NCARI

North Coast Aquatic Resources Inventory

MAPPING STANDARDS AND METHODOLOGY
FOR
CHANNELS, WETLANDS, AND RIPARIAN AREAS
IN THE SANTA ROSA PLAIN, CA

PRODUCED BY SFEI-ASC[1]
FOR
NORTH COAST REGIONAL WATER QUALITY CONTROL BOARD AND THE
WETLAND RIPARIAN AREA MONITORING PLAN (WRAMP)

Revised February 11, 2013

[1] SFEI-ASC is the San Francisco Estuary Institute and Aquatic Science Center (www.sfei.org)

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1.0 Purpose

The purpose of this document is to describe the mapping standards and methods[2] used to develop the North Coast Aquatic Resources Inventory (NCARI) and part of the Laguna de Santa Rosa Wetland and Riparian Assessment project. The goal of NCARI is to represent all aquatic systems and riparian areas in the La Laguna de Santa Rosa valley basin (Santa Rosa Plain). NCARI is the North Coast version of the California Aquatic Resource Inventory (CARI) and is entirely consistent with CARI standards.

The NCARI GIS base map is part of the larger project called the "North Coast Watershed Demonstration Project Using the California Wetland and Riparian Area Monitoring Plan (WRAMP) Framework." The WRAMP toolset includes ways to collect and compile consistent wetland information to support the Wetland and Riparian Area Protection Policy being developed by the State Water Resources Control Board.

WRAMP is organized according to the USEPA three-level framework for comprehensive wetland monitoring and assessment (http://www.epa.gov/owow/wetlands/pdf/techfram.pdf). Level 1 is a series of GIS-based inventories of the location, extent, and diversity of wetlands and other aquatic resources. Level 2 is a rapid field assessment of overall resource health. Level 3 is a quantification of particular aspects of aquatic resource health or stress. According to this framework, NCARI is a Level 1 tool. At this time, WRAMP is being demonstrated in the Tahoe Basin, Sacramento-San Joaquin Delta, San Francisco Bay Area, and Southern California coastal watersheds.

This project demonstrates two tools approved by the California Wetland Monitoring Workgroup (CWMW) to describe the extent and condition of wetlands in California.

This project is funded by the California Natural Resources Agency under the Coastal Impact Assistance Program of the U.S. Fish and Wildlife Service and employs WRAMP tools including:
1) developing a GIS map of all the wetland resources in the Laguna de Santa Rosa study area using scientifically vetted GIS mapping standards based on the California Aquatic Resources Inventory (CARI), and
2) assessing of their ecological condition using a statistically random sample design and the California Rapid Assessment Method (CRAM).

The map data will be used to create a basemap for aquatic resource protection on the Santa Rosa plane. The CRAM assessments will be used to demonstrate repeatable, cost effective measures of stream and wetland condition at the landscape scale.

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[2] NCARI standards were adapted from CARI, the California Aquatic Resource Inventory. NCARI is consistent with CARI, but has additional requirements specific to the La Laguna de Santa Rosa valley basin. NCARI is a regional version of CARI.

2.0 NCARI Study Area

The NCARI study area is the Laguna De Santa Rosa valley basin (Santa Rosa Plain). This area is defined as the western portion of the Watershed Boundary Dataset HUC10 boundary which is defined on the upslope side roughly at the 12% slope mark as defined by the USGS 10 meter National Elevation Dataset. This extent was used to show the overall wetland/flood/water quality context of the Santa Rosa Plain and the included Laguna de Santa Rosa while excluding the upper portion of the watershed.

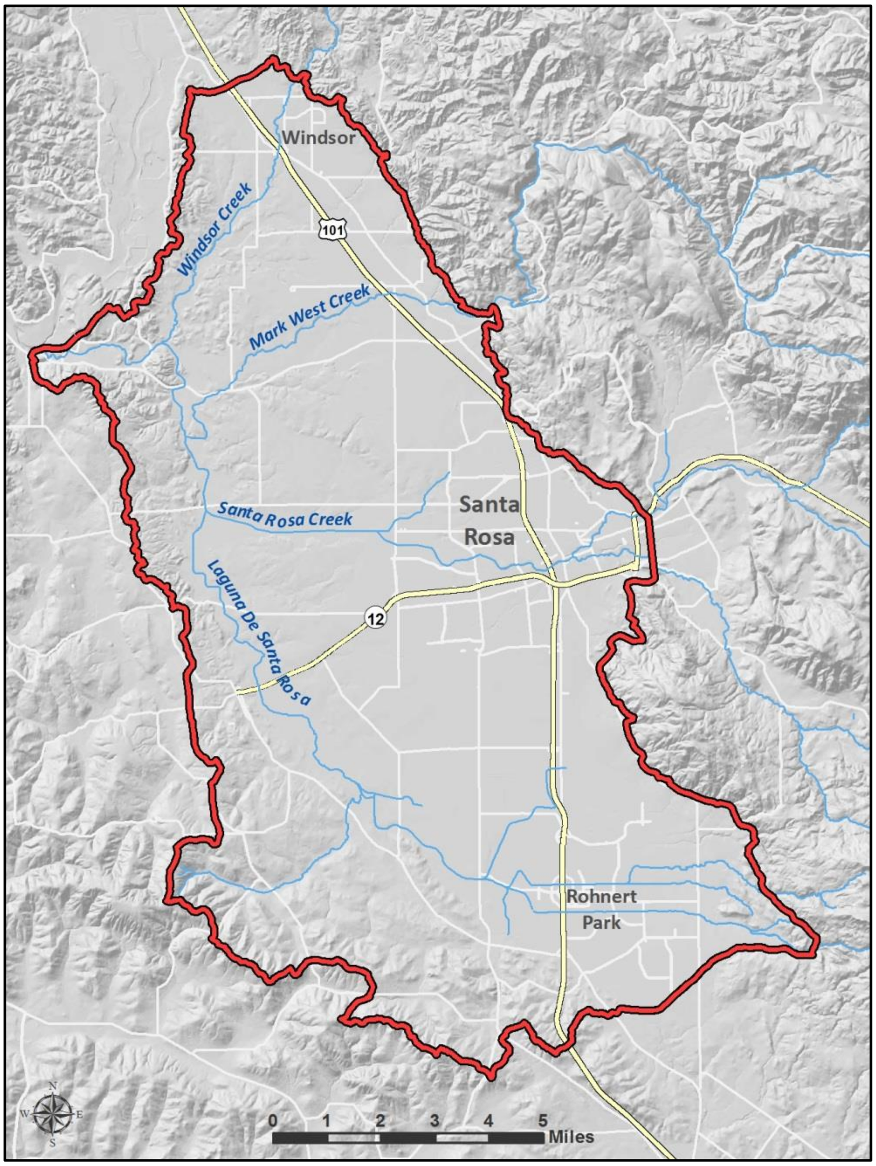


Figure 1: *NCARI study area.*

3.0 Mapping Standards

3.1 Classification System

NCARI classification is an expanded version of the CARI classification system to include aquatic types distinct to the northern California coast region. The NCARI typology and coding system is presented in Table 1, and is explained below. To conform to the classification protocols of national datasets, especially the National Hydrologic Dataset (NHD) of the USGS and the National Wetland Inventory (NWI) of the USFWS, a crosswalk between these systems and the NCARI system has been developed (Table 2).

3.1.1 General Wetland Descriptions

Non-tidal Wetlands

The non-tidal wetlands consist of all the wetlands that are not influenced by marine or estuarine tidal waters. Since the Laguna De Santa Rosa Valley is not influenced by these kinds of tides, the NCARI classification system is limited to non-tidal wetlands, which are simply referred to as wetlands in this document.

Open Water and Vegetated Areas

Many wetlands consist of two basic elements: an open water area and a vegetated area. Open water areas (OW) are at least 90% percent open water using a 100 square meters (m^2) search area, meaning they have less than 10% vegetation cover. Floating and submerged aquatic vegetation found in open water wetlands do not count towards the 10% cover. Vegetated areas (V) therefore have at least 10% vegetation cover. These are areas that lack apparent standing water during the dry season and appear to have less than 10% vegetation cover. The term non-vegetated (U) is only used for wetlands that fit the CARI definition of playas. All three types (OW, V, U) can be natural (N) or unnatural/man-made (U). The N or U code is always present for a wetland area (e.g., “PUU” refers to “Playa Non-vegetated Unnatural”). No playas are currently mapped in the NCARI project extent

Natural or Unnatural Wetlands

Natural wetlands owe most of their existing form and structure to natural processes. They might have been created, restored, enhanced, or otherwise modified by the direct or indirect actions of people, and they might be actively protected or otherwise managed. However, natural processes of geology and climate largely control their character, including their shape, size, location, sediment characteristics, hydrology, chemistry, and biology. Unnatural wetlands do not meet these criteria (e.g. a stock pond or drainage ditch). Further, if the open water area of a wetland is unnatural, then all the associated vegetated area(s) is also considered unnatural.

Deciding whether a wetland area is natural or not requires careful consideration of its apparent form, structure, and hydrological regime, relative to what is expected based on an expert understanding of the likely controlling factors and processes. For any mapping effort, such considerations will evolve into a set of guiding “rules of thumb” that must be applied consistently throughout the mapping effort. Different practitioners must be able to use the same rules in the same way to produce comparable maps. Initial determinations of what is natural might have to be revised as experience is gained. Some rules governing the designation of areas as natural or unnatural are generally applicable.

Modified channels were called out specifically in this project in order to guarantee that these features were represented in the CRAM sample draw. Modified channels have been armored or realigned and connect the upstream watershed to the downstream channels, usually through urban areas that have been confined and/or straightened. These features are less sinuous and are likely composed of artificial substrate. They are different than unnatural channels in that they are part of the natural flow network. Ditches are considered to be unnatural features.

Table 1: *General L1 indicators visible through primary data sources[3] to help distinguish natural from unnatural wetlands*

Riverine wetlands
Form: A wetland is classified as unnatural if its form in plan view is unnaturally straight. For example, ditches, flumes, and canals tend to lack the sinuosity or curvature of natural channels.
Substrate: A wetland is classified as unnatural (CU or TCU) if it is mostly manmade. For example, channels that are constructed of cement or other materials that would not occur in that location due to natural processes.
Non-riverine Wetland types
Impoundment: A wetland that exists because of the impoundment of water behind a levee, dam, etc., is always classified as unnatural, e.g. reservoirs, channel ponds, lakes. This is based on the assumption that the impoundment will be maintained.
All wetlands
Wetland areas that were originally unnatural can become naturalized due to the prevailing actions of natural events and processes. This is the case for many very old unnatural channels with natural flow regimes that have developed meanders, point bars, etc., and for successful wetland creation and restoration projects. The review of various temporal datasets is required to determine change over time. These features should be sinuous, have established vegetation or have a developed substrate.

