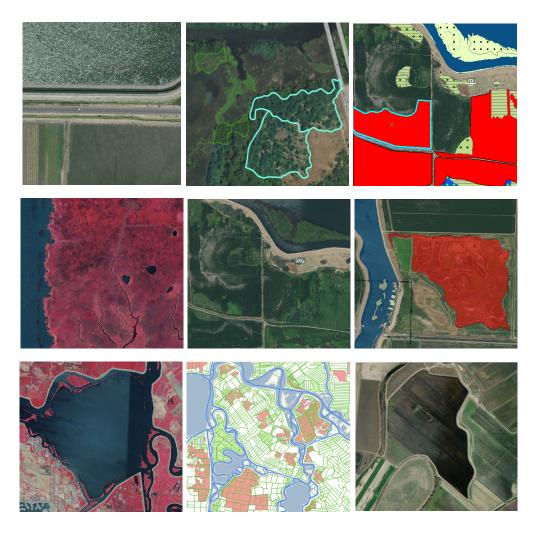
Delta Aquatic Resources Inventory (DARI)



MAPPING METHODS AND STANDARDS FOR CHANNELS, WETLANDS, AND RIPARIAN AREAS IN THE SACRAMENTO – SAN JOAQUIN RIVER DELTA

Prepared by SFEI for
U.S. EPA 2017 Wetlands Program Development Grant
Award # CD99T55501 - SFEI Contribution No. 1147
October, 2023

San Francisco Estuary Institute-Aquatic Science Center Sacramento-San Joaquin Delta Conservancy





Acknowledgments

We would like to thank members of the Delta Aquatic Resource Inventory (DARI) Workgroup for their guidance and the academic DARI interns for their hard work development of the DARI map. This project was funded by a U.S. EPA 2017 Wetlands Program Development Grant. Numerous individuals contributed to the Delta Aquatic Resource Inventory mapping. A list of workgroup members, contributors and mappers is available at https://www.sfei.org/projects/delta-aquatic-resource-inventory.

Suggested Citation:

San Francisco Estuary Institute (SFEI). October, 2023. Delta Aquatic Resources Inventory (DARI): Mapping Methods and Standards for Channels, Wetlands, and Riparian Areas in the Sacramento – San Joaquin River Delta. Produced by SFEI under U.S. EPA 2017 Wetlands Program Development Grant Award # CD99T55501. SFEI Contribution No. 1147. Richmond, CA.

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1 Overview

Purpose

The purpose of this document is to describe the mapping classification system and methods¹ used to develop the <u>Delta Aquatic Resource Inventory</u> (DARI) in 2020. DARI is an inventory of aquatic resources and their associated vegetated areas in the Legal Sacramento-San Joaquin River Delta in California. The inventory was developed in a Geographic Information System (GIS), employing a standardized, and regionally relevant classification system to support environmental planning and resource management tracking at a local and regional scale.

History, Previous Studies, Regulatory Involvement

The DARI methodology was originally piloted in 2011-2012 through a collaborative project of the San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC 2013) and the Department of Water Resources (DWR). That project mapped a small portion of the Delta to support early planning for the Delta Conveyance Project alternative assessments. DARI employed the Bay (BAARI) mapping protocols, and expanded the classification system (as warranted) to include new aquatic resource types not found in the San Francisco Bay region up to the confluence of the Sacramento and San Joaquin Rivers.

In 2017, a U.S.EPA Region 9 Wetlands Program Development grant funded the completion of DARI for the whole legal extent of the Sacramento-San Joaquin Delta. Under this funding, DARI will be incorporated into the <u>California Aquatic Resource Inventory</u> (CARI) and made publicly available through <u>EcoAtlas</u>.

Developed over the past two decades with initial regional development and demonstrations, and later applications statewide, the purpose of EcoAtlas has been to support the State Water Resources Control Board's Clean Water Act Section 401 – Certification and Wetlands Program, and the new State Wetland Definition and Procedures for Discharges of Dredged or Fill Material to Waters of the State (Procedures). EcoAtlas' online geospatial platform employs CARI as the base map for viewing and accessing other environmental datasets, mitigation and restoration project information, rapid condition assessment data, and other water quality monitoring data to support mitigation and restoration planning and tracking at local, regional, and statewide scales. The Landscape Profile Tool, within EcoAtlas, can be used to interactively select a user-defined area from the CARI base map, and generate a profile of the amount, distribution, and diversity of streams and wetlands within the defined area. These geographic summaries help resource managers understand the status of aquatic resources when considering proposed impacts and mitigation projects.

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¹ The following standards were adapted from the Bay Area Aquatic Resources Inventory (BAARI) mapping standards and protocols for the use in the Sacramento-San Joaquin Delta.

This guidance document updates the original pilot *DARI Mapping Standards and Methods* (August 8, 2013) and crosswalks DARI's wetland classification system to the National Wetlands Inventory (NWI) of the USFWS, the National Hydrologic Dataset (NHD) of the USGS and CARI.

DARI Map Extent

The DARI map extent includes the Legal Sacramento-San Joaquin River Delta region in California (**Figure 1**), which covers approximately 737,621 acres.

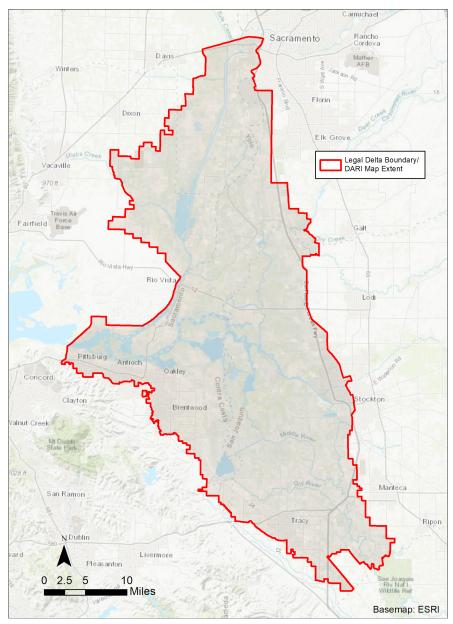


Figure 1. Map of the legal Sacramento-San Joaquin River Delta Boundary / DARI map extent.

2 DARI Classification System

DARI's aquatic resource inventory classes were adopted from BAARI's classification system. It was expanded to include aquatic resources that are distinct to the Sacramento-San Joaquin River Delta employing the same nomenclature. Channel features are mapped in a GIS as linear or linear and polygonal features depending on their channel widths (<10m wide and ≥10m wide). All other wetland types are mapped as polygonal features. The channel network is a line feature class that can be used for modeling and other purposes. It consists of line work that is mapped continuously through narrow and wide channels, and through other aquatic features (including reservoirs and lakes) by the addition of Artificial Paths through those open water features.

Stream order was not added to DARI. This decision took into account a number of considerations that made assigning stream order particularly challenging in the Delta. The DARI mapping study area consists of the lowest stream reaches of much larger watershed units that would be necessary to map in order to accurately assign stream order to downstream channels and main stems. Furthermore the Delta region is a highly modified landscape with unusual hydrology that includes many braided channels and "loops" in channels around islands and within agricultural fields which are problematic for assigning stream order.

It is also important to note that non wetland riparian areas were not mapped within this dataset, however wetland riparian areas may be included in some of the polygonal classes described below (e.g., Tidal Vegetated Woody wetlands). Non-wetland riparian areas are still defined later in section 2 in order to make the distinction of riparian areas that were mapped and those that were not mapped clear.

Table 1 and Table 2 list all the polygonal and linear wetland types mapped in DARI, using the wetland classification system described in section 2. The highest level of classification (Level 1) distinguishes between Tidal and Non-Tidal channels and wetlands. The second level (Level 2) groups aquatic features into channels (or flowing ditches, streams, sloughs, etc. also known as riverine features) and other wetland types that are consistent with the state's Wetland and Riparian Area Monitoring Plan (WRAMP) framework² for monitoring and assessing the amount, distribution, diversity, and condition of streams and wetlands at a watershed or other landscape scale (CWMW 2013).

To link between classification systems of national datasets, including the National Hydrologic Dataset (NHD) of the USGS, the National Wetland Inventory (NWI) of the USFWS, and the statewide CARI dataset, crosswalks between DARI and NHD, NWI, and DARI and CARI are presented in <u>Appendix A</u>.

https://www.sfei.org/projects/statewide-wetland-tracking-science-and-policy-development-support

² For more information:

Table 1. List of DARI's Polygonal Aquatic Features.

Level 1	Level 2	Wetland Type Code	Wetland Type	Short Definition
Tidal	Channel	TC	Tidal Channel Natural	Tidally connected open water or dewatered channel
		TCU	Tidal Channel Unnatural	Tidally connected open water or dewatered channel with straightened planform
	Marsh	TV	Tidal Vegetated Natural	Generally Tule Marsh (can be pickleweed in Western Delta
		TVw	Tidal Vegetated Woody Natural	Tidally connected Willow Wetland (sometimes ash)
	Lagoon	TGPOWU	Lagoon Perennial Open Water Unnatural	Large open water bodies with tidal connection
	Panne	TP	Tidal Marsh Panne Natural	Unvegetated ponds in marsh plain
Non-Tidal	Channel	С	Channel Natural	Sinuous channel inside a leveed island that not influenced by tidal action and sinuous fluvial channels above tidal range
		CU	Channel Unnatural	Straightened channels within leveed islands that are not influenced by tidal action and straightened fluvial channels above tidal range
		cv	Channel Vegetated Natural	Vegetated (herbaceous) portions of natural channels within leveed islands and fluvial channels above tidal range
		CVU	Channel Vegetated Unnatural	Vegetated (herbaceous) portions of unnatural channels within leveed islands and fluvial channels above tidal range
		CVw	Channel Vegetated woody Natural	Willow Wetland (sometimes ash) portions of natural channels within leveed islands and fluvial channels above tidal range
		CVwU	Channel Vegetated woody Unnatural	Willow Wetland (sometimes ash) portions of unnatural channels within leveed islands and fluvial channels above tidal range
		CE	Channel Engineered	Armored unnatural channels (Aqueduct)
	Depressional	DOWN	Depressional Open Water Natural	Small naturally impounded water bodies with no tidal connection
		DOWU	Depressional Open Water Unnatural	Small artificially impounded water bodies with no tidal connection
		DVN	Depressional Vegetated Natural	Vegetation adjacent to depressional open water
		DVU	Depressional Vegetated	Vegetation adjacent to depressional open

		Unnatural	water
Lacustrine	LOWN	Lacustrine Open Water Natural	Lake. Large water bodies >20 acres (8 ha) with no tidal connection. Historically present
	LOWU	Lacustrine Open Water Unnatural	Reservoir or Lake. Large water bodies with no tidal connection
	LVN	Lacustrine Vegetated Natural	Vegetation adjacent to lakes
	LVU	Lacustrine Vegetated Unnatural	Vegetation adjacent to lakes or reservoir
Playa	PUU	Playa Unvegetated Unnatural	A special case of depressional wetlands with shorter duration of flooding and high salinity
	PVU	Playa Vegetated Unnatural	Vegetation adjacent to playas
Slope	SU	Seep Unnatural	Primary water source for seep wetlands is adjacent surface water that migrates through a levee or berm. Seeps tend to be linear in shape.
	FS	Woody Slope Natural	Slope wetland larger than 0.5 acres (0.2 ha) with woody vegetation, usually Willows
	FSU	Woody Slope Unnatural	Slope wetland larger than 0.5 acres (0.2 ha) with woody vegetation. Most common example is along levees and wouldn't be present without a directly human modified environment.
	WM	Non-woody Slope Natural	Slope wetland dominated by monocots or herbaceous vegetation
	WMU	Non-woody Slope Unnatural	Slope wetland dominated by monocots or herbaceous vegetation that forms due to unnatural landform
Vernal Pool	VP	Vernal Pool	A special case of depressional wetlands with vernal pool endemic species
	VPC	Vernal Pool Complex	Multiple vernal pools, swales and the surrounding supporting adjacent non-wetland area
Managed	М	Managed Wetland	The duration and depth of inundation is controlled due to anthropogenic management

Table 2. List of DARI's Linear Aquatic Features.

