NATIONAL WETLAND INVENTORY REPORT FOR THE PROVO RIVER, UTAH

by

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Provo River Mapping Project Geodatabase: https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-755/ofr-755.zip

INTRODUCTION

This report summarizes a recently completed mapping project along the Provo River that covers nearly 33,800 acres of Wasatch and Summit Counties and includes parts of Heber City, Midway, Francis, and Woodland (figure 1). Rapid exurban and suburban development in these areas has replaced historically irrigated agricultural lands causing possible wetland resource conflicts and sparking local concerns about water quality impacts and changes to the rural nature of these communities. The Utah Geological Survey (UGS) developed the project in collaboration with the Utah Division of Wildlife Resources, Wasatch County, and Heber City to provide stakeholders with reliable, accessible wetland mapping data. The project aimed to meet several specific needs: provide an accurate inventory of aquatic habitats along the Middle and Upper Provo River critical for several state sensitive wildlife species and provide local and county officials with accurate wetland locations in rapidly developing areas along Jordanelle Reservoir and in agricultural areas between Heber City and the Provo River. These areas are locally called the North and South Fields, with State Route 113 between Midway and Heber Cities dividing the two areas.

We met these needs by updating the existing National Wetland Inventory (NWI) mapping to modern standards and attribution using recently collected imagery. We considered NWI mapping ideal for this project as it represents wetlands at a scale of 1:12,000 (approximately 30-foot accuracy) and relies on photointerpretation to map features. These factors allowed this project to be completed within a year with lower costs than a typical field-based delineation, but still produced data suitable for accurately identifying small habitat features, informing permitting, and flagging potential wetland resource conflict issues. Additionally, updating NWI mapping expands project reach as many planners and biologists already incorporate the NWI mapping into their existing workflows.

The project also aimed to enhance the utility of typical NWI mapping by applying additional Landscape Position, Landform, Water Flow Path, and Waterbody Type (LLWW) attributes. Ralph Tiner of the U.S. Fish and Wildlife Service (USFWS) developed the LLWW classification system to supplement the wetland type information included in the NWI and better relate the NWI dataset to the hydrogeomorphic (HGM) classes often used during wetland permitting (Tiner, 2014). The LLWW classification considers the geomorphic setting, wetland shape and form, and connectivity to stream networks for each mapped feature. When applied to NWI mapping, LLWW attributes provide additional information about a given wetland allowing identification of wetlands providing unique habitats or ecosystem services. Combined, NWI mapping and LLWW attributes provide detailed information about a given wetland.

Project Area Description

Geography

The project area is within Wasatch and Summit Counties and encompasses sections of the Provo River and associated floodplains from Deer Creek Reservoir north and east through Jordanelle Reservoir to the U.S. Forest Service administrative boundary near Woodland, Utah (figure 1). The project area also includes parts of Midway, Heber, and areas surrounding the Jordanelle Reservoir that local and county officials requested be mapped during project scoping. The project area falls entirely within the Wasatch and Uinta Mountains Level 3 Ecoregion and contains three Level 4 Ecoregions (Woods and others, 2001). The extents of all ecoregions within the project area are summarized in table 1 along with a detailed description of each Level 4 Ecoregion.

The project area follows the Provo River west as it flows through upper Kamas Valley, enters Jordanelle Reservoir, flows out to the south through Heber Valley, and into Deer Creek Reservoir. Topography within the Heber and Kamas Valleys is typical of mountain valleys with predominantly flat to gently sloping terrain dissected into distinct terraces and floodplains by the Provo River as well as perennial tributaries including Snake, Spring, Rock, and Daniels Creeks. Topography surrounding the Jordanelle Reservoir is more typical of semiarid foothills with relatively steeper slopes and numerous drainages carved by seasonal streams, all ultimately draining into Jordanelle Reservoir or the Provo River.

Climate

The project area has a cooler, moister climate than most of the state with average minimum and maximum temperatures in the Heber and Kamas Valleys ranging from 9° to 13°F and 85° to 88°F, respectively, and each valley receiving an average annual precipitation of 15.8 to 16.4 inches (Western Regional Climate Center, 2023). In the valleys, precipitation occurs throughout the year with summers that are distinctly drier than spring, fall, and winter months where precipitation is evenly distributed. The montane foothills surrounding Jordanelle Reservoir are even cooler and wetter, receiving an average annual precipitation of 20 to 25 inches mostly as snow during the winter months (PRISM Climate Group, 2014).