3.1.2 Wetland Type Definitions

Depressional Wetlands (D):

Depressional Wetlands are features predominantly fed by surface water[4] that form in topographic lows. Precipitation, surface runoff, and groundwater are their main sources of water. Some depressions receive and drain water through a channel. If they are connected to

[3] Primary data sources can include LiDAR, imagery and local knowledge.

[4] Hydrologic function is inferred from remote sensing in a landscape and local context. Hydrologic function is further determined in WRAMP Level II and III analysis.

surface drainage, the flow is not enough to create an obvious current of water through the depression, except perhaps during extreme high-water events. Depressional wetlands have a minimum size of 0.025 acres (100 m^2). They can have prominent areas of shallow or seasonally open water (OW) and areas of adjacent vegetation (V). These features can be natural (N) or unnatural (U). The open water areas can include non-vegetated areas that are seasonally flooded and do not support more than 5% vegetation. The open water portion differs from that of lacustrine wetlands by being smaller than 20 acres (8 ha) in area and having an average depth less than 6 feet (ft) (~2 m) during the dry season. The vegetated portion can support woody wetland vegetation (e.g., willows and alders) and herbaceous wetland plants (e.g., sedges and rushes), and does not have an upper size limit.

Figure 2: *Depressional wetlands (DOWU, DVU) and seep wetlands (SN) in an agricultural setting.*

Lacustrine Wetlands (L):

Lacustrine Wetlands are wetlands with areas of open water equal to or greater than 20 acres (8 ha). Natural lacustrine features are commonly called lakes: i.e., they lack dams or other manmade structures that are responsible for creating the open water areas. Unnatural lacustrine features are impoundments behind dams or other manmade structures and are commonly called reservoirs. Lakes tend to vary less in size within and between years than reservoirs, which tend to expand and contract in area due to water management. Lacustrine features have an average depth of at least 6 ft (2 m) during the dry season. They are always comprised of two parts: the area of open water (OW) that is apparent during the wet season and the area of wetland vegetation (V) that borders the open water area. This vegetated area does not have an upper size limit, it simply must be hydrologically dependent on the open water feature. Any wetland areas of a reservoir are classified as unnatural due to the influence of the unnatural impoundment. Lacustrine wetlands can adjoin other wetlands, such as slope wetlands and riverine wetlands.

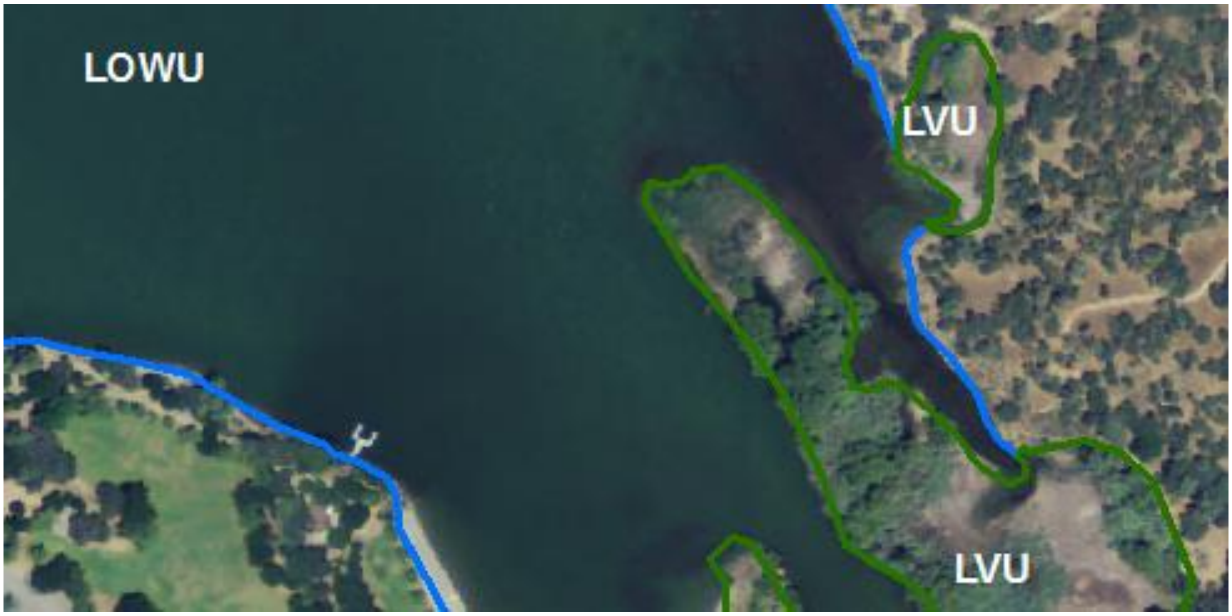


Figure 3: *Example map of lacustrine open water areas (LOWU) and adjoining lacustrine wetlands (LVU) in a reservoir (an unnatural lacustrine feature).*

Seeps and Springs (S):

Seeps and springs are a small type of slope wetland. They form due to seasonal or perennial emergence of groundwater into the root zone, and in some cases onto the ground surface. They form on hillsides, where the contact between an overlying permeable geologic stratum and an underlying impermeable stratum is exposed, or along the base or escarpment of a landslide. They also form along the base of hills, large dunes, or alluvial fans where the water table intercepts the land surface, and can lack well-defined channels. Seeps and springs have no minimum size and can be natural (N) or unnatural (U). Unnatural seeps are usually associated with leaks from manmade impoundments or water storage structures. For example, earthen dams and water tanks often have seeps along their bases.

Forested Slope Wetland (FS):

Forested Slope Wetlands are slope wetlands larger than 0.5 acres (0.2 ha) that form due to a seasonal or perennial emergence of groundwater into the root zone and in some cases onto the ground surface. Forested Slope Wetlands also support more than 30% cover of tall woody vegetation, as evidenced in aerial imagery, or any available vegetation dataset. These wetlands can adjoin non-forested slope wetlands (i.e., wet meadows). Forested Slope Wetlands can also include wetland areas with less than 30% woody cover (i.e., non-forested slope wetlands) that are not larger than 0.5 acres (0.2 ha).

Non-forested Slope Wetlands (i.e. Wet Meadows) (WM):

Non-forested slope wetlands are slope wetlands greater than 0.5 acres (0.2 ha) in size that support less than 30% cover of tall woody shrubs or trees as evidenced in aerial imagery or any available vegetation dataset. They can include areas with greater than 30% cover of tall woody shrubs or trees that are not larger than 0.5 acres (0.2 ha).

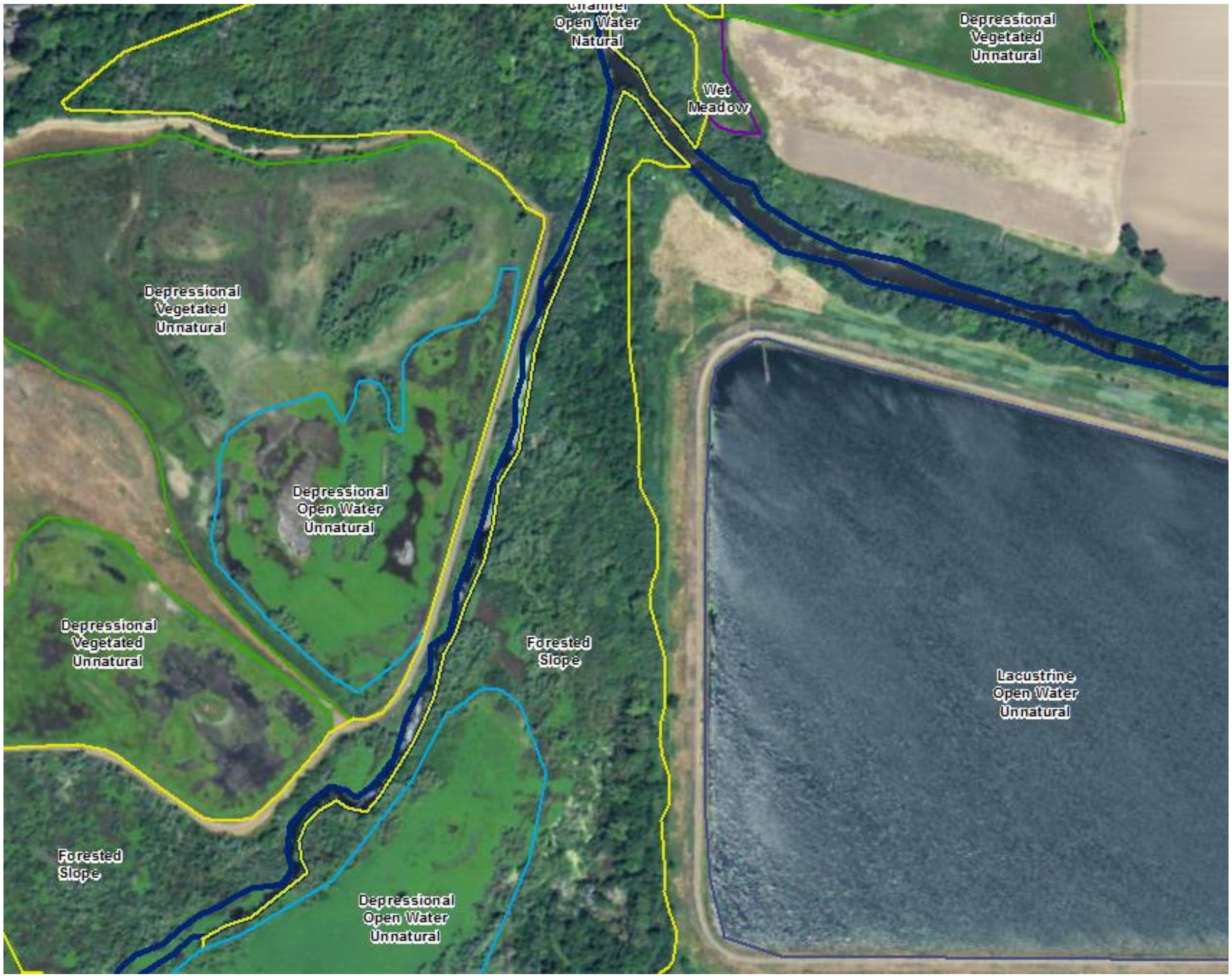


Figure 4: *Example map of unnatural lacustrine wetlands (LOWU), unnatural depression wetlands (DOWU and DVU), forested slope wetlands (FS)*

Vernal Pools (VP):

Vernal pools are a special kind of seasonal depressional wetland having bedrock or an impervious soil horizon close to the surface and supporting a unique vernal pool flora. These depressions fill with rainwater and runoff from small catchment areas during the winter and may remain inundated until spring or early summer, sometimes filling and emptying repeatedly during the wet season. Vernal pools often occur together with vernal swales as vernal pool systems that have many pools of various sizes and shapes, varying floral and faunal composition, and various hydroperiods. Water can move between adjacent pools and swales through the thin soils above the underlying impervious substrate. Individual vernal pools (VP) are mapped at maximum water volume. These features were mapped primarily from the Laguna Foundation 2004 vernal pool dataset. Slight modification according to the 2012 imagery was performed in order to integrate the dataset into NCARI.