Level 1	Level 2	Channel Type Code	Channel Type	Short Definition
Tidal	Channel	TC	Tidal Channel Natural	Tidally connected open water or dewatered channel
		тси	Tidal Channel Unnatural	Tidally connected open water or dewatered channel with a straightened planform due to anthropogenic modifications
Non-Tidal	Channel	С	Channel Natural	Sinuous channel inside a leveed island that not influenced by tidal action and sinuous fluvial channels above tidal range
		CU	Channel Unnatural	Straightened channels within leveed islands that are not influenced by tidal action and straightened fluvial channels above tidal range
		CE	Channel Engineered	Engineered flood control or storm drain channel
		CSD	Channel Subsurface Drainage	Underground flowpath or pipeline
		АР	Artificial Path	Artificial path through open water bodies to provide connectivity for the stream network. Particularly relevant for lagoons and lakes with channels flowing into them.

The Level 1 classification divides wetlands into two major categories which are particularly relevant for distinguishing wetland types within the Delta. These two high-level categories are Tidal and Non-Tidal. In addition, wetlands can be further distinguished with vegetation, size and water depth, and anthropogenic modifiers. The remainder of this section characterizes DARI's wetland types and their modifiers.

Tidal Wetlands (T)

The Tidal channels and wetlands consist of all the areas that are regularly influenced by tidal water movements. These fluctuations might be fully natural or muted due to tide gates, culverts, weirs, etc. Tidal channels can be saline, brackish, or completely freshwater and they exhibit tidal ebbs and flows because of the downstream influence of the tides. The Delta is highly managed for saltwater intrusion³ to protect agricultural lands, municipal water supplies, and ecological habitats. East of Sherman Island, the salinity fluctuates with the tides and the amount of freshwater flow from the Sacramento and San Joaquin Rivers. Managed pumping also has large effects upon the flow directions of Delta waters, and therefore the flow directions within the channel network can be tricky. Within the Level 1 category of Tidal Wetlands we find the following Wetland Types:

³ https://www.watereducation.org/aquapedia/sacramento-san-joaquin-delta-and-salinity

Tidal Channels (TC)

Channels are a landscape feature with a well-defined bed and opposing banks that conveys water above ground at some point during the year. Tidal Channels are subject to tidal influence. Natural Tidal Channels(TC) are often sinuous, but can have slight modification (for example levees). Whereas Unnatural Tidal Channels (TCU) are usually much straighter.



Figure 2. Tidal Channels (TC and TCU).

Lagoon (TG)

Lagoons are large impoundments of water, equal to or greater than 20 acres (8 ha), subject to tidal action, be it full tidal action, muted tides or even occasional or sporadic connection to full tidal action. Tidal Lagoons receive tidal action seasonally (S) or perennially (P) depending on management or natural cycles. Lagoons are generally open water (OW). Vegetation surrounding Tidal Lagoons are classified as Tidal Vegetated (TV). Lagoons can also be natural (N) or unnatural (U). Natural features can occur due to barrier beaches or dunes whereas unnatural features are often modified with levees with tide gates. Typically, Lagoons in the Delta are subsided islands whose levees have breached and are now flooded, creating large tidal open bodies of water (TGPOWU), such as Franks Tract or southern portion of Liberty Island.

Marsh (Tidal Vegetated) (TV)

Tidal Vegetated areas with greater than 10% vascular vegetation cover within a 100 m² area. Tidal vegetation can occur in the form of discrete Tidal Marsh areas or as thin strips of vegetation (typically Schoenoplectus spp.) along shallow portions of Tidal Channels. Tidal marsh is a vegetated wetland that is subject to tidal action and has a suite of plant species that are dependent upon elevation and salinity. Tidal vegetated marsh occurs throughout much of the Delta within the tidal elevation frame, from the lowest extent of vascular vegetation to the elevation of the maximum observed high tide.

Tidal Marsh Panne (TP)

Tidal Marsh Pannes are areas that store surface water in Tidal wetlands during low tide. Marsh pannes are typical features of extensive, well-developed Tidal Marshes. The term refers to natural ponds that form in the marsh plain. These ponds, usually less than one foot in depth, fill with tidal water only during very high tides. They usually support less than 10% cover of vascular plant growth. They may be hypersaline in late summer, but they do not develop thick deposits of salts as do natural or commercial salt ponds. Most pannes are unvegetated, but some support wigeon grass and green macroalgae. There tend to be fewer but larger pannes in brackish marshes compared to salt marshes and even fewer in freshwater marshes (Grossinger 1995). Pannes are more common in the marshes of San Francisco Bay in contrast with the Delta.

Non-Tidal Wetlands (lack of "T" modifier)

Non-Tidal channels and wetlands consist of all other wetlands that are not influenced by the tides. In the Delta, these features can be surrounded by Tidal features but have the tidal influence removed because of levees or other barriers to flow that exclude tidal influence. Examples of these barriers include physical barriers, such as low-level dams, and gates, which can also separate fresh water from saline water and include passageways for navigation and fish migration.

Within this Level 1 category of Non-Tidal Wetlands we find the following Wetland Types:

Non-Tidal Channels (C)

Channels are a landscape feature with a well-defined bed and opposing banks that conveys water above ground at some point during the year. Natural channels are often sinuous and can have slight modification. Whereas unnatural channels are usually much straighter. These typically occur on the [higher outside fringes] of the Delta or are relict channels in areas that have been cut off from tidal action.

Depressional Wetlands (D)

Depressional Wetlands are features that form in topographic lows. If the depression is connected to 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 m²). They can have prominent areas of perennial 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 10% 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 (2 m) during the dry season. The vegetated portion can support woody wetland vegetation (e.g., willows, cottonwoods, alders or ash) and herbaceous wetland plants (e.g., sedges,rushes, grasses), and does not have an upper size limit.



Figure 3. Depressional wetland (DOWU surrounded by DVU).

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 man-made 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) 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 4. Lacustrine open water areas in a reservoir, an unnatural lacustrine feature (LOWU), and adjoining lacustrine vegetated wetlands (LVU).

Playa (P)

Playas are nearly level, shallow, ephemeral (seasonal) or perennial, sodic (i.e., strongly alkaline) or saline water bodies with very fine-grain sediments of clays and silts. Unlike vernal pools, playas have little or no vascular vegetation within the limits of the water body, though they support sparse peripheral vegetation. Playas can consist of open water (OW), associated vegetation (V) and unvegetated areas without standing water (U). These features can be either natural (N) or human modified (U). Unlike lacustrine wetlands, playas are less than 6 ft deep during the dry season, although they can be hundreds of acres in size. Playas are very rare in the Delta due to the lack of interior drainage and wrong climatic characteristics (playas typically form where evaporation greatly exceeds water inflows).



Figure 5. Playa unnatural including vegetated (PVU) and unvegetated (PUU) features.

Seeps and Springs (S)

Seeps and springs are a form of slope wetland that form due to the intersection of groundwater with the land surface. Seeps and springs form in locations where the seasonal or perennial emergence of groundwater feeds the root zone and in some cases emerges onto the ground surface. Unlike woody slope wetlands or wet meadows, seeps and springs form at a discreet location (a spring that forms at a point or a seep that forms as a line on a slope), rather than over a larger area. Outside of the Delta this often occurs along cliffs or bluffs, or at the base of a hillslope. However, because the Delta lacks steep topography, seeps and springs are most typically found at the base of slopes [in the fringe areas of the Delta] or at the base of the inboard side of levees. In these locations, surface water on the outboard side of the levee seeps through the levee and emerges on the inboard side, along the levee slope. Slope wetlands are greater than 0.025 acres (100 square meters) and lack well-defined channels. They can consist of both woody wetland vegetation (e.g., willow, ash, alder) and herbaceous wetland plants (e.g., sedges and rushes). Seeps and springs can be natural (N) or unnatural (U). Unnatural seeps would occur because of human modifications to the landscape, such as at the inboard side of levees (Figure 6). Due to the prevalence of subsidence in the delta⁴, the increase in elevation difference between the island interior (lower) and the top of the surrounding tidal channels (higher) often increase the prevalence and extent of this occurring. Water seeping out along the berm of a stock pond is another example of an unnatural seep (SU).

⁴ Mount and Twiss 2005, https://escholarship.org/uc/item/4k44725p

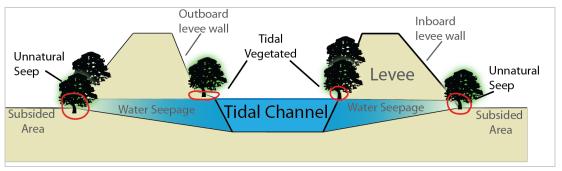


Figure 6. Levee cross-section showing the location of unnatural seeps (SU) on the inboard side of levees.

Woody Slope Wetland (FS)

Woody 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 across a larger area than a seep or spring. The ground surface in these wetland locations typically have a very gentle slope or essentially no slope. Woody Slope Wetlands also support more than 30% cover of tall woody vegetation (e.g., willows or ash trees), as evidenced in aerial imagery, or any available vegetation dataset. These wetlands can adjoin non-forested slope wetlands (i.e., wet meadows). Woody 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). An example of a woody slope wetland is an area on the gentle slope extending from a flat field down to the adjacent channel that is dominated by sandbar willow (Salix exigua). Oaks do not occur in any wetland classes including FS, but can be indicative of riparian areas that are not being mapped in the DARI 2020 effort (see Non-Wetland Riparian Areas section).

Non-woody Slope Wetlands (Wet Meadow) (WM)

Non-woody Slope Wetland, or Wet Meadow, features are groundwater-fed wetlands that exist in gently sloped or flat topography. They are similar to woody slope wetlands, in that groundwater feeds the root zone of the wetland vegetation, except they lack the woody vegetation species cover. These areas are found across the Delta, including on slopes that are adjacent to other wetland types or in broad, flat wetland plains. They can also be found in farmed areas where wetland plants or bare soil exist due to persistent emerging groundwater. WM features in farmed areas are only mapped if they have not been farmed in two or more image years, although those years do not have to be consecutive.



Figure 7. Wet Meadow Unnatural (WMU).

Vernal Pools

Vernal pools are a special kind of seasonal depressional wetland having a shallow subsurface bedrock or impervious soil horizon that prevents the surface water from infiltrating, and that support a unique suite of vernal pool endemic floral species. 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 drying repeatedly during the wet season. Vernal pools often occur together with vernal swales as vernal pool systems (or complexes) that have many pools of various sizes and shapes, varying floral and faunal composition, and varying hydroperiods. Water can move between adjacent pools and swales via surface water flow or via shallow subsurface flow through the thin soils above the underlying impervious substrate.

The DARI mapping team largely relied upon existing individual vernal pool or vernal pool complex features from previous mapping efforts, however when additional vernal pools or vernal pool complexes were obviously present in the imagery and DEM they were mapped. A large percentage of vernal pools and vernal pool complexes mapped in DARI were provided by Carol Witham and Bob Holland (Witham 2012).

Individual Vernal Pools (VP)

Large individual vernal pools (VP) are mapped when an individual pool is discernible in the imagery. Generally the minimum size of individual pools mapped were 0.025 acres (100 m²). Individual pools were not consistently distinguished from vernal pool complexes.

Vernal Pool Complex (VPC)

Vernal pool complexes are landscapes that support several vernal pools and swales that are smaller than the targeted mapping unit that are hydrologically interconnected and are mapped as one unit. These features are usually identifiable because of the distinctly textured landscape of pools and swales, and sometimes they also include mima mounds.

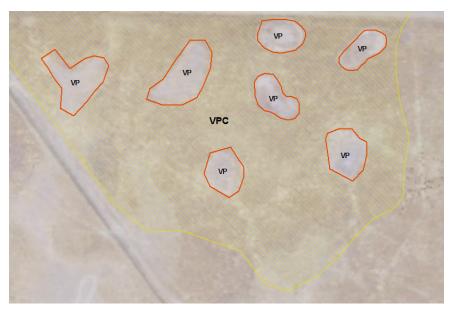


Figure 8. Individual vernal pools within a vernal pool complex.

