and <33% rock. (YES/NO/UNKNOWN)
- 5.10. **Comments:** note any difficulty in classifying the polygon, important indicators used, etc.
6. **Collect information on suitability as WEI study site**
7. **Collect Vouchers:** If the identity of dominant or diagnostic plants is uncertain, collect vouchers of these species.
8. **Photographs:**
 - 8.1. Identify polygon before taking photos by photographing map or datasheet
 - 8.2. Take several clear, focused photographs to capture overall polygon conditions, including vegetation and hydrology
 - 8.3. Take photos of any fens encountered

Key to Mapping Classification

1. Polygon is characterized by peat accumulating soils (at least 20 cm of peat within the top 40 cm of the soil); non-peat accumulating areas, if any, are less than 25 m by 25 m in size [FEN]
 - 1' Polygon may or may not contain peat accumulating areas (depth); non-peat accumulating areas are present and are greater than 25 m by 25 m in size.
2. Polygon contains one or more peat accumulating areas (depth) that are at least 25 m by 25 m in size AND contains one or more non-peat accumulating areas that are at least 25 m by 25 m in size [FEN-MEADOW]
 - 2' Polygon lacks one or more peat accumulating areas that are at least 25 m by 25 m in size
3. Polygon is characterized by water tables that are within 2 m of the soil surface during the growing season; vegetation includes an herbaceous stratum that is dominated by wetland obligates (OBL) or facultative wetland (FACW) species with 67% or greater canopy cover (willows, alders, or lodgepole pine may also be present); soils display characteristic of wet meadows such as dark organic surface horizons [MEADOW]
 - 3' Polygon is characterized by water tables that are deeper than 2 m from the soil surface during the growing season; vegetation various, lacks an herbaceous stratum that is dominated by wetland obligates (OBL) or facultative wetland (FACW) species with 67% or greater canopy cover, may be dominated by facultative (FAC, FACU) or upland (UPL) herbaceous species, willows, alder, or lodgepole pine; soils lack the characteristics of wet meadows such as dark organic surface horizons [NON-TARGET]

References

Frenzel, E. and S. Haultain. 2015. Sequoia and Kings Canyon National Parks Wilderness Meadow Assessment Project Final Report. Unpublished report, Division of Resources Management and Science, Sequoia and Kings Canyon National Parks, Three Rivers CA 93271

Accuracy Assessment Data Sheet

SITE DESCRIPTION		
AA polygon ID number		
Place name		
Observers		
Date		
HYDROLOGICAL INDICATORS		
Soil surface condition	Dry / Moist / Sat / Inn	Dry / Moist / Sat / Inn
Ground water features	Yes / No / Unk	Yes / No / Unk
Perennial streams	Yes / No / Unk	Yes / No / Unk
Seasonal streams	Yes / No / Unk	Yes / No / Unk
Pools	Yes / No / Unk	Yes / No / Unk
Hydro type 1, %		
Hydro type 2, %		
Hydro type 3, %		
Hydro type 4, %		
Hydro type 5, %		
SOIL INDICATORS		
Peat (20 in 40) > 25m x 25m	Yes / No / Unk	Yes / No / Unk
Fen ID numbers		
Non-peat > 25 m by 25 m	Yes / No / Unk	Yes / No / Unk
Soils organic, fine textured	Yes / No / Unk	Yes / No / Unk
VEGETATION		
Total herb canopy cover, %		
Dominant spp wetland rating if known		

CLASSIFICATION		
Fen/Mdw/Fen-Mdw/Non-target	F / M / F-M / NT	F / M / F-M / NT
> 15 m wide / > 0.5 ha area (Y/N/U)		
COMMENTS (continue in field books if needed)		

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 102/128657, May 2015

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U.S. Department of the Interior



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