Channels:

Channels are a landscape feature with a well-defined bed and opposing banks that conveys water above ground at some point during the year. Channels are further classified as follows. Table 2 provides some general indicators of natural and unnatural channels. These features were mapped primarily from the Laguna Foundation 2002 1k Hydrography. Slight modification and additions according to the 2012 imagery was performed in order to integrate the dataset into NCARI.

C: Channel (C) features are those with mostly natural hydrology and mostly natural form and structure.

CM: Channel Modified (CM) are features that have been clearly straightened or modified but are at relatively the same location as the natural feature would have been. These features connect Natural waters upstream to downstream waters.

CU: Channel Unnatural (CU) features are mostly unnatural form and structure but mostly natural hydrology. These features are visibly unnatural (non-sinuous, visible artificial substrate, no established vegetation).

SD: unnatural sub-surface drainage (SD) channels are those in an unnatural landscape (e.g., urban, suburban, or croplands).

CS: channel segment within a wetland that does not connect to any other channel (excluding artificial paths). Channel Segments (CS) are channels that surface in the middle of a wetland where the groundwater flow is strong enough to cut a channel, but is not connected to an upstream or downstream channel or open water wetland.

AP: artificial pathways (AP) are used to indicate the connection of non-channelized surface flow through an area of open water or wetland. Artificial pathways are not visible in the primary data but are used to connect defined channel segments to ensure connectivity for hydrology modeling, e.g. flow, sediment transport, etc. The AP classification allows these features to be excluded from estimates of channel length. Mapped channels that are obstructed from view in the imagery by dense vegetation should ***not*** be classified as AP. Use the channel (C) classification for these features.

Table 2: *Crosswalk between NCARI and the Cowardin classification system used by the NWI of the USFWS. Grayed out values are not found in the La Laguna de Santa Rosa valley basin. See appendix B for a cross-walk from NCARI/BAARI codes to CARI classification.*

NCARI	NCARI Classification Description	Cowardin, et al. (1979)
BD	Bay Deep	E1UBL(h)
BS	Bay Shallow	E1UBM
GPOWN	Lagoon Perennial Open Water Natural	E1UBL
GPOWU	Lagoon Perennial Open Water Unnatural	E1UBL(x/h)

NCARI	NCARI Classification Description	Cowardin, et al. (1979)
GPVN	Lagoon Perennial Vegetation Natural	E2EM1N
GPVU	Lagoon Perennial Vegetation Unnatural	E2EM1N(x/h)
GPUFN	Lagoon Perennial Unvegetation Flat Natural	E2USN
GPUFU	Lagoon Perennial Unvegetation Flat Unnatural	E2USN (x/h)
GSOWN	Lagoon Seasonal Open Water Natural	E1UBL
GSOWU	Lagoon Seasonal Open Water Unnatural	E1UBL(x/h)
GSVN	Lagoon Seasonal Vegetation Natural	E2EM1N
GSVU	Lagoon Seasonal Vegetation Unnatural	E2EM1N(x/h)
GSUFN	Lagoon Seasonal Unvegetation Flat Natural	E2USN
GSUFU	Lagoon Seasonal Unvegetation Flat Unnatural	E2USN (x/h)
TV	Tidal Vegetation	E2EM/N
TNV	Tidal Nascent Vegetation	E2EM1N(x/h)
TP	Tidal Panne	E2USP
TMF	Tidal Marsh Flat	E2SBN
TBF	Tidal Bay Flat	E2USN(x/h)
DOWN	Depressional Open Water Natural	PUBH/USC*
DOWU	Depressional Open Water Unnatural	PUBH/USC(x/h)*
DVN	Depressional Vegetated Natural	PSS/EM/FO
DVU	Depressional Vegetated Unnatural	PSS/EM/FO(x/h)
SN	Seep or Spring Natural	PSS/EMB
SU	Seep or Spring Unnatural	PSS/EMB
LOWN	Lacustrine Open Water Natural	L1UBIH/L2USC
LOWU	Lacustrine Open Water Unnatural	L1UBH/L2USC(x/h)
LVN	Lacustrine Vegetated Natural	PSS/EM/FO
LVU	Lacustrine Vegetated Unnatural	PSS/EM/FO(x/h)
POWN	Playa Open Water Natural	PUBH1/7
POWU	Playa Open Water Unnatural	PUBH1/7(x/h)
PVN	Playa Vegetated Natural	PSS/EM/FO1/7
PVU	Playa Vegetated Unnatural	PSS/EM/FO1/7 (x/h)
PUN	Playa Unvegetated Flat Natural	PUSC1/7
PUU	Playa Unvegetated Flat Unnatural	PUSC1/7(x/h)
VP	Vernal Pool	PEM1C/Ai
VPC	Vernal Pool Complex	PEM1C/A/Ui
FS	Forested Slope	PSSE

NCARI	NCARI Classification Description	Cowardin, et al. (1979)
WM	Non-Forested Slope (Wet Meadow)	PEMB/E
WMU	Non-Forested Slope (Wet Meadow)	PEMB/E
C	Channel	various**
CU	Unnatural Channel	various**
CM	Modified Channel	various**
SD	Subsurface Drainage	not shown
SS	Channel Segment	*various***
AP	Artificial Path	*not shown*
CUF	Channel Unvegetated Flat (in-channel)	R2USC
CUFU	Channel Unvegetated Flat (in-channel)	R2USC
CV	Channel Vegetated (in-channel)	PEM/SS/FO
CVU	Channel Vegetated (in-channel)	PEM/SS/FO
TC	Tidal Channel	E2SBN
TCU	Tidal Unnatural Channel (natural flow)	E2SBNx

* PUBH and PUBH(x/h) may contain AB. BAARI does not map PAB, though some UB may have algal vegetation.

** Stream order can be used as a proxy for water regime, though with any generalization this might produce errors. Recommendations from NWI are 1st and 2nd order = Temporarily Flooded (A), 3rd and 4th = Seasonally Flooded (C), 5th through 8th = Permanently Flooded (H)

3.2 Scale and Targeted Mapping Unit (TMU)

The NCARI mapping scale and targeted mapping unit (TMU) varies based on general habitat type. TMU is a desired minimum mapping unit but *slight* exception can be made on a case by case basis (within 50m^2 for polygons or 25m for lines). The goal is to maximize the detail of a dataset, capturing small but important wetland areas, such as springs and seeps, while producing a consistent dataset for the region. The consistent determination of the presence or absence of wetland areas depends on making this determination at a standard spatial scale.

Non-tidal wetlands are identified at a tmu scale of 1:5000. However, after a wetland area has been identified and classified, a larger scale view (up to 1:1000) can be used to map the boundary of the area. The targeted mapping area for most non-tidal polygonal features is 0.025 acres (100 sq m). Wet meadows have a targeted mapping area of 0.5 acres (~2,000 sq m). Lacustrine open water has a targeted mapping area of 20 acres (~81,000 sq m). Natural channels (C) have a targeted mapping length of about 160 ft (50m). Unnatural channels (CU and CUF) have a targeted mapping length of about 80 ft (25m). However, any channel that interconnects any two kinds of surface waters has no targeted mapping length.

Table 3: *Summary of tmu and vegetation type*

Group	Wetland Type	Size Limit	Vegetation
Slope Wetlands (Groundwater)			
	Seeps and Springs	>100 m² (0.025 acres) <0.5 Acres	Herbacious and Woody
	Forested Slope	>0.5 Acres	Woody
	Non-Forested Slope (Wet Meadow)	>0.5 Acres	Herbacious
Topographic Depressions (Surface Water)			
	Depressional Open Water	>100 m² (0.025 acres) <20 Acres	None
	Depressional vegetated	>100 m² (0.025 acres)	Herbacious and Woody
	Lacustrine Open Water	>20 Acres	None
	Lacustrine Vegetated	>100 m² (0.025 acres)	Herbacious and Woody

3.3 Projection and Datum

NCARI data was digitized and maintained in into NAD 83 California Teale Albers. To be uploaded into EcoAtlas (www.ecoatlas.org), the data will be re-projected into WGS84 Web Mercator.

3.4 Data Sources

3.4.1 Primary Data

National Agricultural Imagery Program (NAIP)

To establish consistency across the project, the National Agriculture Imagery Program (NAIP) available through the US Department of Agriculture (USDA) serves as the base imagery from which all features are mapped. The NAIP images are natural color and color infra-fed (CIR), 1-m pixel resolution, georectified digital aerial photographs. The choice to use NAIP was based on the spatial coverage, year flown and data availability. NAIP imagery is publicly available without cost from the USDA and covers the entire state of California, which is important to ensure state-wide consistency of these standards. NAIP datasets are flown periodically for California which helps ensure the aquatic resources inventory is current. For more information visit http://www.fsa.usda.gov/FSA/. All wetland areas mapped for WRAMP must be consistent with NAIP imagery. The 2012 NAIP dataset was the primary image dataset used for the NCARI project.

Sonoma County 2011 High Resolution Imagery

This high resolution digital aerial photography dataset was acquired in Spring 2011. The imagery is 4-band (near infrared, red, green and blue), with 6 inch spatial resolution for most of the county and 3-inch resolution in areas of Santa Rosa and Windsor. The image acquisition was funded through a collaboration between USGS, the County of Sonoma, the Sonoma County Water Agency, the Agricultural Preservation and Open Space District, the Town of Windsor, the City of Petaluma, and the City of Santa Rosa. This dataset was used selectively only on features that were questionable in all NAIP image years and further detail was necessary.