Managed Wetlands

Managed wetlands, 'M-Managed', are areas that are flooded intermittently <u>and</u> intentionally, but may not have all of the other characteristics of wetlands. For example, some areas functionally serve as wetlands, but are not naturally occurring and often are dominated by non wetland associated vegetation. These areas are identified as being repeatedly inundated by water as evidenced by the following:

- Proximity to pixels with ~>50% in the recurrence index of the 1984-2018 Global Surface Water dataset
- Direct evidence of flooding in at least 1 image in the last 10-20 years (assuming no major landscape change) on Google Earth, or evidence of recent flooding in 2 or more images

- Vegetation types present
- Association with lowest spots in landscapes that are already subsided far below sea level and the adjacent channels

SFEI's Delta Modern Habitats mapping layer and time series imagery available on Google Earth can help identify these areas.

Examples of managed wetlands include areas that are intentionally flooded during specific seasonal periods, such as duck clubs, habitat restoration sites, flood abatement, wastewater treatment ponds, and working agricultural areas including rice fields or other regularly flooded crops such as corn and alfalfa. These agricultural lands are regularly flooded to provide nutrients for future crops and to provide wildlife habitat for migratory birds and fisheries during critical seasons. Within habitat restoration areas, aquatic features are mapped as their specific type of wetland that they function as on the landscape and then given the value of "M" in the "Managed" field as described below. However often the aquatic features and wetlands exhibit characteristics of multiple wetland types and are then mapped as the more general type of 'M-Managed'. Habitat restoration features can be identified by their overlap with polygons taken from EcoAtlas' Project Tracker, as well as from their physical characteristics, such as small raised areas that are anthropogenic in origin in flat areas that have a water regime managed to support wetland vegetation. Often you can see sinuous channels, that may or may not be fully wetted, that are carved in these wetlands that otherwise do not follow topographic changes in the landscape.

When the type of managed wetland is apparent the management type will be indicated under the "WetTypeOther" field.

We also want to include the possibility of wetlands of various kinds being identified as 'managed' (generally meaning the flooding is managed), as there can be various classes of wetlands (Depressional, Slopes, etc.) where the flooding is controlled for some duration. For this, Managed Wetlands of all kinds (including WetlandType = 'M-Managed') will be noted in the field named 'Managed'. M will be the base value. Where possible supplemented by 'M Ag', 'M Restor', and possibly others.

Examples of Managed Wetlands

Intermittently inundated working lands are mostly sporadically flooded agriculture and carbon sequestration projects. For example, managed wetlands include land currently used in active agricultural production that is subject to intentional and managed seasonal flooding. These include agricultural lands that require seasonal flooding as a management practice for crop growth or are purposefully flooded seasonally for wildlife habitat benefits or carbon sequestration. Typical crops that require seasonal flooding include rice, corn, and alfalfa. Agricultural areas that are mapped have evidence of inundation, and have other evidence of being annual agricultural crops (e.g., rows, farm roads, or nearby ditches).

Another example of working lands that are included in the Managed class are Non-Tidal marshes (DOWU, DVU, maybe WMU). These include diked wetland areas dominated by wetland-associated vegetation (e.g. typha), and the local wetland hydrology is controlled or very strongly influenced by water management practices on a particular parcel, island, or tract. Water control facilities manipulate the timing, duration, and depth of flooding. Examples include areas managed for waterfowl food production (duck clubs) or carbon sequestration.

Another example of managed wetlands are areas reserved for the rerouting of floodwaters around Sacramento (Yolo Bypass) and other areas. There is no previously existing comprehensive dataset for these areas.

Non-Wetland Riparian Areas (not mapped)

Non-wetland riparian areas are not mapped in DARI. A riparian area is an area through which physical and biological processes interconnect aquatic or wetland areas to their adjacent terrestrial areas. Riparian areas are distinguished by gradients in biophysical conditions, ecological processes, and biota. They can include terrestrial areas that measurably influence, or that are influenced by, the conditions or processes of the aquatic or wetlands areas. For any given form and structure of a riparian area, its width depends on its function (SFEI 2016).

In addition, the National Research Council (2002) riparian definition includes "areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands".

Riparian areas are not mapped in DARI because they do not meet the definition of being a wetland. That is, they do not meet the three wetland criteria of: the presence of wetland soils, saturation for a period of time, or supporting wetland plant species. However, as described above, these areas are closely associated with wetlands and every wetland has an associated riparian area. Riparian areas start where the wetland stops; the two areas share a common boundary. The riparian area generally extends outward, or away from the wetland feature. The width of a riparian area is variable, and will depend upon a number of factors including topography, type of associated wetland feature, land use, and moisture gradient. Some areas are quite wide, while others can be very narrow (1m or less). While riparian areas are typically thought of as supporting woody vegetation, riparian vegetation can also consist of herbaceous and grassy vegetation as well.

Wetland Modifiers

For many Wetland Types there are several modifying wetland descriptors which provide additional information about the wetland feature. These modifiers are included in the wetland classification system and described below. The full list of all unique Wetland Type combinations mapped in DARI (including these modifiers) is provided in <u>Table 1</u> and <u>Table 2</u> at the beginning of Section 2: DARI Classification System.

Open Water (OW) and Vegetated Areas (V)

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 m² search area, meaning they have less than 10% vegetative cover. Vegetated areas (V) therefore have at least 10% vegetation cover. The code Non-vegetated (U) is only used for wetlands that fit the wetland definition of *playas* and should not be confused with the unnatural wetland modifier of the same code (U, see below). For example, "PUU" refers to "Playa Non-vegetated Unnatural"). These non-vegetated playas are areas without standing water during the dry season, less than 10% vegetation cover. All three types (OW, V, U) can be natural (N) or unnatural/man-made (U), see below.

Woody (w)

Descriptor added to a vegetated wetland area that is wooded (typically composed of willow but can include other woody species such as ash, cottonwood, and alder). For example a Tidal Vegetated Woody Natural (TVw) classification is used to denote tidally connected wetland areas that are dominantly covered in tree species and are natural. Note that Oaks (Quercus spp.) do not occur in any wetland areas including Woody Slope Natural (FS), TVw, or Channel Vegetated Natural (CVw), but can be indicative of riparian areas that are not mapped in DARI (see Riparian section).

Natural (N) or Unnatural (U) 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, the 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; for example, 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.

Note that the "U" (Unnatural) code is always included at the end of unnatural wetland types (at the end of the letter code). However, the "N" (Natural) code is not always added to the end of the wetland type code but is implicitly implied when a code does

not end with a "U" (see <u>Table 1</u> and <u>Table 2</u> above). The U for Unnatural and the N for Natural are always found in the last position within the wetland class code.

Engineered (E)

Some channels are classified as engineered when they represent flood control or water carrying aqueducts. These engineered channels are typically heavily armored/bounded by stable engineered banks or channel walls. The engineered classification differentiates between these maintained hardened channels and the more common earthen irrigation or drainage ditches. An example within the Delta of an Engineered Channel can be found on the south west corner of the Clifton Court Forebay.

Deep (d) vs Shallow (s)

Distinguishing between deep vs shallow does not require manual mapping. This distinction will be made by dividing up the channel polygons by using the DEM.

For Tidal Channel polygon features, 12ft below MLLW will be used as the cutoff between shallow and deep subtidal channels. While it is difficult to define an exact depth at which the cutoff between shallow and deep water occurs, this cutoff value is consistent with a number of sources listed below:

- The San Francisco Bay Adaptation Atlas (<u>SFEI & SPUR 2019</u>: 26-27). Based on the approximate depth where "resuspension of sediments by wind-driven waves" occurs.
- The approach is being considered by Wetlands Regional Monitoring Program (WRMP) (personal communication with Josh Collins, SFEI).

Shallow Depths (<12 ft below MLLW) are also inclusive of:

- The depth at which we no longer find persistent submerged aquatic vegetation (SAV) (~ 10 ft/3 m, with most attenuation shallower than ~6.6 ft/2 m) (personal communication with Shruti Khanna, CDFW).
- 4.3 ft (1.31 m) -- median depth of the photic zone in Delta (<u>Durand et al. 2016</u>).
- 9.8 ft (3 m) below MHHW -- used in CAMT Delta Salmon Rearing study as the depth at which suitability for rearing Chinook Salmon begins to decrease. (adapted from Friesen, T.A. 2005. Biology, behavior, and resources of resident and anadromous fish in the Lower Willamette River: Final report of research 2000-2004. Oregon Department of Fish and Wildlife.)

3 Mapping Scale and Target Mapping Unit (Tmu)

The target mapping unit (Tmu) is a desired minimum mapping unit for developing DARI. The goal is to maximize the detail of the dataset, capturing small yet important habitats (e.g., seeps) while producing a consistent dataset for the region. Presence or absence of a wetland feature is identified at a standard mapping scale. However, after a wetland feature is located and classified at a standard mapping scale of 1:2500, a larger map scale (up to 1:1000) may be appropriate for digitization.

- Aquatic Features are reviewed for quality assurance at a scale of 1:5000. The Tmu for most polygonal features is 0.025 acres (100 sq m).
- Lacustrine Open Water wetlands (LOWN or LOWU) have a Tmu of 20 acres (~81,000 sq m).
- Natural channels (C) have a Tmu length of 50m.
- Unnatural channels (CU) (e.g., ditches), engineered (CE) and subsurface channels (CSD), have a Tmu length of 25m.
- Any channel that connects a water body to another wetland feature has no Tmu. For example, a channel that can be used to drain an unnatural depression will have no Tmu.

4 Projection and Datum

All DARI data, at all stages of mapping, are maintained in the California Teale Albers with North American 1983 Datum (NAD). This dataset will be merged with the other CARI datasets which is also projected in California Teale Albers, NAD 1983.

5 Data Sources

Aerial imagery, LiDAR-derived digital elevation models (DEMs), and bathymetry data are the *primary digitizing source datasets* that a mapper will use to differentiate between Tidal and Non-Tidal wetlands and define the boundaries of each aquatic feature in DARI. Other digitized aquatic resources, vegetation, bathymetry, and habitat data are *secondary exploratory and confirmation data sources* that support and inform the mapping process described in <u>Section 7: Mapping Procedures</u> below.

Primary Mapping Data Sources

To establish consistency across the Legal Delta, the *National Agriculture Imagery Program's* (*NAIP 2018*) aerial imagery, available through the US Department of Agriculture (USDA, http://www.fsa.usda.gov/FSA/), was selected as the primary data source from which all aquatic features are mapped (or digitized).

The 2018 NAIP data (downloaded in February 2019) covers the full extent of the Legal Delta mapped in DARI 2020. It consists of 4 band, natural true color and infrared imagery at a 1 m pixel resolution, and georectified to the national standards at a 1:24,000 scale. These digital aerial imagery capture leaf-on conditions.

The choice to use NAIP was based on precedent, 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 for incorporating DARI into the statewide CARI dataset, and when transferring the mapping standards to other parts of the state. NAIP datasets are flown periodically for California which helps ensure the aquatic resources inventory can be updated.

USGS LiDAR-Derived topobathymetric model (DEM 2017) data is used as needed to help identify and map water lines (similar to NHD), interpret vegetation and slope information, identify levees and ditches, and help identify farmed wetlands based on topographic features. It also helped in the QA Review process.

The most recent dataset used to map DARI 2020, was flown in December 2017 and published online at the National Map Portal in April 2019 (https://viewer.nationalmap.gov/basic/, Project Name: CA_Sacramento_2017) through the USGS 3D Elevation Program (3DEP). The DEM units are in meters with a horizontal resolution of 2 m, and a projection of NAD83 (NSRS2007)/UTM zone 10N. A fact sheet can be found here:

http://gisarchive.cnra.ca.gov/iso/ImageryBaseMapsLandCover/LIDAR/DeltaLIDAR2017/LiDAR%2 Ofactsheet_FINAL_June2019.pdf.