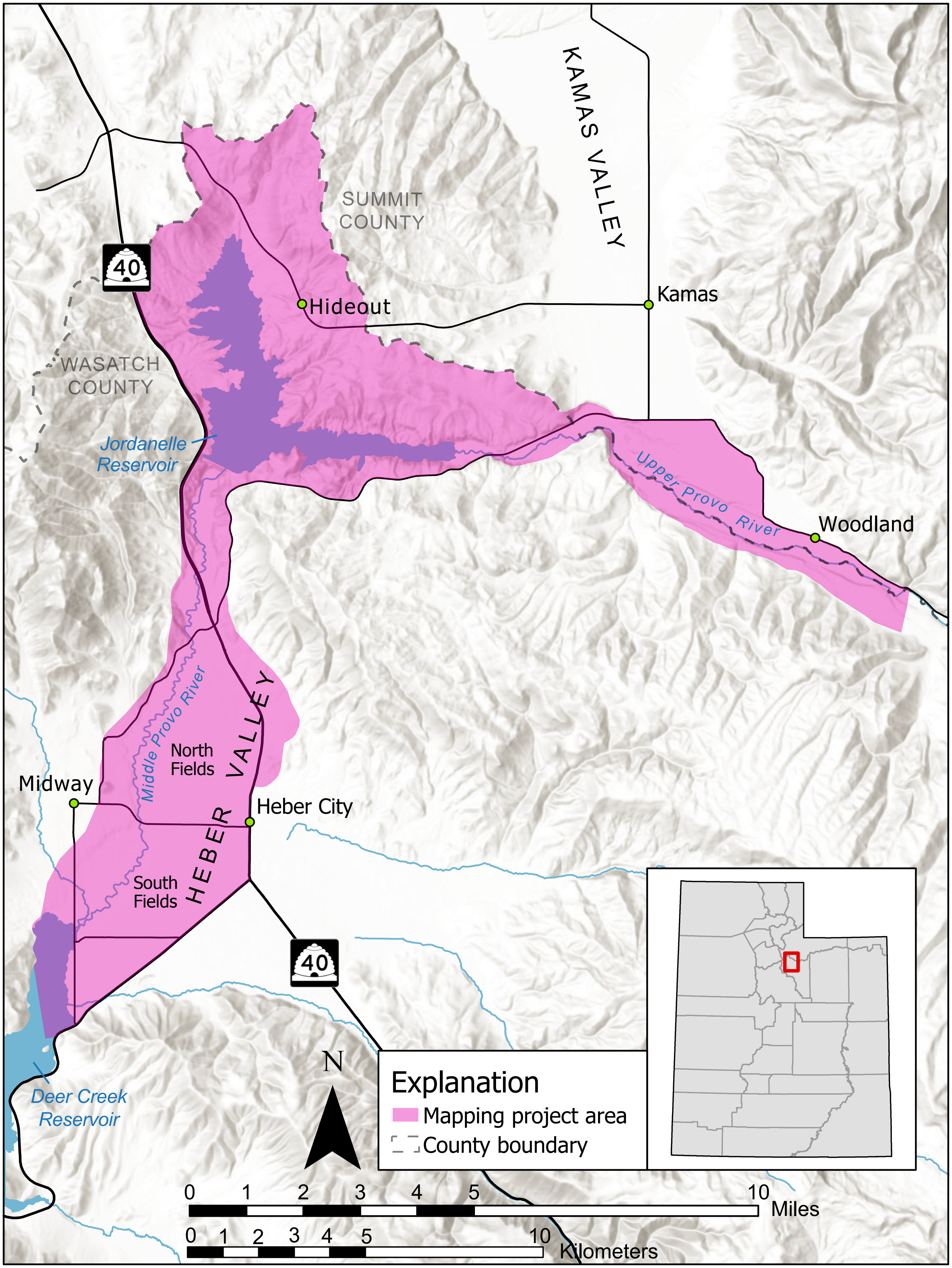

***Figure 1.** Project area location map.*

Table 1. *Ecoregions in the project area, adapted from Woods and others (2001).*

Level 3	Level 4	Description	Acres in Project area
Wasatch and Uinta Mountains	Wasatch Montane Zone	The partially glaciated Wasatch Montane Zone consists of forested mountains and plateaus underlain by sedimentary and metamorphic rocks. Douglas fir and aspen parkland are common and Engelmann spruce and subalpine fir grow on steep, north facing slopes. Perennial streams provide water to lower, more arid regions.	154 (0.5%)
	Mountain Valleys	The unforested Mountain Valleys ecoregion contains terraces, flood plains, alluvial fans, and hills. It is affected by cold temperatures and has a short growing season. Potential natural vegetation is mostly Great Basin sagebrush. Today, irrigated cropland, irrigated pastureland, and rangeland are common. Turkey farms, feedlots, and dairy operations occur locally. Land use contrasts with that of nearby high plateaus and mountains.	14,195 (42.0%)
	Semiarid Foothills	The Semiarid Foothills ecoregion is found between about 5000 and 8000 feet elevation. Widely spaced juniper and pinyon typically occur in a matrix of sagebrush, grama grass, mountain mahogany, and Gambel oak. Maple-oak scrub is common in the north but southward, it is gradually replaced by pinyon juniper woodland at lower elevations and ponderosa pine at upper elevations. Livestock grazing is common. Some rangeland has been cleared of trees and reseeded to grasses.	169,171 (57.5%)

Land Use

Heber Valley, Kamas Valley, and the surrounding mountains are the traditional and ancestral homelands of the Ute and Shoshone Tribes, and the project area occupies a transitional area between their historical lands. The Shoshone and Utes traditionally hunted and gathered throughout the region, and wetlands were largely unaltered until arrival of Euro-American settlers in 1858 (American West Center, 2023).

Since the 1850s, land within the Heber and Kamas Valleys has been extensively converted for agriculture, and a network of canals, ditches, and large impoundments has been created to distribute irrigation diversions throughout the valley. Initial efforts diverted from the Provo River or nearby perennial springs and creeks to flood irrigate fields for pasture and crops. Large-scale irrigation began in 1860 with an organized effort to entirely divert water from Lake and Center Creeks to supply Heber City residents (Raty, 1954). Other historical irrigation efforts include the 1895 construction of the Timpanogos Canal to irrigate the North and South Fields as well as the initial 1882 transbasin diversion of water from the Strawberry River to supplement Daniels Creek (Raty, 1954). Current irrigation practices differ with pressurized sprinkler systems and larger transbasin diversions from the Strawberry, Weber, and Duchesne Rivers, but many historical agricultural areas, particularly those in the North and South Fields, have been continuously irrigated for over a century and support extensive wetland complexes (USFWS, 1984).