Laguna Foundation 1k Hydrography

The protocol for the development of the Laguna Foundation 1k Hydrography dataset was multi-step: 1) using the 2002 aerial photogrammetry of Sonoma County within ArcGIS, the route of all visible waterways and water bodies was traced using a 1:1,000 scale, 2) using the National Elevation Dataset and its byproducts (100ft, 50ft, 20ft, 10ft, 5ft, 2ft, and 1ft contours), obscured waterways were traced at a 1:1,000 scale; 3) layered examination of georeferenced USGS topographic quadrangles was performed to double check the work for completeness (but not for accuracy) and to add feature names; 4) layered examination of soils and surficial geology was undertaken to spot-check ambiguous areas; 5) field reconnaissance was conducted using a hand-held GPS unit to verify the position of stream crossings at roadways. Note that the National Elevation Dataset, which strives for 7-meter positional accuracy, was adjusted on the fly and heavier reliance was place on the aerial photography. We believe this 1K Hydrography dataset to be an accurate depiction of the creeks, channels and ponds of the watershed as it looked in 2005 to a positional accuracy of 10 feet.

This was the base dataset for the NCARI streams layer. These channels were integrated into the dataset by adding attribution and flow direction. Additional channels and connections were also added when necessary.

Laguna Foundation Vernal Pools

The Llano and Piner regions are home to a concentrated collection of vernal pools. The locations of these have been carefully mapped by the California Dept. of Fish and Game as part of the work to create a California Tiger Salamander (CTS) Conservation Strategy for the Santa Rosa Plain. Creation of this dataset entailed the use and interpretation of georeferenced color aerial photographs taken in 2004, analysis of CTS occurrences documented within the California Natural Diversity Database, and consultation with knowledgeable professionals. The dataset consist of 1225 features categorized into possible and verified CTS sites. This is a credible and well documented dataset. For more information contact the Wildlife and Habitat Data Analysis Branch at CDFG http://www.dfg.ca.gov/.

These vernal pools were only added where the vernal pools were evident in the 2011 or 2012 image year. Vernal pools were not added where the landuse/landcover changed since 2004 resulting in loss of possible vernal pools. This dataset was minimally modified and comprises the majority of the mapped vernal pools for this dataset. Additional QAQC was not performed on these features.

3.4.2 Ancillary Data

Ancillary data are used where identification of aquatic resources is inadequate using the primary data alone. In general, ancillary data are used to better understand topography, the effects of NAIP vintage on the visibility of aquatic resources in NAIP imagery, and to help detect subsurface drainage. The following specified ancillary data has been used for NCARI. Additional local data can be included as needed.

ArcHydro

ArcHydro is an automated stream network generated from a DEM using GIS. Elevation, flow accumulation, and flow direction determine the initiation and location of a channel or channel network. The ArcHydro channel network was primarily used as a guide to determine the likely locations of first-order (headward) channels.

ArcHydro was performed on the Hydrologically Enforced LiDAR DEM. This DEM was corrected by Watershed Sciences by enforcing flow through waterbodies and culverts. Estimation of the initiation (point of origin) of each likely first-order channel was based on a 10,000 cell accumulation or 2,500 square meter uppermost area of the channel's catchment basin. This size basin was used because it captured the majority of first-order channels evident from visual inspection of the LiDAR hillshade, without abundant over-mapping of channels (automated invention of channels not evident in the primary or ancillary data). The use of ArcHydro is discussed further in the section below on the use of LiDAR to map channels.

Watershed Boundary

The watershed extent (project boundary) was created from the Mark West Creek HUC 10 watershed unit from the Watershed Boundary Dataset. This watershed was divided along the valley/foothill boundary using a slope dataset derived from the USGS 10 meter Digital Elevation Model. The boundary was defined using a 12% slope threshold to separate the valley floor from the foothills along the eastern portion of the watershed.

National Wetlands Inventory (NWI)

NWI is produced by the US Fish and Wildlife Service (USFWS). These data vary markedly in accuracy, in terms of omissions, boundaries, and misclassifications. The NWI data should only be used as a preliminary indication of the likely existence, location, and classification of major areas of aquatic resources.

Existing Vegetation Data (CALVEG)

Visible Ecological Groupings (CALVEG) comprise the only regional set of vegetation data for NCARI and are derived from recently completed interpretation of 2005 1:24,000 scale LANDSAT imagery. The 2005 data are an update of the vintage 2000, 1:100,000 scale version originally done for the U.S. National Forest Service administrative areas within the Basin, including private land inholdings. These data are mainly used in NCARI to help identify wet meadows and forested slopes.

Digital Raster Graphic (DRG)

The DRG is a scanned image of the 1:24,000 scale Topographic Quadrangle (7.5 minute quadrangle or “quad sheet”) provided by the U.S. Geological Survey (USGS). These data are used to help view major roads and buildings, as well as topography and major water bodies, including large channels. The contour lines provided with the DRG can be helpful for visualizing topography and estimating the flow directions of channels and channel networks.

Google Earth and Google Earth Pro

Google Earth (free) and Google Earth Pro (requires license fee) are publically accessible, online GIS tools. Google Earth provides access to high-resolution aerial imagery and topography, as well as local ground-based photography and local place names. Google Earth Pro provides non-georectified downloads of this same aerial imagery. Google Earth imagery is digitized in areas where it shows major landscape changes, such as large developments, fires, etc., that are more recent than the primary vintage imagery data or other ancillary data. In these circumstances, the high-resolution imagery for the recently altered area is downloaded from Google Earth Pro and georeferenced in ArcGIS to meet the standards of the primary data sources.

Other Local Data

Local data can be used to spot-check areas for classification. However, pre-existing maps and classifications of aquatic resources using these data apart from this NCARI SOP should not be assumed to be correct. Local maps of aquatic resources often reflect particular objectives and methodologies that are not entirely inconsistent with NCARI. Examples of local data that have been used to produce the current version of NCARI include maps of stormdrains and road culverts provided by Caltrans, and maps of wet meadows and other slope wetlands provided by local cities and counties within the Basin.

3.4.3 Data Source Field

The “SourceData” field describes which source dataset or datasets were used to identify and map each wetland area. Certain areas are digitized with a heavy reliance on ancillary datasets, including in some cases relatively older imagery. Local and regional experts can also be used to help identify and classify wetland areas that are otherwise very difficult to include. Such areas are annotated with the code “Local_Review.” The “Organization” field is used to attribute the person or agency that provided the local review.

4.0 Mapping Procedures

The following text describes the CARI (and NCARI) mapping procedure in five basic steps. All mapping must follow this proscribed stepwise procedure.