The 2017 DEM layer was attributed with tidal datums per Siegel and Gillenwater 2019 (Draft) as the guide for distinguishing between Tidal and Non-Tidal reaches in the Delta.

Future updates and edits to DARI should be digitized using these and/or more recent versions of these primary data or comparable sources.

Secondary Data Sources

Secondary data include pre-existing digitized aquatic features used as a starting point for mapping. These data served as a reference for *reviewing and updating* DARI based on the primary imagery and DEM sources.

Beta version of aquatic features (DARI beta)

Four data sets were used to compile separate line and polygon layers of the most current digital map of aquatic features in the Legal Delta:

- National Hydrography Dataset (NHDPlus_HR_2019)
- National Wetland Inventory (NWI 2018),
- Modern Delta Habitats (SFEI-ASC 2014⁵), and
- the 2012 DARI pilot dataset to support the Delta Water Project's alternatives analysis (SFEI-ASC 2013, unpublished).

Each dataset is described below.

⁵ The 2014 Delta Modern Habitat GIS data are available upon request at ecoatlas@sfei.org.

National Hydrography Dataset (NHDPlus_HR_2019). The NHDPlus High Resolution (HR) "Beta" dataset is produced by the USGS. It is a national, geospatial model of the flow of water across the landscape and through the stream network. The NHDPlus HR is built using the National Hydrography Dataset High Resolution data at 1:24,000 scale or better, the 1/3 arc-second (10 meter ground spacing) 3D Elevation Program data, and the nationally complete Watershed Boundary Dataset.

The NHDFlowline is the fundamental flow network consisting predominantly of stream/river and artificial path vector features. It represents the spatial geometry, carries the attributes, and contains linear referencing measures for locating features or "events" on the network. Additional NHDFlowline features are canal/ditch, pipeline, connector, underground conduit, and coastline. These features (with the exception of coastline) were used in preparing *DARI beta*.

The data can be downloaded from:

 $\frac{\text{https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution}{n}$

National Wetlands Inventory (NWI 2018). NWI is a polygon layer produced by the US Fish and Wildlife Service (USFWS). These data vary in time and accuracy. They should only be used as an indication of the likely existence, location, and classification of major features.

The following six USGS 7.5' quads were updated by NWI in the Legal Delta region since 2010 and were included in preparing *DARI_beta*: Clarksburg; Florin; Courtland; Bruceville; Honker Bay; Antioch North. The remaining quads were last updated in the 1980s. The NWI data collection method for the Delta used color infrared imagery at 1:8,000. The wetland features were mapped at a resolution of 1:4,000. The data can be downloaded from the NWI Wetlands Mapper at https://www.fws.gov/wetlands/data/mapper.html.

Modern Delta Habitats. SFEI's Delta Landscapes Project (funded by the US Fish and Wildlife Service and the California Department of Fish and Wildlife's Ecosystem Restoration Program⁶) developed a body of work to inform landscape-scale restoration of the Sacramento-San Joaquin Delta ecosystem (https://www.sfei.org/projects/delta-landscapes-project). The work included developing a habitat map by compiling several vegetation and natural communities geospatial datasets into a standardized map that extends across the Legal Delta. For more information see Appendix A of A Delta Transformed: Ecological Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta (SFEI-ASC 2014). Aquatic Resource related habitat types (such as managed wetland classes, willow related classes, wet meadow classes etc.) from this dataset were incorporated into the DARI beta polygon layer.

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⁶ http://www.dfg.ca.gov/erp/

2012 DARI pilot dataset (SFEI-ASC 2013). As mentioned above, DARI was first developed for a portion of the Delta by SFEI under contract with DWR to support Conservation Measure 1 (conveyance) of the Bay Delta Conservation Plan EIR/EIS in 2011 to 2013. The 2012 DARI pilot used NAIP 2007 imagery and LiDAR based DEM as the Primary data sources for digitizing a small portion of the Delta to support the Delta Conveyance Project's EIR/EIS study. The mapping effort employed the BAARI mapping methods and classification system and added new Wetland Types (as needed) for new aquatic features found in the study area. The DARI 2012 dataset was incorporated into DARI_beta, and the aquatic features of all four datasets were standardized to the DARI 2012 classification system (where possible) to serve as the starting point for the DARI 2020 mapping effort (*DARIbeta_WetType* in the geodatabase).

Other Data Sources (Ancillary Data)

Other data sources (or ancillary data) are supporting information used to help mappers evaluate, classify, and confirm the extent or classification of wetland features. Ancillary data are extremely important for evaluating wetland areas that are difficult to interpret from the primary aerial imagery and/or LiDAR based DEM. Examples include: vegetation data, aerial imagery from previous years of NAIP or Google Earth (both provide historical time series imagery that help mappers interpret seasonal and temporal changes), bathymetry, and other local datasets.

The following datasets were used to map DARI in 2020. However, other local data can be included to enhance the interpretation of aquatic features in their landscape setting in future updates.

Bathymetry and Topography (2005-2012) data from DWR was completed in 2012 from the U.S. Geological Survey in collaboration with the California Department of Water Resources. The resolution of the DEM is 10m. These data were largely used to differentiate between shallow and deep channels. The dataset was provided to SFEI by Shawn Mayr at DWR (shawn.Mayr@water.ca.gov).

Fregoso, Theresa A., Wang, Rueen-Fang, Alteljevich, Eli, and Jaffe, Bruce E., 2017, San Francisco Bay-Delta bathymetric/topographic digital elevation model(DEM): data release DOI:10.5066/F7GH9G27, U.S. Geological Survey, Coastal and Marine Geology Program, Pacific Coastal and Marine Science Center, Santa Cruz, California. https://www.sciencebase.gov/catalog/file/get/58599681e4b01224f329b484

Vegetation Data (VegCamp 2016). The Geographical Information Center, North State Planning and Development Center, and California State University, Chico (Kreb et al. 2019) updated the California Vegetation Classification and Mapping Program's Vegetation Dataset for the Delta (VegCAMP 2007) produced by Aerial Information Systems for the Department of Fish and Wildlife. The 2019 update was based on the 2016 NAIP aerial imagery (1m resolution). The 2019 effort retained the line work and attributes of the 2007 VegCamp dataset when static and was amended in areas where change occurred. The map resolution was 1:5,000. The updated

vegetated polygons were mapped to the alliance level of the National Vegetation Classification System (NVCS) hierarchy if it was possible to discern the vegetation type at the given resolution of the imagery. Otherwise, vegetation was mapped to the group level.

The DARI mapping team used VegCamp 2016 data to support the identification and/or confirmation of vegetated wetland areas. They created a working vegetation layer from VegCamp 2016 that grouped plant species (by NCVS_Name) based on if they are wetland obligate species that almost always appear in wetlands, are facultative wetland species usually appear in wetlands, or are not found in or adjacent to wetlands. Thirty-four plant species were grouped into the following four 'usual habitat types' to help DARI mappers identify vegetated wetlands: wetlands or riparian woodland, possibly wetland-riparian, usually riparian, or usually upland (Table X). These usual habitat types were used to help interpret the imagery and lidar data. It was especially helpful for distinguishing areas that might be woody vegetated wetlands from areas that were non-wetland riparian areas. These usual habitat types also helped to highlight areas that might be wetlands and to direct a closer investigation of the 2018 NAIP and 2017 lidar imagery. If the NAIP and lidar elevation data did not support or indicate a possible aquatic feature that was indicated in VegCAMP, then no aquatic feature was mapped. The Sacramento-San Joaquin River Delta 2016 data and documentation can be accessed at: https://wildlife.ca.gov/Data/VegCAMP

Table 3. NVCS plant species (NVCS_Name) grouped by usual habitat type for DARI supporting vegetation layer.

POSSIBLY WOODY WETLAND OR RIPARIAN WOODLAND	
Salix exigua	
Salix gooddingii	
Salix laevigata	
Salix lasiolepis	
Salix lucida	
POSSIBLY WETLAND OR POSSIBLY WETLAND RIPARIAN	
Arid West freshwater emergent marsh	
Atriplex prostrata - Cotula coronopifolia	
Azolla (filiculoides, microphylla)	
Carex barbarae	
Californian warm temperate marsh/seep	
Californian mixed annual/perennial freshwater vernal pool / swale bottomland	
Juncus arcticus (var. balticus, mexicanus)	
Naturalized warm-temperate riparian and wetland group	
Schoenoplectus (acutus, californicus)	

	Schoenoplectus americanus
	Southwestern North American alkali marsh/seep vegetation
	Temperate Pacific tidal salt and brackish meadow
	Typha (angustifolia, domingensis, latifolia)
	Western North American disturbed alkaline marsh and meadow
USUALL	Y RIPARIAN
	Acer negundo
	Alnus rhombifolia
	Fraxinus latifolia
	Juglans hindsii and Hybrids
	Platanus racemosa
	Populus fremontii
	Quercus lobata
	Ailanthus altissima
	Eucalyptus spp Ailanthus altissima - Robinia pseudoacacia
	Quercus agrifolia
	Quercus wislizeni (tree)
WATER	OR MODIFIED
	Water
	Urban
	Agriculture
OTHER	
	Ludwigia (hexapetala, peploides)

Previous versions of VegCamp (VegCamp 2007) were referred to as needed to evaluate change over time. The Department of Fish and Wildlife's Vegetation dataset for the Delta was developed by Aerial Information Systems using true color 1-foot resolution aerial photography from spring 2002 with additional marginal areas of the study area supplemented by true color 1-meter resolution photography from summer 2005. The Sacramento-San Joaquin River Delta 2007 data and documentation can be accessed at: https://wildlife.ca.gov/Data/VegCAMP

Google Earth Pro is a free, publically accessible geographic information system. Google Earth provides high resolution imagery and topography, as well as, photographs and place names. Google Earth has a time slider that allows for the examination of imagery from multiple dates.

This was used to assess the existence and persistence of wetlands. Google Earth Pro can be downloaded at: https://www.google.com/earth/versions/

2012 Vernal Pool Habitats (Witham et al. 2014). This project updated a 2005 geodatabase of vernal pool habitats in the Great Valley CA in 2012 and compared changes in the amount and distribution of vernal pool habitats between 2005 and 2012. The project defined "Vernal pool habitat" as vernal pools and their surrounding upland (typically grasslands). The features in this dataset provide an estimate of percent cover and density of vernal pool habitat within each polygonal feature. The Witham/Holland vernal pool habitat geodatabase was used in the DARI mapping effort as a guide to help locate areas where vernal pools and vernal pool complexes are likely to be present. The NAIP 2018 imagery was used to actually map the vernal pool complexes and individual vernal pools. For more information visit https://vernalpools.org/. Data can be downloaded at: https://databasin.org/datasets/248a624e6f264668a83e39f388caaf72

European Commission Joint Research Centre's Global Surface Water Dataset (Landsat) 1984-2018

Jean-Francois Pekel, Andrew Cottam, Noel Gorelick, Alan S. Belward, High-resolution mapping of global surface water and its long-term changes. Nature 540, 418-422 (2016). (doi:10.1038/nature20584)

From the Global Surface Water Dataset, we used the Recurrence map. The Recurrence map provides information concerning the inter-annual behavior of water surfaces and captures the frequency with which water returns from year to year. Although based on a relatively coarse spatial scale of roughly 30m, this dataset was useful to help identify areas that were frequently inundated. This layer helped to identify fields that were managed in a way that function as wetlands frequently such as flooded rice fields. This layer also helped to identify at a coarse scale where to look for other inundated aquatic features. Data can be downloaded at: https://global-surface-water.appspot.com/

Expert local knowledge was also used to review the draft dataset and identify missing aquatic features. New features identified by local experts were cited with the code "Local_Review". The "Organization" field is used to attribute the person or agency that provided the local review.

Documenting the Data Sources

The "SourceDataset" attribute field in the DARI geodatabase describes the source dataset or datasets used to identify and map each aquatic feature. Most aquatic features will be mapped using the primary data sources. However, some areas (or feature classes) may be digitized with a heavy reliance on ancillary data or older images in order to capture the full extent of a feature. Examples of this include using the Global Surface Water Dataset, or using Google Earth imagery to better establish the water regime and extent of an aquatic feature.

6 DARI Geodatabase Schema

The following schema includes all finaled fields used in DARI with an accompanying description. See <u>Appendix C</u> for a list of intermediary fields used when developing DARI.

DARI Polygon Layer:

WetlandType -

This field provides a multi-letter code describing the wetland type. Refer to Data Dictionary for a complete list of codes.

WetTypeOther -

This field contains additional information regarding wetland use or status. This includes if a wetland is part of a known duck club, rice field, other flooded agriculture, livestock waste pond, or restoration area. This information was added where readily available and may not be exhaustive for the region.

SourceDataset -

This field provides a list of concatenated source datasets that were used for delineation and classification of a polygon. Each source is separated by a ";".

Depth -

This field distinguishes deep (greater than 12 feet below MLLW) and shallow tidal channels (less than 12 feet below MLLW).

Managed -

This field allows a convenient selection of all aquatic features mapped as managed.

Tidal -

This field provides a convenient distinction between tidal and non-tidal aquatic features.

Natural -

This field provides a convenient distinction between natural and unnatural features. Given the highly modified nature of the Delta, this distinction could be somewhat subjective and other definitions of the two categories would lead to different results.

Veg -

This field provides a convenient distinction between woody and non-woody vegetated areas.

Name -

This field provides feature name information and was originally populated from existing NWI data. It is not comprehensive of all local names in the Delta and could be improved through the CARI Editor tool.

DARI Line Layer:

WetlandType -

This field provides a multi-letter code describing the wetland type. Refer to Data Dictionary for a complete list of codes.

SourceDataset -

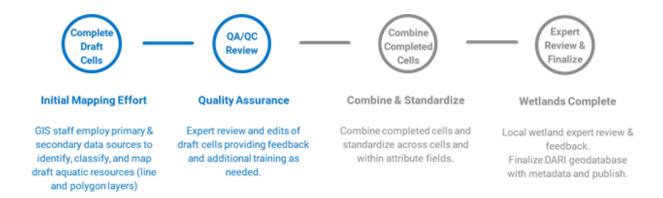
This field provides a list of concatenated source datasets that were used for delineation and classification of a polygon. Each source is separated by a ";".

Name -

This field provides feature name information and was originally populated from existing NHD data. It is not comprehensive of all local names in the Delta and could be improved through the CARI Editor tool.

7 Mapping Procedures

This section describes the Aquatic Resources Inventory development process employed by the DARI 2020 mapping team.



Complete Draft Cells - Detailed Mapping Workflow

The Legal Delta region was divided into 160 5 km grid cells and GIS trained mapping staff were assigned cells to work on (**Figure 9**). Staff followed the same stepwise procedure described below and the same individual mapped all the features for any given cell. This ensured traceability for quality control and helped to achieve consistency across all cells.

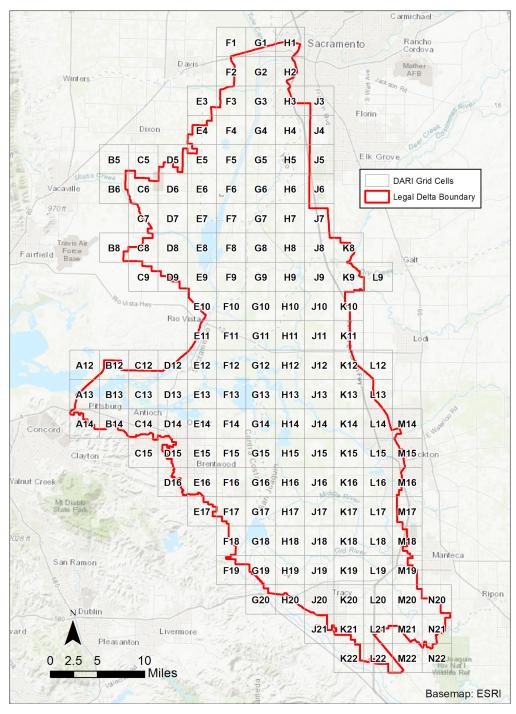


Figure 9. Map of DARI's 5 km² grid cells used to map aquatic resources in the Legal Delta (n=160).

Within the grid cell layer a field was used by the DARI mapping team to track the progress status of that particular cell. Below is the schema used to describe the cell progress status:

Code	Code Status
0	Not started
1	In progress
2	Ready for QA
3	QA round complete, ready for mapper revisions
4	Mapper revisions complete
5	Mapper revisions approved and added to Master

Each mapper stepped through the following steps to complete a DRAFT DARI dataset that was then submitted for quality assurance review and feedback.

- 1. Identify the 5km grid cell(s) to be mapped
 - a. Note whether any adjacent cells have been mapped already
 - b. Check the grid cell status to confirm it is free to map "0 Not started"
- 2. Ask yourself 'where is this in the Delta and what's going on in this cell?'
 - a. Zoom out: look at the cell's position in the Delta. What wetland maintaining forms and processes are present there? For example: review the tidal extents, fluvial extents, levee barriers, subsidence, evidence of managed flows.
- 3. Review the DARI beta layer within your cell.
 - a. Presence/Absence of wetlands. Do you agree?
 - b. Classification of wetlands: Do you agree?
- 4. Create DRAFT mapping polygon and line layers
 - a. In ArcCatalog, make a copy of the DARI_DRAFT_Template.gdb (containing blank polygon and linework feature classes) into your local DRAFT_Mapping folder in order to maintain consistent fields and schemas.
 - b. Rename your copy of the GDB and feature classes within it: "[MapperName]_[gridcellcode]_DRAFT" and "[MapperName]_[gridcellcode]_Linework_DRAFT"
 - c. change status of grid cell status field to '1 In progress'
- 5. Bring your DRAFT mapping layers into your Mapping MXD

- 6. Start your edit session on your DRAFT layers
 - a. Right-click your DRAFT mapping layer in your Table of contents
 - b. Edit Features>Start Editing
- 7. Capture and classify all wetlands with your cell(s).
 - a. Try to maintain good topology (no slivers, no overlaps, no gaps, no duplicates, no unintentional dangles, line vertices must match at ends, etc.)
 - b. Polygons may be directly copied from *DARI_beta* and either used as is or modified to match 2018 NAIP Imagery and 2019 topo-bathymetry LiDAR. If *DARI_beta* polygons are not sufficiently accurate it may be more efficient to draw fresh polygons.
 - c. For any potential wetland feature, utilize the primary data sources to decide if it is a wetland, the boundaries of that wetland, and the correct wetland type. Use the secondary sources to support your decisions.
 - d. Mapping styles and practices vary from person to person. There are no rules on how you should map; for instance, beginning with lines or polygons, completing the cell north to south, or completing Tidal features before Non-Tidal features. Each mapper will develop their own style and rhythm. However, each mapper must practice good GIS habits and be cognizant of maintaining a high quality of mapping throughout each cell.
 - Some possible approaches include: starting with tidal channels first; completing the mapping of each island or tract one at a time; the use of the draw tool to create a series of parallel lines across the cell to help with a systematic row by row or column by column inspection of the cell area.
- 8. Daily Backup- make daily backups so as not to lose your work and to share with the team.
 - a. After saving edits and quitting ArcMap, ZIP today's version of the DRAFT GDB
 - i. Right click > Send To > Compressed (Zipped) folder
 - b. Rename the ZIP: [originalfilename] [today'sYYYYMMDD].zip
- 9. Self Quality Assurance Check
 - a. Review the integrity of your polygons, and
 - b. completeness of the attribute table, especially the core and QA fields:
 - i. WetlandType
 - ii. WetTypeOther
 - iii. SourceDataset
 - iv. Mapper2020

- v. QA Question
- vi. Notes (if needed)
- 10. Update DARI MASTER layers (polygon and line layers)
 - a. Start an Edit session on your version of the DARI MASTER layer
 - b. Reconcile your version to bring in any updates. Check cell boundaries for adjacent features that may need to be edge-matched with your DRAFT data.
 - c. Check that the wetlands classifications agree for wetlands crossing cell boundaries
 - d. Select any features you would like to transfer (might be all of them)
 - e. Use the 'Append' tool, or Copy/Paste your polygons into your version of the integration branch
 - f. Match edges of your cell with pre-existing polygons and lines, if any
 - g. Save Edits and Post Changes
- 11. Update the GridCells_5km Progress attribute.
 - a. Find your cell and change the status of 'Progress' field to "2 Ready for QA".
- 12. Mapped grid cell is ready for QA review by QA-Officer
 - a. At this point, one of the QA Officers will spend time reviewing each feature within the cell that was mapped. Details of the QA process are described in section 9 below.
- 13. Identify next adjacent or assigned cell
 - a. change status of 'Progress' field to '1 In progress'
 - b. Map the next cell!

8 Standardizing the MASTER DARI Geodatabase

Once the initial DARI mapping of the 5 km² cells was completed and individual grid cells passed QA review (described below), cells were incorporated into the MASTER DARI geodatabase and standardized as follows:

- All features that crossed cell boundaries were reviewed to ensure their edges and classification codes matched.
- Wetland Type codes were reviewed and standardized.
- Explode multipart features.
- Adjacent polygons with the same field values were merged.
- Topology checks were run to remove all duplicates, overlaps, gaps, and slivers.
- Data Source information was standardized.

- Artificial paths were standardized and identified where line features intersected non channel open water polygons (mostly for lakes and lagoons).
- Deep vs shallow tidal channels were attributed based off of bathymetry data and the definitions specified above.
- All features that were under their target or minimum mapping unit were reviewed and removed or corrected (merged or deleted).
- Pannes and Playa features were visually reviewed.
- Selections of polygons were made to review and fix any existing questionable adjacent polygons (e.g. depressional wetland polygons sharing a boundary with tidal features).
- Lines were dissolved on all fields, checks run to address line vertices that need to be snapped, trimmed, and/or planerized to correct linework topology errors.
- Line feature classes were compared to overlapping polygon feature classes in order to ensure consistency between the two feature classes.
- All field values were standardized where possible.

9 DARI Oversight and Quality Assurance and Quality Control (QAQC)

QAQC is essential to assess and document the accuracy of any GIS based aquatic resources inventory. Careful training on the DARI mapping methods and classification system, and mentoring of mapping staff is also essential. The DARI 2020 mapping effort had an oversight workgroup and two levels of QA review: (1) all grid cells were reviewed by QA Officers and, (2) once the entire geodatabase was compiled and standardized a random 10% sample was reviewed to assess the overall quality of the inventory.

Bay-Habitat GIS Workgroup

The DARI 2020 project hosted the ongoing *Bay-Habitat GIS Workgroup* (or Level-1 workgroup) consisting of local and national wetland scientists and GIS experts that meet on a regular basis to advise and review project content including: (1) the development of any new wetland types specific to the Delta region, (2) draft GIS datasets, and (3) updates to the classification system and/or cross-walks. A level-1 oversight group is essential to ensure the integrity of the final GIS product, while also supporting and facilitating local usage.

Training the DARI Mappers and Grid Cell Level QA Review

The DARI 2020 mapping effort employed a small group of GIS mappers who digitized the aquatic resources in the Legal Delta based on DARI's mapping procedures. The mappers were extensively trained on the DARI mapping procedures and classification system by SFEI's GIS and wetlands experts and DARI QA Officers: Pete Kauhanen, Micha Salomon, Lauren Stoneburner, and Sarah Pearce. Pete Kauhanen and Micha Salomon conducted all of the initial training for the mappers, including wetland identification as well as GIS mapping practices. The QA Officers provided guidance and fielded questions during the mapping process. The officers also

reviewed all newly digitized draft 5km grid cells from each of the mappers in detail in an iterative QA review process described further below ⁷.