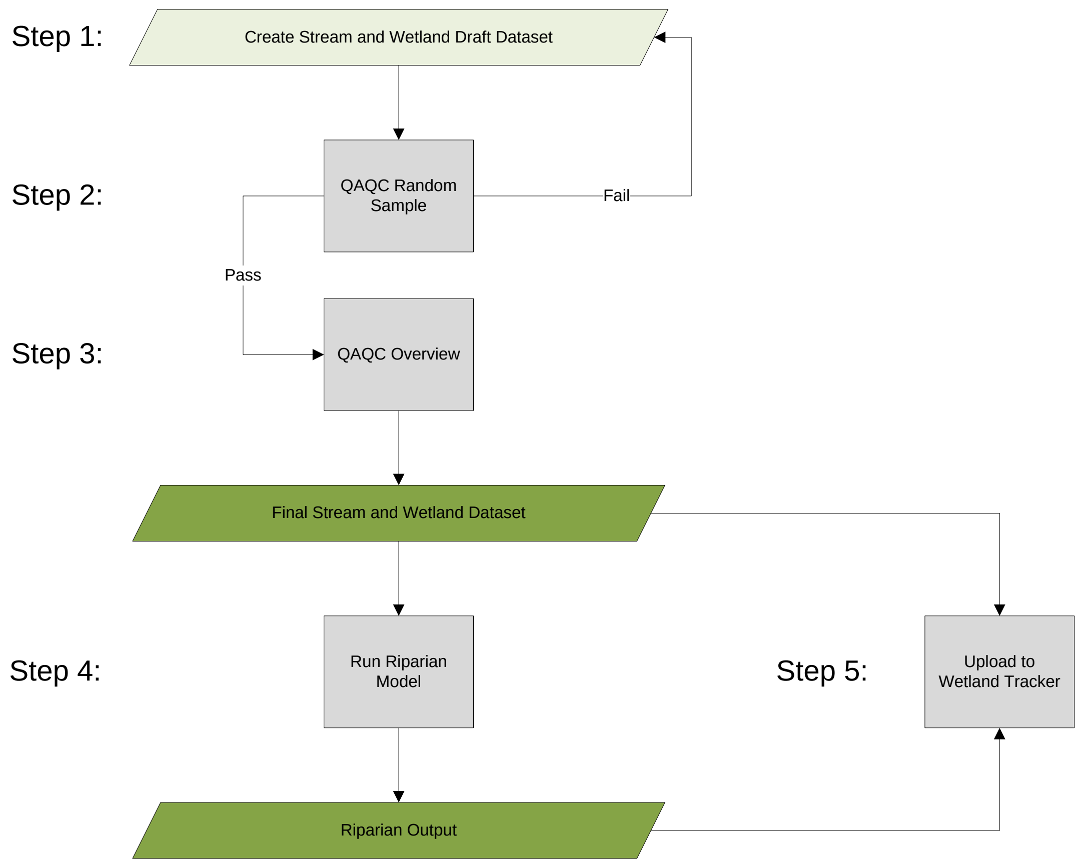


Figure 5: *Five basic steps of the CARI mapping procedure*

4.1 Channel Mapping

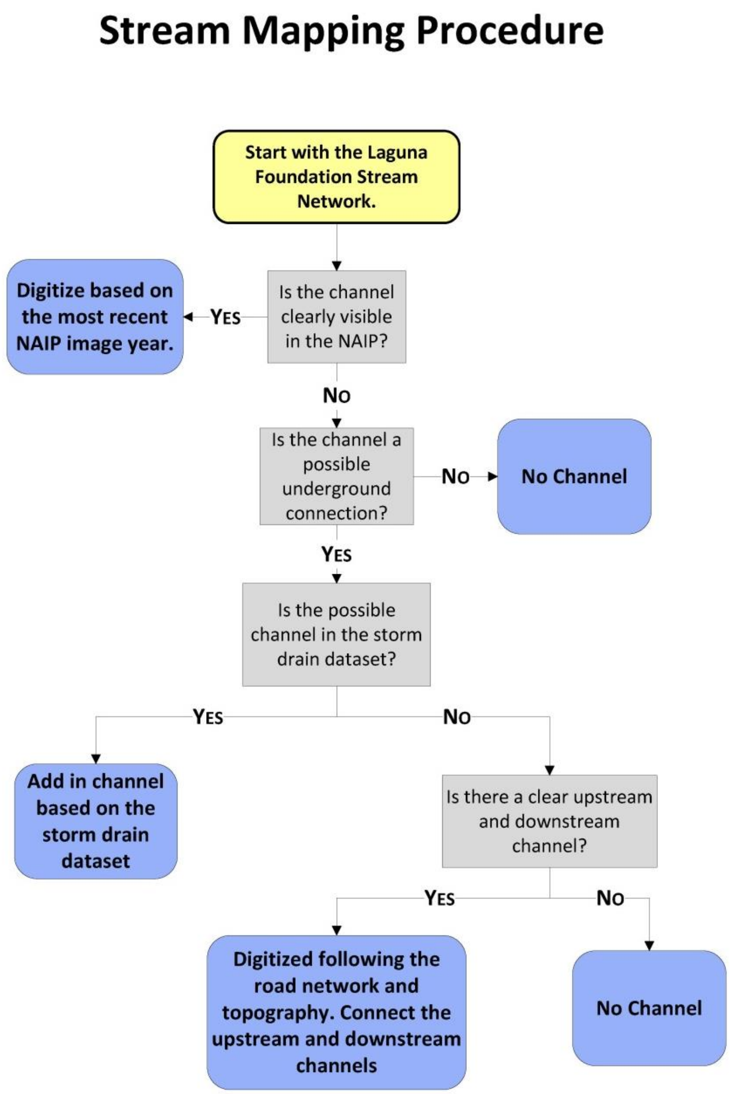


Figure 6: *Channel mapping decision tree*

4.1.1 General considerations for mapping channels

- Do not rely solely on the ArcHydro or the hillshade dataset when identifying and mapping channels. Channel mapping requires full use of all primary and ancillary data. In low slope areas imagery is especially important
- Digitize channels from upstream to downstream. Always use "Snapping" to connect segments, particularly the "End" option.
- If channel is clearly visible, but appears to fade and fail to connect to another channel, wetland, or other waterbody, the artificial connection should be digitized as an artificial path (AP).

- Use Google Earth in cases where updated imagery is available for viewing, especially in areas subject to recent change, but use it only for reference. Attribute [Source_Imagery] field as “GEyyyy” (Google Earth and imagery year).
- Channels should be digitized as polygons when both banks are visible and the channel width (from bank to bank) is larger than 5m.
- The boundary where a channel ends and another water body (such as a lake or depressional wetland body begins is mapped where the channel begins to flare or widen thereby transitioning to the other water body. This can be indicated by a change in vegetation.

4.1.2 Landscape specific considerations for mapping channels

In the upper-most areas of watersheds

1. Using ArcHydro, compare channels to the primary imagery.
    a. If a channel can be identified in the Imagery, digitize based on the most recent image year and classify.
    b. If there is no evidence of a channel in the imagery, consult ancillary sources. For low slope areas ArcHydro flowline should not be used as a primary source.
2. Using the DRG, interpret the contour lines to determine whether or not a channel is likely to form, based on lateral hillsope, catchment size, longitudinal slope, etc.
    a. If topography indicates a channel would likely form, digitize using the DRG and classify.
    b. If there is no evidence in the DRG or NED of a channel, do not digitize.

In urban landscapes

1. Using ArcHydro, compare channels to the primary imagery.
    a. If a channel can be identified in the Imagery, digitize based on the most recent image year and classify.
    b. If there is no evidence of a channel (e.g., due to urbanization) in the imagery, consult the stormdrain ancillary dataset, if available.
2. In the stormdrain dataset, check to see if the data identifies a subsurface drain.
    a. If there is evidence of a subsurface drain, digitize the segment based on the ancillary data and classify.
    b. If there is no evidence of a subsurface drain in the stormdrain dataset (or if there is no available stormdrain dataset), and there is a third-order or higher-order channel entering the area, then digitize a draft stormdrain of shortest length feasible based on the street grid to connect to the nearest clearly evident downstream channel, and classify.

c. If there is no third-order or higher-order channel entering the urban area in question, and there is no evidence of a subsurface drain in the ancillary dataset, do not digitize a channel of any kind, including a temporary storm drain.

Slope Wetlands

Slope Criteria	Explanation
Clearly saturated soil	Soils exhibit a saturated a deep red color in soil or a bright red coloration for vegetation in the CIR; Avoid irrigated/watered landscapes (agriculture, lawns)
Hydrologic Context	Near a channel or open water body. Unnatural slopes will occur down gradient of unnatural features (stock ponds, roads, dams, etc)
Topographic context	in a valley or concave slope area, or where a steeper slope flattens out
Elevation	Elevation between the 60 and 70 foot contour is also a likely wetland zone for the Laguna. Everything where the elevation is less than 60 feet should be assumed to be a wetland unless there is contrary evidence.
Ancillary dataset	Seeps and springs can be found on the USGS topoquads, NWI, or NHD. Presence in these ancillary datasets automatically classifies the wetland as a maybe or a high.

Table 4: Slope Identification Criteria

Certainty Level	Criteria
High "Definte"	3 or more Criteria identifiable in NAIP 2012, and Clearly saturated in two or more other image year.
Medium "Probable"	2 or more Criteria identifiable in NAIP 2012, and Clearly saturated in more than one image year.
Low "Possible"	2 Criteria identifiable in NAIP 2012, and Clearly saturated in one image year

Table 5: Certainty levels (Used to identify areas of uncertainty for increase review and validation)

Braided channels

1. If channel is braided, all prominent sub-channels at least 25m long should be digitized.

Wide channels

1. If a channel's banks are apparent in the imagery, digitize the stream from bank to bank as a polygon in the wetland layer and attribute with appropriate channel classification.

Channel Segments and Artificial Paths

1. During the polygon mapping, it is important to update the line-work for hydrological connectivity. This is essential for consistency with NHD, and for NCARI to adequately support landscape-level hydrological modeling.
2. If the channel does in the primary imagery, then this portion of the line-work could be attributed as an artificial path (AP).
3. The channel segments that are clearly evident in the LiDAR and imagery, but are not connected to any other waterbody or subterranean pathway should be classified as a stream segment (SS).

4.2 Wetland Mapping

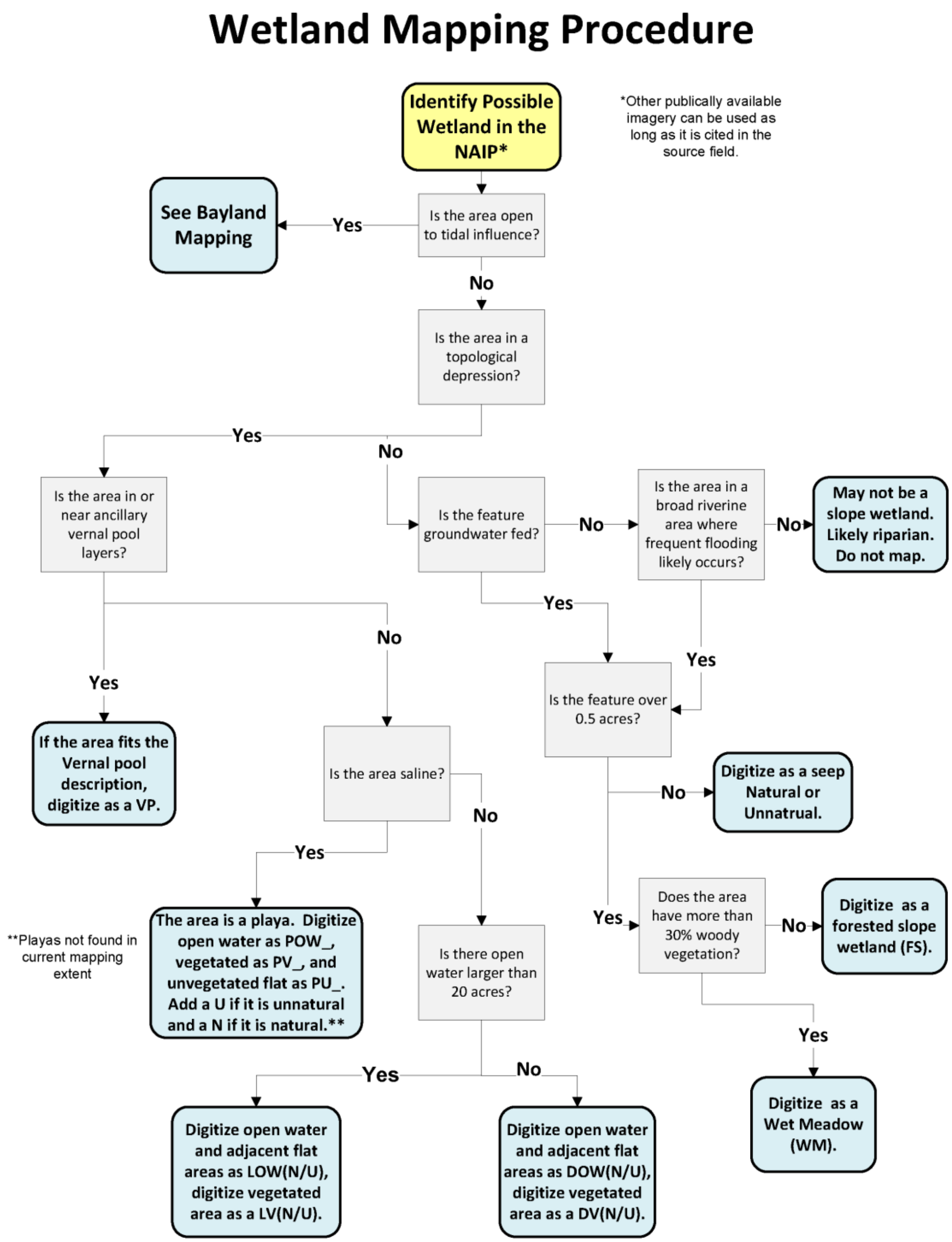


Figure 7: *Wetland mapping decision tree*

4.2.1 General considerations for mapping wetlands

- Using the wetland mapping procedure (Figure 11 and 12), cleanly digitize wetland areas without any unnecessary vertices (i.e. small spikes, overlapping areas, etc.). When creating new wetland areas adjacent to existing ones, always use “Auto-complete Polygon” and “Snapping” to avoid topology errors, such as slivers or gaps between areas.
- Ensure that there are no overlapping polygons when mapping. Use the editor clip tool to remove overlapping areas when digitizing an open water area in the center of a vegetated wetland.
- Overlay the channel layer on the imagery while digitizing wetland areas; the channel layer will provide flow direction and other indicators or clues about the locations of wetland areas.
- Use Google Earth in cases where updated imagery is available for viewing, especially in areas subject to recent change, but only for reference. Attribute [Source_Imagery] field as “GE”, along with the year of the image.