QA Review of All Grid Cells

The QA Officers reviewed all newly digitized grid cells completed by each DARI mapper. In an iterative QA and mentoring process, both the line and polygon layers were carefully reviewed by SFEI's QA-officer for completeness of attribute fields, accuracy against the Primary data mapping data (2018 NAIP imagery and 2017 LiDAR based DEM), accuracy in the Wetland Type classification, and accuracy in GIS topology (e.g. ensuring line segments aligned, or polygon edges were aligned). The officers provided comments and/or edits to the draft datasets and returned them to the original mapper for updating. In addition, during the initial months of mapping, the officers met with mappers weekly to provide additional feedback and training.

The mappers reviewed comments and made corrections to both individual polygons and/or lines, as well as to multiple features that had the same errors. Once updated, the grid cell was returned to the QA officers for a second review and finalization. Typically a different QA officer performed the second QA step. At this time the officer would confirm that all features were "finalized" and no remaining errors existed within the cell. The cell was then marked as final.

Throughout the mapping process, the project lead and QA Officers met weekly to address questions, provide general feedback, and generally keep the team aligned on mapping protocols or new developments.

Final 10% Random Sample Accuracy Assessment Review

Once the final MASTER DARI GIS dataset was compiled for the full extent of the Legal Delta, all cells reviewed by QA Officers, and standardized (see Sections 8 and 9 above), a random sample of 10% of the finalized cells were generated and reviewed among SFEI's QA Officers for each of 4 key mapping parameters (alignment [overlay], over-mapping, under-mapping, and attribution [coding]) to quantify mapping consistency across the dataset. The 2020 DARI QAQC units for the final 10% random sample employed the same 5 km² grid cells that were established for creating DARI (see Figure 4 in Section 7 above). This random sampling approach provides an objective accuracy assessment of each of the parameters for a known percentage of the mapping effort that is representative of the effort as a whole.

Random Sampling Tools

ESRI tools were used to select a random 10% sample (16 grid cells) of the 160 DARI grid cells.

Note: If needed, the freeware "Geospatial Modeling Environment (GME)" GME is a platform designed to facilitate rigorous spatial analysis and modeling. The GME tools can also be used to create a vector grid of the DARI QAQC units and then perform a random selection of 10% of the units for the final QA review. **Figure 10** is an old screenshot of the previous version of the tool. The tools are available at: http://www.spatialecology.com/gme/index.htm.

⁷ The QA Officers were not the same people who digitized the draft map.

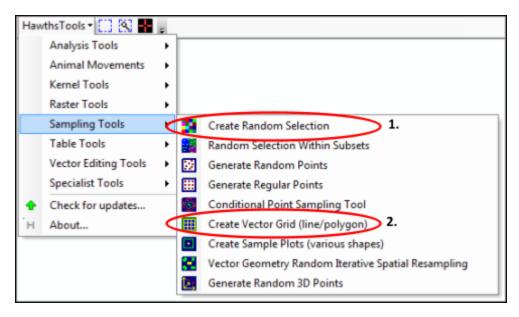


Figure 10. Screenshot of the grid cell and random sampling tools available in Geospatial Modeling Environment).

10 Accuracy Assessment Procedures

SFEI's three QA Officers each exchanged and reviewed the 16 grid cells (10% of the mapped area) so that each officer reviewed new cells that they had not previously evaluated or corrected during the initial mapping effort. The following review process was completed for both the line and polygon layers.

Line Layer (Channel Network)

Overview

- Visually inspect the stream network at 1:10,000 using the assessment unit border and mapping datasets (imagery, DEMs, supplemental data) when necessary. This is a general overview used to correct any gross errors (such as misclassifications, missing features, misalignment of features with imagery etc.).
- Look for streams that cross over raised areas, such as ridges and levees.
- Make sure all channel classification codes are correct, and no aberrant codes exist.
- Dissolve linework by wetland type and source (and any other attribute field you wish to keep). Then explode multipart features and "planarize" the lines.
- Edge-match features that cross adjacent units by snapping lines to endpoint.
 Then merge the lines if they are the same type, and split line segments at ends.
- review all linear features under the minimum mapping unit with dangles to ensure alignment with mmu guidelines.

Specific Process

Ten percent of each assessment unit is randomly sampled as explained above.

- 1. Organize data in file geodatabases by assessment unit (5 km² grid cells).
- 2. Organize versions of accuracy assessment by dataset.
 - o Quad AA 1
- 3. Import draft stream network as a feature class into the dataset.
- 4. Clip the draft stream network to the sampled grid cell and rename the feature class "DRAFT".
 - quad DRAFT
- 5. Make a copy of DRAFT feature class in the same geodatabase and rename "STANDARD," with the initials of the reviewer appended to the name. This STANDARD feature class will be edited for the accuracy assessment process.
 - o quad STANDARD PQ
- 6. Edits to the STANDARD feature class are done by a wetland mapping professional exactly according to the DARI mapping standards and protocols. The mapping professional must not be the same person who digitizes the draft map. Review steps listed above.
- 7. Create a topology for the feature dataset.
 - Apply the following rules: "Must Not Have Dangles," "Must Not Overlap,"
 "Must Not Self-Overlap," "Must Not Intersect," "Must Not Self-Intersect."
 - Dissolve linework by type and source, explode multi-part features, and run the "planarize" tool found in the topology toolbar, to re-segment lines (be sure to remove all domains from the feature before you planarize).
- 8. Run the First Order Tool. This tool finds all first-order channels and verifies the length is greater than the mmu for that channel type. All first-order channels below the mmu must be checked for adherence to standards on a case-by-case basis. That is, if they are not connected to a water body or touching the cell boundary (a subset of a longer channel), they should be deleted. Merge the main stem lines where a tributary is deleted.
- Compile all reviewed assessment units and run the "Stream Network QAQC Model". This model will check for differences in the DRAFT and QAQC STANDARD layers in alignment, under-mapping, over-mapping, and feature attribution (coding). An accuracy assessment results table will be exported to the input geodatabase.

These coding parameters measure the accuracy of draft channel classifications relative to the corrected standard channel map (**Figure 11**).

i. ALIGNMENT

The alignment parameter measures the degree to which the draft channel map is aligned with the corrected QAQCchannel map. Each draft channel must be within 7.5 meters of its corresponding corrected QAQC channel. The length of a draft channel that exists within this area will be considered correctly aligned.

ii. OVER-MAPPING

The over-mapping parameter measures the amount of the draft channel map that extends beyond the corrected QAQC channel map. The total length of the draft channel network is compared to the total length of the corresponding corrected QAQC channel network, discounting the area of misalignment (as calculated by the Alignment metric).

iii. UNDER-MAPPING

The under-mapping parameter measures the amount of the standard channel map that extends beyond the draft channel map. The total length of the draft map is compared to the total length of the standard map, discounting the area of misalignment (as calculated by the Alignment metric).

iv. CODING

The coding parameter indicates if the feature attribution of stream and wetland type codes are correct (i.e., consistent between the DRAFT and QAQC STANDARD layers).

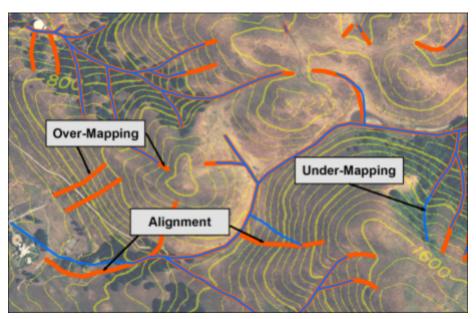


Figure 11. Example of channel mapping errors.

- 11. For this accuracy assessment, accepted passing parameter error rates units are less than 15%. If any of the parameters do not meet the standards, additional refinement of the dataset is needed inorder to bring it into accepted ARI standards. Error rates can direct mappers to target review of features that represent the largest source error. Once the dataset is refined it can undergo a new random sample and accuracy assessment to reassess the datasets' accuracy.
- 12. The final data's accuracy assessment values become a permanent attribute of the dataset.

Polygonal Wetlands Layer

Overview

- Visually inspect the wetlands network at 1:10,000 using the assessment border and mapping datasets (imagery, DEMs, supplemental data) when necessary. This is a general overview used to correct any gross errors.
- Look for misidentification errors, particularly tree shadow mistaken for open water, and dark areas mistaken for actual seeps and springs. Vegetation surrounding open water is often overlooked, and this must be attributed separately.
- Make sure all classification codes are correct, and no aberrant codes exist.
- Dissolve polygons by wetland type and data source (and any other attribute field you wish to keep) and explode multipart features.
- Merge adjacent quads by merging polygons of the same wetland type, and make sure no small slivers or overlapping areas exist.

Specific Process

Ten percent of each assessment unit is randomly sampled as explained above (the same sample as used for lines).

- 1. Organize data in file geodatabases by assessment unit (5 km² grid cells)
- 2. Organize versions of accuracy assessment by dataset.
 - Quad AA 1
- 3. Import draft aquatic feature polygons as a feature class into the dataset.
- 4. Clip the draft aquatic feature polygons to the sampled grid cell and rename the feature class "DRAFT".
 - o quad DRAFT

- 5. Make a copy of DRAFT feature class in the same geodatabase and renamed "STANDARD", with the initials of the reviewer appended to the name. This STANDARD feature class will be edited for the accuracy assessment process.
 - quad STANDARD PQ
- 6. Edits to the STANDARD feature class are done by a wetland mapping professional according to the DARI mapping standards and protocols. The mapping professional must not be the same person who digitizes the draft map. Review steps listed above.
- 7. For QAQCed wetlands, merge all polygons by type, then explode multi-part features. Create a topology for the feature dataset and apply the following rules: "Must Not Overlap", "Must Not Have Gaps". Also check the Shape_Area field and make sure all wetlands are larger than the targeted mapping unit size for each wetland class.
- 8. Once corrections have been made, the DRAFT and corrected STANDARD layers are fed into the "Polygon QAQC Model". This model checks for differences in alignment (overlay), over-mapping, under-mapping, and attribution (coding). A table of error parameters will be exported to the geodatabase supplied in the input.

These coding parameters measure the accuracy of draft quad's classification of wetlands and aquatic systems (**Figure 12**). Coding is only compared in areas where both the QAQC standard data and draft data have overlapping polygons.

i. OVERLAY ALIGNMENT

The overlay parameter measures the validity of the intersecting draft polygons with the corrected standard polygons. Overlay is determined using common areas of interpretation or intersecting regions. Three overlay parameters are measured: overlay alignment, overlay over-mapping, and overlay under-mapping.

ii. OVER-MAPPING

The over-mapping parameter measures the degree to which the draft data include more polygons than the corrected QAQC Standard.

iii. UNDER-MAPPING

The under-mapping parameter measures the amount of area not mapped in the draft data that is mapped in the corrected QAQC standard.

iv. CODING

The coding parameter indicates if the feature attribution of stream and wetland type codes are correct (i.e., consistent between the DRAFT and corrected QAQC STANDARD layers).

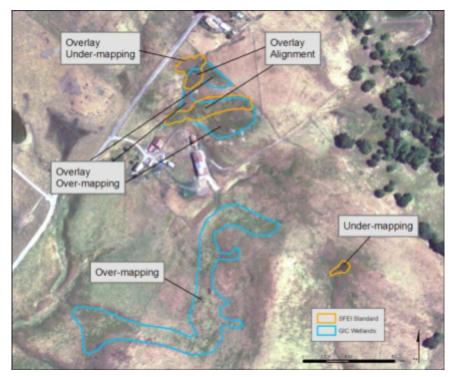


Figure 12. Example polygon mapping errors, showing overlay alignment, overlay over-mapping, overlay under-mapping, over-mapping, and under-mapping (coding parameter is not represented). Not all visible wetlands were mapped for this example.

- 9. For this accuracy assessment, accepted passing parameter error rates units are less than 15%. If any of the parameters do not meet the standards, additional refinement of the dataset is needed inorder to bring it into accepted ARI standards. Error rates can direct mappers to target review of features that represent the largest source error. Once the dataset is refined it can undergo a new random sample and accuracy assessment to reassess the datasets' accuracy.
- 10. The final data's accuracy assessment values become a permanent attribute of the dataset.

Accuracy Assessment Results

Line Accuracy Assessment Results (rounded to the nearest 1/100th of a percent)

Alignment Percent Error	0.37%
Over-Mapping Percent Error	1.41%
Under-Mapping percent Error	0.53%
Coding Length Percent Error	9.19%

Polygon Accuracy Assessment Results (rounded to the nearest 1/100th of a percent)

Coding Area Percent Error	0.63%
Coding Count Percent Error	2.69%
Over-Mapping Percent Error	0.72%
Under-Mapping Percent Error	0.47%
Overlay Alignment Percent Error	0.17%
Overlay Over-Mapping Percent Error	0.31%
Overlay Under-Mapping Percent Error	0.17%

The final accuracy assessment showed particularly low error rates. This can be attributed to a number of factors. First of all each quad had been reviewed by QA Officers/wetland mapping experts numerous times to ensure that mapping was being conducted in a manner that is in alignment with the DARI SOP. They first were reviewed to help direct and train the original mappers of grid cells and then reviewed a second or third time and corrected by QA Officers to bring them further into alignment. Efforts were made to have different QA Officers review cells at each step. Secondly, during the accuracy assessment changes were made to the corrected Standard layers when classifications or feature delineations were clearly wrong. There were instances where best professional judgment is called and a classification or boundary of a delineation isn't fully clear. As long as there was evidence in the mapping data to support the classification then it was not corrected in the "Standard" layer. An example of this could be agricultural ditches mapped as unnatural channels. In some cases initial mappers mapped more of these in some grid cells than in other grid cells because they were faint and may or may not really seem like a true ditch that is conveying water. Since that determination from heads up digitizing is somewhat subjective, these linear features were only removed in the "Standard" layer if there wasn't any indication that a ditch was there at all. This acknowledges that there is

some error from human interpretation of the remotely sensed data and it was difficult to quantify it in the accuracy assessment process without significant field reference data collection. Additional approaches that may help to limit this type of error in the future would be to employ more automated mapping methods to provide additional mapping consistency as well as possibly provide more quantitative definitions of landscape features such as agricultural fields and different types of ditches within them.

11 Data Limitations

The purpose of DARI was to map channels, wetlands and deepwater habitats in the Legal Delta to produce information on the location, type and size of these resources. The data were prepared from the analysis of high altitude imagery. Wetlands were identified based on vegetation, visible hydrology and geography.

A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or DARI classification. The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the ancillary data.

Metadata should be consulted to determine the date of the source imagery used and any mapping conventions or issues that may have been identified. Wetlands or other mapped features may have changed since the date of the imagery and/or field work due to natural processes or human related activity. Therefore, there may be differences in polygon boundaries or classifications between the information depicted in the DARI geodatabase and the actual conditions on the ground.

12 References

- California Wetlands Monitoring Workgroup (CWMW). 2013. California Rapid Assessment Method (CRAM) for Wetlands, Version 6.1 pp. 67. Available at:

 https://www.cramwetlands.org/sites/default/files/2013-04-22_CRAM_manual_6.1%20all.pdf
- Durand et al. 2016 https://escholarship.org/uc/item/85c9h479
- Friesen, T.A. 2005. Biology, behavior, and resources of resident and anadromous fish in the Lower Willamette River: Final report of research 2000-2004. Oregon Department of Fish and Wildlife.
- Grossinger, R.M. 1995. Historical Evidence of Freshwater Effects on the Plan Form of Tidal Marshlands in the Golden Gate Estuary. Masters Thesis.
- Kreb, Bian, E. Fintel, L. Askim, and L. Scholl. 2019. Vegetation and Land Use Classification and Map Update of The Sacramento-San Joaquin River Delta. Prepared for the Delta Stewardship Council by the Geographical Information Center, North State Planning and Development Center, and California State University, Chico. November 2019. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=174866&inline
- Moore, R.B., L.D. McKay, A.H. Rea, T.R. Bondelid, C.V. Price, T.G. Dewald, and C.M. Johnston. 2019. *User's guide for the national hydrography dataset plus (NHDPlus) high resolution: U.S. Geological Survey Open-File Report 2019—1096*, 66 p., Available at: https://pubs.usgs.gov/of/2019/1096/ofr20191096.pdf
- Mount and Twiss 2005, https://escholarship.org/uc/item/4k44725p
- San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC). 2013. Mapping Standards and Methodology for Channels, Wetlands, and Riparian Areas in the Sacramento San Joaquin Delta. Produced by SFEI-ASC and The Department of Water Resources for Conservation Measure 1 (conveyance) of the Bay Delta Conservation Plan (BDCP) EIR/EIS. Unpublished August 8, 2013.
- San Francisco Estuary Institute-Aquatic Science Center (SFEI-ASC). 2014. A Delta Transformed: Ecological Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta. Prepared for the California Department of Fish and Wildlife and Ecosystem Restoration Program. A Report of SFEI-ASC's Resilient Landscapes Program, Publication #729, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA. Report is available at www.sfei.org/projects/delta-landscapes-project.
- San Francisco Estuary Institute (SFEI). 2016. California Wetland and Riparian Area Protection Policy. Technical Advisory Team. Technical Memorandum No. 5: Stream Definition (Final Draft). SFEI Contribution No. 1001. Version 2. April 20, 2016.
 - https://www.sfei.org/documents/california-wetland-and-riparian-area-protection-policy-technical-advisory-team-technical-3
- SFEI & SPUR 2019. San Francisco Bay Adaptation Atlas. pp. 26-27.

- Siegel, S. and D. Gillenwater. 2020. Methods used to Map Habitat Restoration Opportunity Areas for the Delta Plan Ecosystem Amendment. Draft Technical Memorandum prepared for the Delta Stewardship Council. Sacramento, CA. March 10, 2020.
- Witham, C.W., R.F. Holland and J.E. Vollmar. 2014. Changes in the Distribution of Great Valley Vernal Pool Habitats from 2005 to 2012. Sacramento, CA. Report prepared for the U.S. Fish and Wildlife Service and Bureau of Reclamation CVPIA Habitat Restoration Program under Grant Agreement No. F11AP00169 with the USFWS.

Appendix A. DARI Crosswalks to CARI and NWI

Table A.1. Crosswalk between DARI and the CARI Classification.8

^{*}For TV, TVw, and TP, NWI Freshwater Modifiers can be used to help distinguish Non-saline boundaries (S,R,T,V).

D	ARI Classification		CARI Classification
Wetland Type Code	Feature Description	Click Code	Click Label
тс	Tidal Channel Natural	ORNRTSN	Openwater Riverine Natural Tidal Subtidal Non-vegetated
тси	Tidal Channel Unnatural	ORURTSN	Openwater Riverine Unnatural Tidal Subtidal Non-vegetated
TV	Tidal Vegetated Natural	WENENIv*	Wetland Estuarine Natural Non-saline Intertidal Vegetated
TVw	Tidal Vegetated Woody Natural	WENENIF*	Wetland Estuarine Natural Non-saline Intertidal Forested
TGPOWU	Lagoon Perennial Open Water Unnatural	OGUGnSN	Openwater Lagoon Unnatural Subtidal Non-vegetated
ТР	Tidal Marsh Panne	WENENIN*	Estuarine Saline Natural Non-saline Intertidal Non-vegetated
С	Channel Natural	WRNRuuu	Wetland Riverine Natural
cu	Channel Unnatural	WRURuuu	Wetland Riverine Unnatural
cv	Channel Vegetated Natural	WRNRuuv	Wetland Riverine Natural Vegetated
cvu	Channel Vegetated Unnatural	WRURuuv	Wetland Riverine Unnatural Vegetated
CVw	Channel Vegetated woody	WRNRuuF	Wetland Riverine Natural Forested
CVwU	Channel Vegetated woody Unnatural	WRURuuF	Wetland Riverine Unnatural Forested
CE	Channel Engineered	ORURuuN	Openwater Riverine Unnatural

⁸ This table only shows DARI classifications found in the current project extent.

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			Non-vegetated
DOWN	Depressional Open Water Natural	ODNDuuN	Openwater Depressional Natural Non-vegetated
DOWU	Depressional Open Water Unnatural	ODUDuuN	Openwater Depressional Unnatural Non-vegetated
DVN	Depressional Vegetated Natural	WDNDuuv	Wetland Depressional Natural Vegetated
DVU	Depressional Vegetated Unnatural	WDUDuuv	Wetland Depressional Unnatural Vegetated
LOWN	Lacustrine Open Water Natural	OLNLnuu	Openwater Lacustrine Natural
LOWU	Lacustrine Open Water Unnatural	OLULnuu	Openwater Lacustrine Unnatural
LVN	Lacustrine Vegetated Natural	WLNLnuv	Wetland Lacustrine Natural Vegetated
LVU	Lacustrine Vegetated Unnatural	WLULnuv	Wetland Lacustrine Unnatural Vegetated
PUU	Playa Unvegetated Unnatural	WDUPnnN	Wetland Depression Unnatural Playa Non-vegetated
PVU	Playa Vegetated Unnatural	WDUPnnv	Wetland Depression Unnatural Playa Vegetated
SU	Seep Unnatural	WSUSSnv	Wetland Slope Unnatural Seep and Springs Vegetated
FS	Woody Slope Natural	WSNSFuF	Wetland Slope Natural Forested
FSU	Woody Slope Unnatural	WSUSFuF	Wetland Slope Unnatural Forested
WM	Non-woody Slope Natural	WSNSWuH	Wetland Slope Natural Wet Meadow Herbaceous
WMU	Non-woody Slope Unnatural	WSUSWuH	Wetland Slope Unnatural Wet Meadow Herbaceous
VP	Vernal Pool	WDUVluu	Wetland Depression Unnatural Individual Vernal Pool
VPC	Vernal Pool Complex	WDUVVuu	Wetland Depression Unnatural Vernal Pool System

М	Managed	WDMDSnu	Wetland Depressional Managed Seasonal
	*Managed type: Duck Ponds	WDMDSnu	Wetland Depressional Managed Seasonal
	*Managed type: Rice Fields	WDMDSnf	Wetland Depressional Managed Seasonal Farmed
	*Managed type: Restoration Area	WDMDSnu	Wetland Depressional Managed Seasonal
	* Add "M" Anthropogenic Modifier to all wetlands with Managed Modifier	M	
Channel Type Code	Feature Description		
тс	Tidal Channel Natural	OTN	Tidal Riverine Natural
TCU	Tidal Channel Unnatural	оти	Tidal Riverine Unnatural
С	Channel Natural	WRN	Fluvial Riverine Natural
cu	Channel Unnatural	WRU	Fluvial Riverine Unnatural
CE	Channel Engineered	ORU	Fluvial Riverine Unnatural
CSD	Channel Subsurface Drainage	WRS	Subsurface Drainage
АР	Artificial Path	AP	Artificial Path

Table A.2. Crosswalk between DARI and the Cowardin classification system used by the NWI of the USFWS.

Draft completed by Elaine Block, Wetlands Coordinator (West Coast States), NWI, Fish and Wildlife Service.