4.2.2 Specific considerations for wetland types

Depressional and Lacustrine

- Natural depressional wetlands occupy topographic depressions – low areas where rainwater and surface runoff collect, and into which groundwater can rise. Look for natural depressional wetlands in the lowermost areas of valleys large and small, on broad floodplains, on saddles along broad ridge tops, between small hills, and behind beaches and dunes along lake shores.
- Unnatural depressional wetlands are common as stock ponds and irrigation ponds behind small dams and levees. Any man-made pond that is too small to be a lacustrine wetland should be classified as a depressional unnatural wetland.
- Depressional wetlands tend to have indeterminate boundaries where the vegetated area of the wetland appears to blend with the upland vegetation. The boundary can be very difficult to map. To map the upland boundary of the vegetated wetland area, first focus on an interior region of the area. This area is usually darkest green in color in NAIP natural color imagery, or deepest red in color infrared (CIR) imagery. Then look progressively landward until, based on the primary imagery and all ancillary data, the weight of evidence suggests the location of ordinary high waterline (OHW).
- Floating or submerged aquatic vegetation in pond and lakes should be labeled and merged with the corresponding “Open Water” (OW) polygon.
- Unnatural depressional and lacustrine wetlands may not be filled to capacity at the time of the imagery. In these cases, digitize the boundary of the open water feature as it would appear when the depression or lake is full.
- Mapping the landward (upland) boundary between the vegetated areas for either large depressional or lacustrine wetlands and adjoining slope wetlands can be very difficult.

The general approach is to determine the likely ordinary high waterline (OHW) of the depressional wetland or lacustrine feature, and to assume that the boundary generally corresponds to the OHW. The OHW can be estimated based on the change in color signature or texture of the vegetation as evidenced in the primary imagery or LiDAR, as well as the elevation contours from the DRG and the topographic detail evident in the LiDAR-based DEM. Local expertise can be very helpful to identify the boundary line. Questions to answer while identifying this boundary include:

— What is the direction and pattern of surface runoff into the depressional or lacustrine wetland?

— Is there a clear topographic boundary for the depression (this boundary can be used as surrogate for the wetland boundary)?

— Based on vegetation color or texture, is there an obvious area of saturated land upslope from the apparent OHW (this would likely be an area of slope wetland)?

- Based on the answers to these questions, map the area primarily using the imagery, elevation contours, and LiDAR as guides.

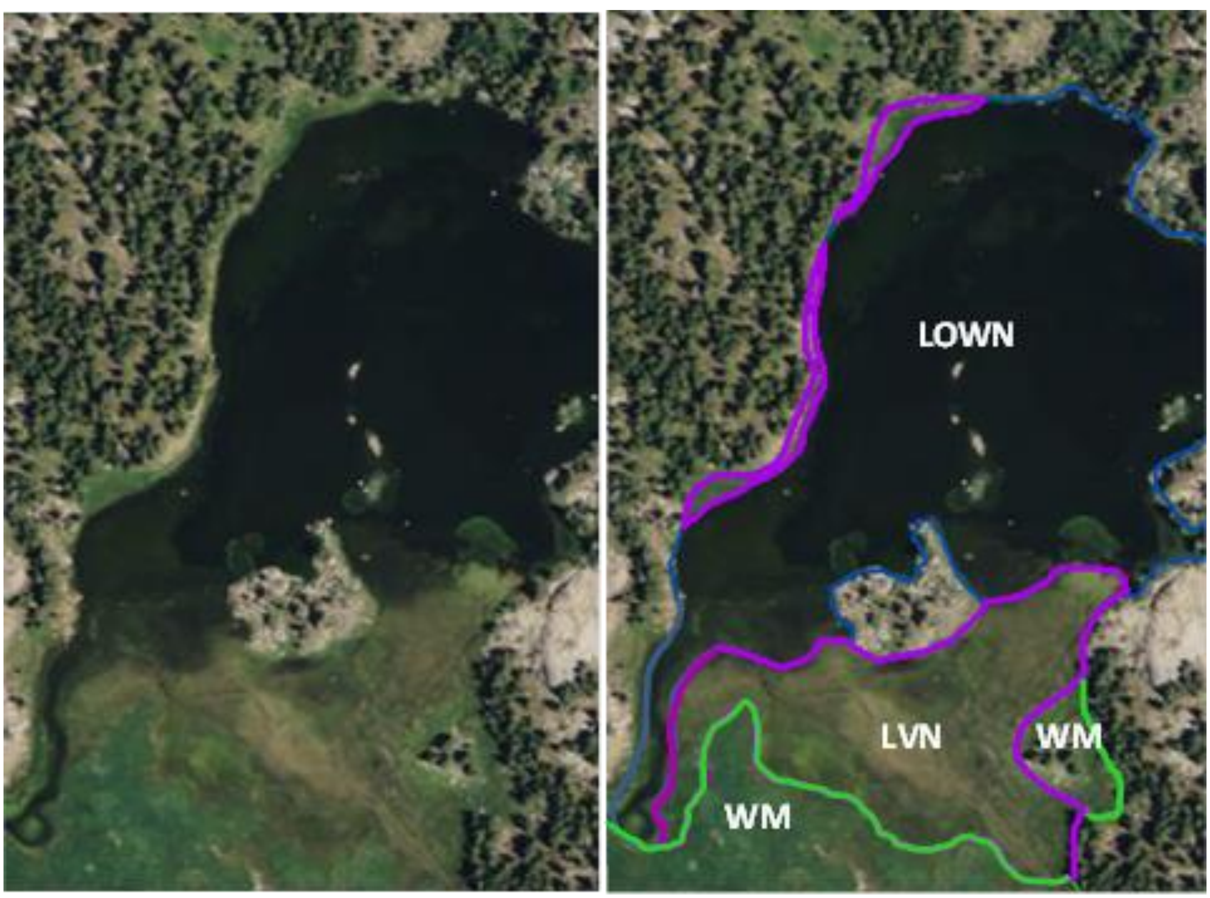


Figure 8: *Example map of the relatively distinct boundary between the open water area of a natural lacustrine wetland (LOWN) and its vegetated area (LVN), and the much more subtle boundary between the vegetated area of the lacustrine wetlands (LVN) and the adjoin wet meadow (WM).*

Seeps and Springs

- Seeps and springs (SN, SU) tend to occur uphill from where natural channels originate, on slopes where groundwater encounters an impervious geologic stratum, or at the base of slopes where groundwater emerges into the root zone of vegetation. Always look for slope wetlands immediately above the upstream end of first-order channels (headwaters), and immediately above or below landslides on grassy hillsides. Check the darker brown and black areas in the natural color NAIP imagery; they are often areas saturated with groundwater.

Forested Slopes/Wet Meadow

- The easiest way to identify forested wetland areas is to look for the brighter green trees in the natural color NAIP imagery (bright red in CIR imagery), where the topography would indicate a wetland might exist. Wetland trees are usually broad-leaf species, such as alders and willows, which are lighter green in natural color and brighter red in CIR imagery. Trees in non-wetland areas of the Basin are usually coniferous, which appear darker green and (or less bright red in CIR imagery).
- The highest-hit LiDAR hillshade, if available, can be very helpful. If LiDAR is not available . The wetland forests typically have a softer more rounded texture. The riparian vegetation is lighter in color when compared to the coniferous forest because the coniferous trees are usually taller and narrower which casts more (simulated) shadow in the hillshade.
- The boundary of a forested slope or wet meadow wetland can be difficult to determine, especially if, instead of an abrupt change in the tree cover, there is a more gradual transition. To standardize mapping the extent of non-forested slope wetlands, the boundary is defined when the tree cover when viewed from aerial imagery is becomes greater than 30%. This should be evaluated at 20 meter intervals.

Laguna Foundation Vernal Pool Integration

The laguna foundation vernal pools were selectively added to the NCARI dataset based on a simple set of rules: If the based on the 2009 – 2012 NAIP imagery years.

4.3 General Review and Post-processing

4.3.1 Review of channels and channel networks

1. Visually inspect the stream network of the entire QAQC unity at 1:5,000 using the primary data and ancillary data as necessary. This is a general overview used to correct any major errors that are observed.
    - Make sure the flow direction is in the correct direction. It helps to symbolize the flow direction by drawing the lines with arrows at the end of each segment.

- With an understanding of flow direction, look for mapped channels that erroneously cross ridges or otherwise indicate uphill flow.

2. Make sure all channel lines are coded, and that they are coded correctly.
3. Dissolve linework by type and source (and any other attribute field you wish to keep). Then explode multipart features and “planarize” the lines.
4. Edge-match features that cross adjacent quad sheets (or other QAQC units) by snapping lines to endpoint. Then merge the lines if they are the same type, and split line segments at ends.
5. Calculate Strahler stream order (i.e., channel order) using RivEx or a similar program.
6. Check the channel order and make sure that it was calculated correctly. Channel order should increase downstream (i.e., as flow passes through confluences). Within any given channel network, if channel order decreases in the downstream direction, then some upstream channel lines were either not snapped together or have been attributed with incorrect flow direction. Correct any errors in channel geometry or attributes.

4.3.2 Review of wetlands

1. Visually inspect the mapped wetlands of the entire QAQC unity at 1:5,000 using the primary data and ancillary data as necessary. This is a general overview used to correct any major errors that are observed.
2. Look for identification errors, such as tree shadows mistaken for open water of depressional wetlands, and dark areas of soil or non-wetland vegetation mistaken for slope wetlands. The vegetated areas of lacustrine and depressional wetlands are easily overlooked. Be sure such areas are digitized and correctly attributed.
3. Make sure all wetland polygons are coded, and that the codes are correct.
4. Dissolve polygons by type and source (and any other attribute field you wish to keep) and explode multipart features.
5. Merge adjacent quad sheets (or other QAQC units) by merging polygons of the same type, and make sure no small spikes or overlapping areas exist.

4.4 Quality Assurance and Quality Control (QAQC)

QAQC is essential to assess and document the accuracy of NCARI. A random sampling approach to QAQC is recommended. This effort utilized existing Level-2 field work to perform field validation. The Level-2 California Rapid Assessment Method (CRAM) stream and wetland assessments in the Santa Rosa Plain employed a probabilistic sampling design, following the Generalized Random-Tesselation Stratified (GRTS) approach developed by the USEPA for the National Environmental Monitoring and Assessment Program.[5] In this approach, CRAM

[5] http://www.epa.gov/nheerl/arm/designing/design_intro.htm

assessment sites (termed Assessment Areas or AAs in the CRAM manual), are randomly selected from the study area, while accounting for the total proportion of the resource dataset.

Draft wetland maps illustrating the mapped wetland locations were added to the CRAM field packets (Figure 9). These maps were then verified during CRAM evaluations. Areas where the wetland presence or absence was uncertain or the field team was not able to be visually or physically verify were not used in the validation process. Vernal Pools were not validated as part of this process since they were not included in CRAM analysis and were not mapped prior to CRAM fieldwork.

The field team checked for over-mapping, under-mapping, and coding. Over-mapping measures the degree to which the draft wetland data include more polygons or area than what was seen in the field. The under-mapping parameter measures the amount of area not mapped. The coding parameter measures the accuracy of the classification of wetlands and aquatic systems. Coding is only compared in areas where both the QAQC standard data and draft data have overlapping polygons. These parameters were mapped and quantified in ArcGIS (Figure 10).

Figure 9: Field validation sheet

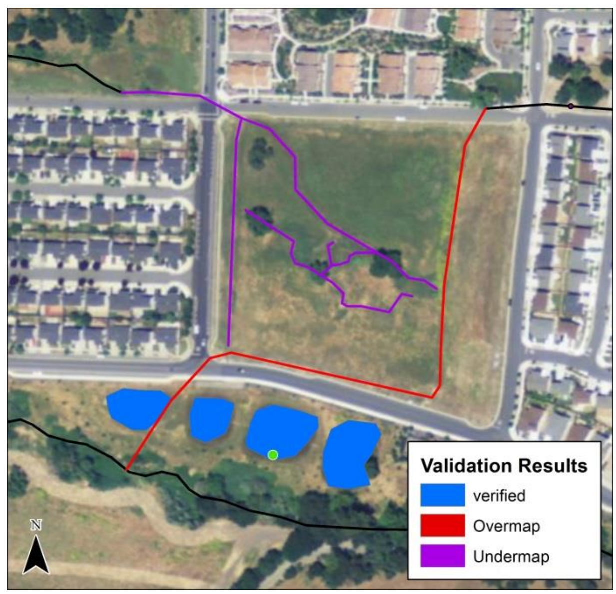


Figure 10: Resulting QAQC

A total of 48 sites were visited resulting in the field check 88 wetlands polygons totaling 381 acres of wetland (13%) and 86 channel segments totaling 29 km of streams (4%). This resulted in an accuracy score of **91.4%** and **89.4%** for wetland polygons and linear channels respectively.

Wetlands	Acres	Percent
Valid	348.61	91.4%
Attribution Error	5.20	1.4%
Over-map	18.37	4.8%
Under-map	9.08	2.4%

Streams	Kilometers	Percent
Valid	26.05	89.4%
Attribution Error	0	0%
Over-map	2.02	6.9%
Under-map	1.08	3.7%

Table 6: QAQC results for wetlands (left) and Streams (right)

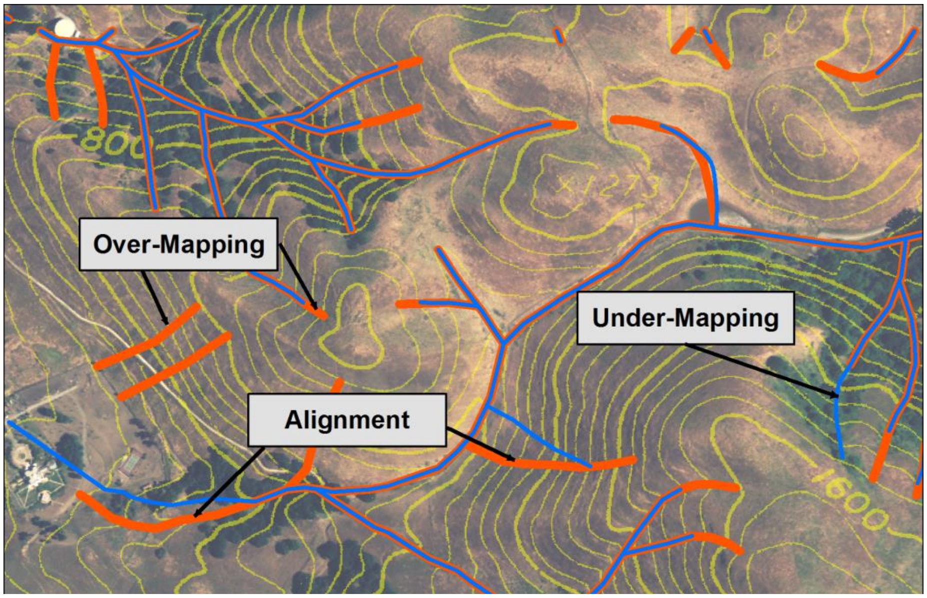


Figure 11: Line mapping error types

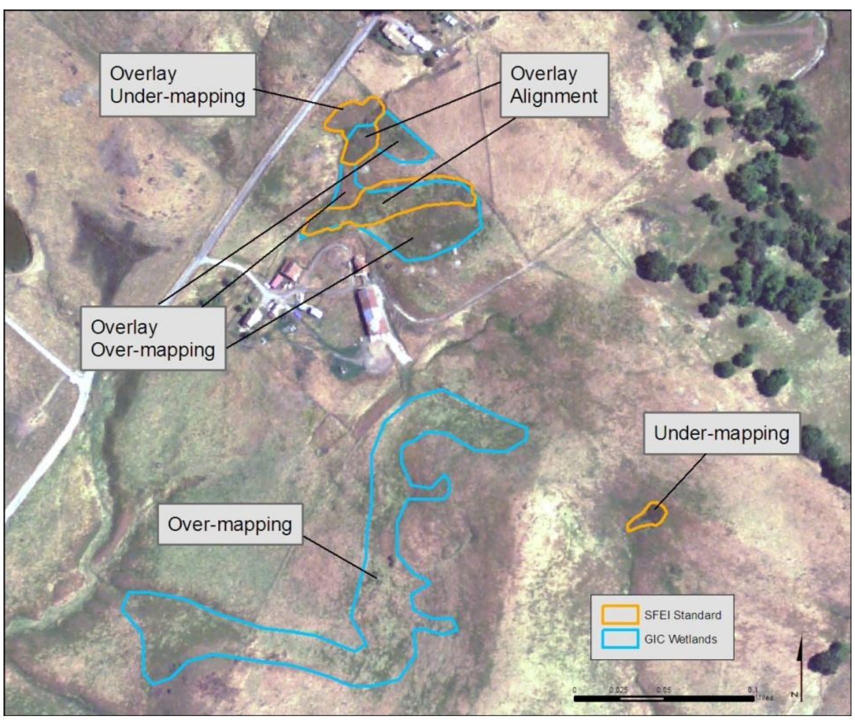


Figure 12: Example polygon mapping errors, showing overlay alignment, overlay over-mapping, overlay under-mapping, over-mapping, and under-mapping (coding parameter is not represented). Not all visible wetlands were mapped for this example.

4.6 Riparian Model

The National Resource Council (NRC) defines riparian areas as "areas through which surface and subsurface hydrology connect… and significantly influence exchanges of energy and matter." The WRAMP riparian model is a cost-effective way to map riparian extent based on this definition. The model is modular; each module generates a map of riparian areas pertaining to a particular set of riparian functions. At this time, the riparian model is formulated to represent the following functions.

The riparian model runs in ArcGIS version 9.3x using a Visual Basic for Applications (VBA) script using ArcObjects and standard ESRI geoprocessing tools, and is embedded in a map document (mxd). The model uses NCARI output data (i.e., the NCARI data for channels and wetlands), a DEM, and a vegetation layer as input data. The preferred vegetation data are produced through the Vegetation Classification and Mapping Program (VegCAMP), managed by the CA Department of Fish and Game (http://www.dfg.ca.gov/biogeodata/vegcamp/). In the absence of VegCAMP data, the vegetation data provided as CalVeg 2005 produced jointly by the by the US Forest Service and CA Fire and Resource Assessment Program (FRAP) can be very useful (http://www.fs.fed.us/r5/rsl/projects/mapping/accuracy.shtml). However, any suitable data layer for plant cover by species or plant community can be used. The vegetation data input must have fields for vegetation type, tree height and standard buffer distance (SBD). "Tree height" is the height of plants with average heights greater than 6 meters. "SBD" is the height of plants below an average height of 6 meters. Therefore, plants with "tree height" values will have "SBD" values of 0, and vice versa. For a more explanation of the riparian model, see the Riparian Model User Guide (http://www.sfei.org/sites/default/files/UserGuide_12202010.pdf).

The riparian mapping does not provide any information about the relative importance or influence of various riparian functions. it is not intended to replace on-the-ground empirical observation of riparian extent or condition. It is instead intended to display the greatest likely extent of riparian areas for selected riparian functions based on qualified input data.

4.5.1 Vegetation module

This module estimates the approximate extent of riparian functions depending on vegetation, including especially bank stability and allochthonous input (i.e., inputs of leaf litter, large woody debris, leaf litter, etc).

4.5.3 Hillslope module

This module is intended to extend the riparian zone into mass wasting processes, such as landsliding, dry raveling, and debris flowing, that can deliver sediment and other materials into wetlands and channels.