Level 1	Level 2	Wetland Type	Stands For	Cowardin Classification	Cowardin Classification 2	Cowardin Classification 3
Tidal	Channel	тс	Tidal Channel Natural	R1UBT	E1UBL	
		TCU	Tidal Channel Unnatural	R1UBTx		
	Marsh	TV	Tidal Vegetated Natural	PEM1S	E2EM1P	PAB3/4T
		TVw	Tidal Vegetated Woody Natural	PFO1S	PSS1/6S	E2SS6P
	Lagoon	TGPOWU	Lagoon Perennial Open Water Unnatural	PUBT		
	Panne	TP	Tidal Marsh Panne	PUSS		
Non-Tidal	Channel	С	Channel Natural	R4SBA		
		CU	Channel Unnatural	R4SBAx		
		cv	Channel Vegetated Natural	PEM1A		
		CVU	Channel Vegetated Unnatural	PEM1Ax		
		CVw	Channel Vegetated woody	PFO1A	PSS6A	PSS1A
		CVwU	Channel Vegetated woody Unnatural	PFO1A	PSS6A	PSS1A
		CE	Channel Engineered	R2UBFr		
	Depressi onal	DOWN	Depressional Open Water Natural	PUBF		
		DOWU	Depressional Open Water Unnatural	PUBFx/h		
		DVN	Depressional Vegetated Natural	PEM1A	PSS1A	PFO1A
		DVU	Depressional Vegetated Unnatural	PEM1Ax/h	PFO1Ax/h	PSS6Ax/h

Lacustrin		Lacustrine Open Water			
е	LOWU	Unnatural	L1UBHx/h		
		Lacustrine Vegetated			
	LVU	Unnatural	PEM1Ax/h	PFO1Ax/h	PSS6A/x
Slope	su	Seep Unnatural	PEM1B		
	FS	Woody Slope Natural	PFO1B	PSS1/6B	
	FSU	Woody Slope Unnatural	PEM1Bh	PSS1/6Bh	
	WM	Non-woody Slope Natural	PEM1B		
		Non-woody Slope			
	WMU	Unnatural	PEM1Bh		
Vernal					
Pool	VP	Vernal Pool	PEM1A		
	VPC	Vernal Pool Complex	PEM1A		
Managed	М	Managed	PEM1Am/f		

Appendix B. Converting DARI to NWI classification

DARI was subsequently crosswalked and converted to NWI classifications using a crosswalk and through additional spatial analysis to assign vegetation type, water regime, salinity, and other special modifiers. This included using the dominant CalVeg alliance classes via the Delta VegCAMP dataset to distinguish evergreen/deciduous and broad-leaved/needle-leaved categories; using a 2017 LiDAR-derived normalized digital surface model (nDSM) to distinguish shrub-scrub vs. forest; and using occurrence and seasonality raster layers from the Global Surface Water inundation products to help assign water regime modifiers. A discussion with a representative from the Delta Stewardship Council led to the recommendation that the Suisun Bay boundary, a proxy for the Delta Stewardship Council's X2 boundary, serve as the delineation between saline and non-saline features. Lastly, stream connectivity was evaluated to refine classes attributed as either diked/impounded or excavated. The resulting version of DARI was then run through NWI's Verification Tools to ensure that it met NWI standards. Due to funding limitations this version of DARI has not been published, but has been shared with NWI staff to help update future versions of NWI.

Crosswalks and classifications were developed in consultation with NWI's "Data Collection Requirements and Procedures for Mapping Wetland, Deepwater and Related Habitats of the United States."

The code used for the crosswalk and conversion to NWI classification is stored here: https://stash.sfei.org/projects/GC/repos/dari_nwi/browse/DARI_to_NWI.py

Appendix C. General Considerations for Mapping

This section lists specific recommendations for mapping line and polygonal wetland features based on the experience of the mappers. It is a summary of tips and considerations that may help a new mapper get oriented to the level of detail needed to consistently map based on the DARI mapping methods and classification system.

For line features

 Map the linear ditches as lines and attribute them with a "Buffer" field with the length in meters equal to half the total width of the ditch banks. Channels with irregular widths will need their polygons to be digitized manually.

⁹ Dahl, T.E., J. Dick, J. Swords, and B.O. Wilen. 2020. Data Collection Requirements and Procedures for Mapping Wetland, Deepwater and Related Habitats of the United States. Division of Habitat and Resource Conservation (version 3), National Wetlands Inventory, Madison, WI. 91 p. (Original document published 2009

- The 2017 LiDAR Hillshade is the best for identifying the majority of ditches but it is
 possible for a non-seasonal ditch to exist in 2018 NAIP imagery that is not in the 2017
 LiDAR. A ditch that is identified in the 2018 imagery should be mapped.
- Digitize stream segments from upstream to downstream in the direction of flow. Always
 use "Snapping" to connect segments, particularly the "End" option. This is particularly
 difficult with ditches. For The Delta, try your best to have the ditches flow out to a main
 channel.

For Polygon Features

- Consulting Wetland Mapping Flow Chart, digitize wetland cleanly without any unnecessary vertices (i.e. small spikes, overlapping areas, etc.). When creating new wetland features adjacent to existing ones, always use "Auto-complete Polygon" and "Snapping" to avoid topology errors such as sliver or small gaps between features.
- 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 streams layer on the imagery while digitizing wetlands in order to provide clues to flow direction.
- Use Google Earth in cases where updated imagery is available for viewing, especially in areas subject to constant change, but only for reference.

Landscape specific considerations

For possible Tidal features connected across a levee

- Use imagery clues over multiple years to decide if the feature is Tidal or Non-Tidal.
- Extensive vegetation growth on the questionably tidal side of the feature indicates low water flow. This feature may not be tidal.
- Evidence of a large culvert or open Tidal gate may also indicate that the feature is tidal.
- Significant narrowing of the channel also indicates lower water flow. These features may not be tidal.

Feature Specific Considerations

Depressional and Lacustrine

- Natural depressional wetlands occupy topographic depressions low areas on flat ground where rainwater and surface runoff collect. This can be particularly difficult with the flat topography of the Delta. Use the LiDAR contours and hillshade along with the imagery to guide the digitization of the depressional boundary.
- Using multiple image years can reveal where water tends to pool.

- 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.
- Habitats within depressional wetlands tend to have indeterminate boundaries where the
 wetland vegetation blends with the upland vegetation. The boundary can be very
 difficult to map. Focus on the most distinctive area of the wetland. Extend the boundary
 outward from the most distinctive area only as far as the imagery or ancillary data
 provides unequivocal evidence of wetness.
- Floating or submerged aquatic vegetation in ponds 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 time of imagery. In these cases, digitize the boundary of the open water feature as it would appear full.

Seeps and Springs

• Unnatural Seeps (SU) tend to occur at the base of slopes or levees where water seeps through from the larger channel to the subsided landward area.

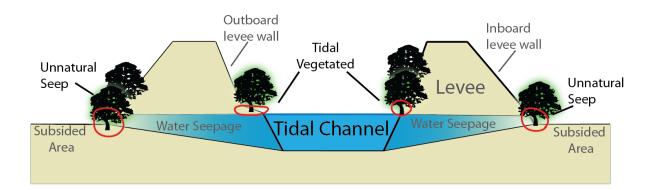


Figure 13: Levee cross-section and unnatural seep locations.

Wet Meadow Unnatural

- The wet meadow must have wetland plants in at least two of the imagery datasets.
- The wetland should be digitized based on the most recent image where the wetland signature is discernible.
- Wet Meadows are essentially slope wetlands in flat areas. That is an area where groundwater reaches the ground surface in a flat area.

Vegetated Wetland Areas

 Mapping the associated vegetated areas for depressional and lacustrine wetlands can be very difficult. It requires the use of multiple ancillary datasets. The general idea for areas where wet meadows are immediately adjacent to (or adjoining) lacustrine or depressional wetland features is to define where the source of water that is supporting the vegetation is coming from. This can be done using aerial imagery color signature and texture as well as the elevation contours. It may help to view different years of imagery to see how much the water level fluctuates.

- The questions to ask while trying to delineate these features are:
 - What is the direction of water flow around this waterbody? Vegetated areas are typically on the up-gradient side of the waterbody.
 - Is there a clear decrease in slope or depression boundary?
 - Is there a heavily saturated vegetated area on the up-gradient portion of the waterbody that is apparent in the imagery?
- Map the area primarily using the imagery and the elevation contours of the LiDAR topobathymetry DEM as a guide.

Table 4. General indicators to help distinguish natural from unnatural wetland.

Channels - Riverine Wetlands

<u>Form:</u> A channel 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.

<u>Substrate:</u> A channel wetland is classified as unnatural (CU or TCU) if it is mostly man-made. For example, channels that are constructed of cement or other materials that would not occur in that location due to natural processes.

Other Non-riverine Wetland Types

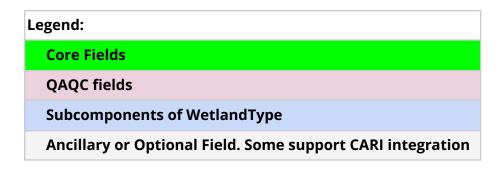
<u>Impoundment:</u> A wetland that exists because of the impoundment of water behind a levee, dam, berm, etc., is always classified as unnatural. Examples include reservoirs (unnatural lakes), channel ponds, stock ponds, and agricultural irrigation ponds. This is based on the assumption that the impoundment 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 naturalized features should be sinuous, have established vegetation or have a developed substrate.

Appendix D. Working DARI Geodatabase Schema

The following schema was used for drafting DARI with a team of mappers and during the QA process. These fields enabled tracking of the mapping and QA status of each cell. Many of these working DARI cells were dropped or modified/standardized prior to finalization of DARI.



Field	Notes	Required
WetlandType	multi-letter code describing the wetland type. Refer to Data Dictionary for a complete list of codes	Y
WetTypeOther	Holding Area where WetlandType='Other' and we need a defining placeholder for a Type that is not on the field Domain preset list	lf WetlandType=Other
SourceDataset	source(s) from which the wetland polygon was digitized, or otherwise incorporated into DARI	Y
Mapper2020	Mappers name or initials. Will be deleted before delivery.	Υ
QA_Question	For mappers' questions and comments to relay to the QA team. Will be deleted before delivery.	Y
QA_response	For QA team response to mappers' questions. Will be deleted before delivery.	N (PK/MS to complete)
Tidal	attributed with a 'T' for all wetlands connected to the tides	N (PK/MS to complete)
Class	1-3 letter code indicating a major category of wetlands (C= Channel, TGP= Perennial Lagoon, VPC=Vernal Pool Complex. etc.) Refer to Data Dictionary for a complete list of codes	N (PK/MS to complete)
Surface	OW=Open Water, V=Vegetated, U=Unvegetated (dewatered Playas only)	N (PK/MS to complete)
Natural	N=Natural, U=Unnatural	N (PK/MS to complete)
VegType	w=woody vegetation is present (mostly to indicate the presence of Willows within a Tidal Marsh matrix should they exist), s= persistent submerged vegetation (probably for Tidal classes only, but revisit MS 12-2019)	Y but only for TV

	M=some type of monitoring regime. Other modifier codes for subtypes TBD (MS 12-2019). Potential Subtypes mentioned by TAC (Thomas) include Seasonally inundated agriculture or working lands (e.g., rice, corn, alfalfa) Wet areas or lands in farmed areas	
Managed	■ Intentionally flooded areas for carbon sequestration ■ Managed Non-Tidal marshes (e.g., duck clubs)	Yes only if Managed
VPCorAdj	Y=Vernal Pool Complex or adjacent. Used to flag wetlands that are part of Witham et al. 2012 or other Vernal Pool mapping efforts, and features that are adjacent to those VPCs. This is to track wetlands that are likely part of the VP system but may not be Vernal Pools themselves (e.g. channels running through a VP complex).	Yes if VP,VPC or adjacent to these
Depth	d=deep >12 ft below MLLW, s=shallow <12 ft below MLLW. (for Tidal Channels TC only)	N (PK/MS to complete)
Notes	For additional information not covered by the other fields. Will retain relevant entries in delivered dataset. 2020	Y only if needed for clarification. Delete existing contents if no longer relevant
Name	(optional) Include if the feature has a GNIS or other official name (e.g. Sacramento River)	N
orig_class	to reference original classification system of the source dataset (e.g. class within DARI 2012 pilot, Delta Modern Habitats) may be deleted later	N
orig_class orig_dataset	(e.g. class within DARI 2012 pilot, Delta Modern Habitats) may be	N N
	(e.g. class within DARI 2012 pilot, Delta Modern Habitats) may be deleted later to reference the original source dataset that was incorporated into DARI_beta (e.g. DARI 2012 pilot, Delta Modern Habitats). May be	
orig_dataset	(e.g. class within DARI 2012 pilot, Delta Modern Habitats) may be deleted later to reference the original source dataset that was incorporated into DARI_beta (e.g. DARI 2012 pilot, Delta Modern Habitats). May be deleted for the final version. Maintains the Cowardin Class used by NWI. Useful for polygons from the DARI 2012 pilot study that themselves originated from	