4.6 Upload to Wetland Tracker

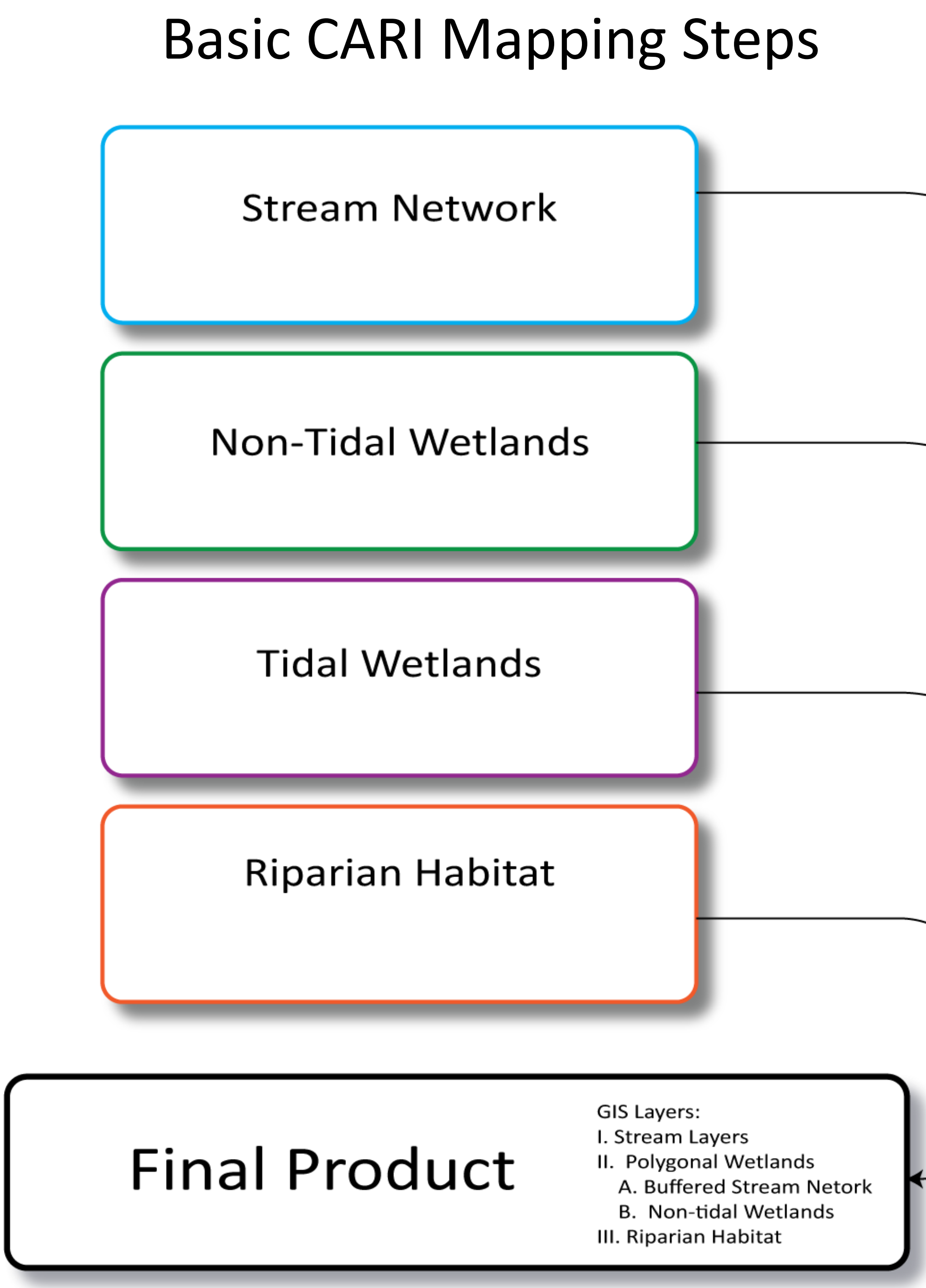
The NCARI data that pass the 4 above steps in the QAQC procedure are uploaded to the EcoAtlas information delivery system (http://www.californiawetlands.net/tracker/ba/map). The

EcoAtlas website provides public and secured access to WRAMP data, including CARI and its regional versions, such as NCARI. To upload NCARI into EcoAtlas, it must be processed as follows.

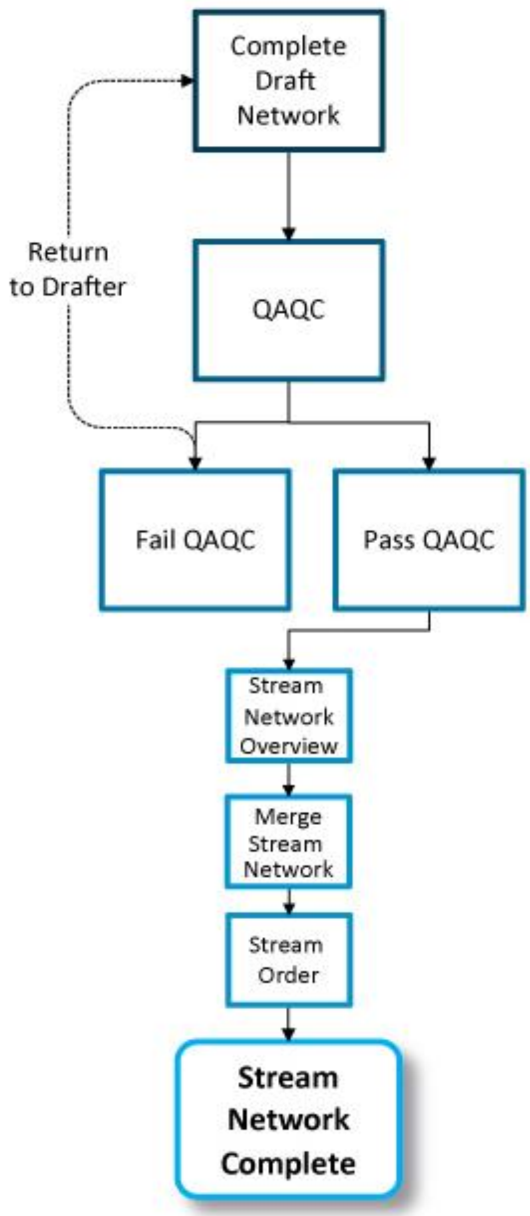
Four fields need to be added to the NCARI datasets: “ClickCode,” “ClickLabel,” “LegLabel,” and “LegCode.” The “ClickCode” is identical to “WetlandType.” The “ClickLabel” is a long text description of the classification code (e.g. “DOWU” = “Depressional Open Water Unnatural,” “C” = natural channel,” etc). The “LegLabel” is the code that appears in the EcoAtlas legend. The “LegCode” is the code version of the “LegLabel.” These are conflated codes based on “WetlandType,” and are generalized from 47 to 18 categories. This allows for a much simpler legend in the EcoAtlas, while retaining the full classifications when a user downloads NCARI data. The “LegLabel” and “LegCode” are then associated with specific RGB color values, which are used to symbolize the wetlands, channels, and riparian areas in EcoAtlas (see Appendix A).

Appendix A

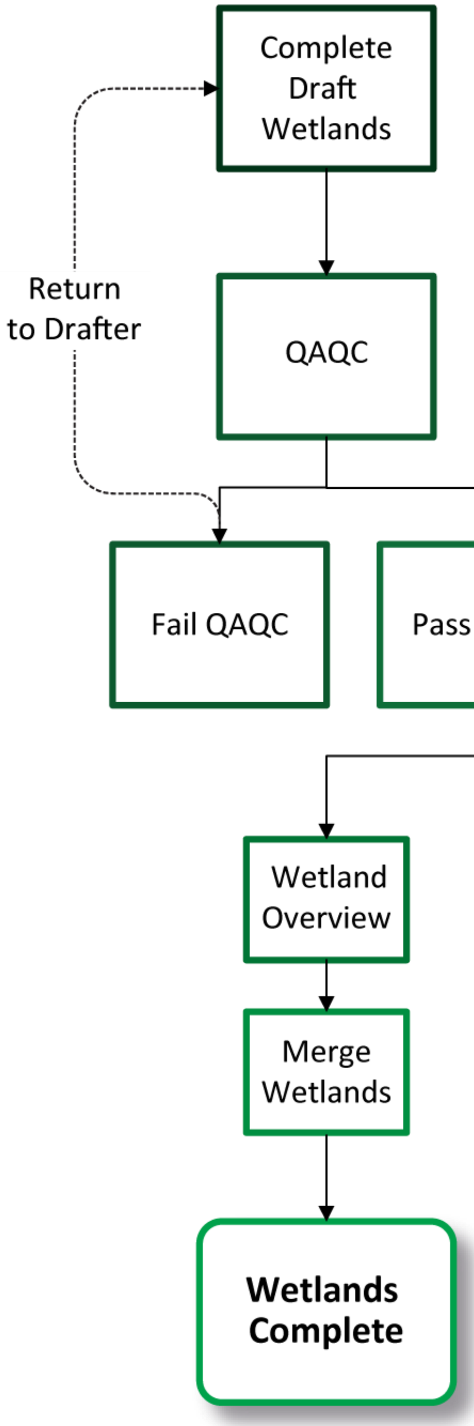
Basic level 1 Workflow Charts



Channel Mapping Steps



Wetland Mapping Steps



Appendix B

Table 7. Regional NCARI Classification to CARCS crosswalk and CRAM Module

NCARI Codes	California Aquatic Resource Classification System [CARCS]		California Rapid Assessment Method for Wetlands [CRAM] Classification	
	Major Class	**Class**	**CRAM Module**	**CRAM Sub-module**
DOWN	Open Water	Depression	Depression	unknown
DOWU	Open Water	Depression	Depression	unknown
DVN	Wetland	Depression	Depression	unknown
DVU	Wetland	Depression	Depression	unknown
SN	Wetland	Slope	Slope	Wet Meadow
SU	Wetland	Slope	Slope	Wet Meadow
LOWN	Open Water	Lacustrine	Lacustrine	n/a
LOWU	Open Water	Lacustrine	Lacustrine	n/a
LVN	Wetland	Lacustrine	Lacustrine	n/a
LVU	Wetland	Lacustrine	Lacustrine	n/a
FS	Wetland	Slope	Slope	Forested Slope
WM	Wetland	Slope	Slope	Wet Meadow
C	Wetland	Riverine	Riverine	unknown
SS	Wetland	Riverine	Riverine	unknown
CU	Wetland	Riverine	Riverine	unknown
CM	Wetland	Riverine	Riverine	unknown
AP	Wetland	Riverine	None	unknown
CUF	Wetland	Riverine	Riverine	unknown
CV	Wetland	Riverine	Riverine	unknown