The U.S. Bureau of Reclamation-funded Provo River Project impounded the Provo River to deliver irrigation and domestic water to the Wasatch Front by constructing the Deer Creek Dam in 1941 and also constructed levees, excavated and straightened portions of the channel, and stabilized channel banks along the Provo River throughout the Heber and Kamas Valleys (Bell, 1997). These efforts intended to increase storage capacity within the Provo River and provide flood control for adjacent agricultural areas but also removed riparian forests, floodplain wetlands, and instream habitats providing crucial wildlife habitat (Bell, 1997; Utah Reclamation Mitigation and Conservation Commission [URMCC], 1997). The Provo River Restoration Project (PRRP), completed in 2008, aimed to restore these riverine habitats and mitigate additional losses from the 1993 construction of Jordanelle Reservoir by migrating levees back from the channel, reintroducing meanders, and constructing ponds supported by side channels to mimic historical floodplain conditions and habitats (URMCC, 1997). The PRRP extends the entire 12-mile length of the Middle Provo and creates a roughly 0.25- to 0.5-mile corridor throughout Heber Valley containing extensive and diverse wetland and riparian features.

MAPPING METHODS

Imagery and Supporting Data

Source Imagery

The mapping was conducted using the most recent National Agricultural Imagery Program (NAIP) imagery collected during September of 2021. Despite capturing seasonal low-water conditions during a historic drought and poorly representing average conditions, we used the 2021 NAIP as our source imagery as it best represented current development and land use change extents.

Supporting Data

All wetland boundaries were mapped to features visible in the source imagery, but several other datasets were reviewed alongside the 2021 NAIP imagery to support mapping wetland boundaries, types, and water regimes. These datasets included historical and recent imagery, high-resolution light detecting and ranging (lidar) data, existing wetland and hydrography mapping, and water-related land use information. Additional datasets depicting specific land uses or landscape features were used to assign landscape position and additional modifiers for LLWW automation (table 2).

Table 2. *Supporting data for NWI and LLWW mapping.*

Dataset[1]	Description	Source[2]	Relevant Date(s)
Imagery			
Historical Orthophotos	1-meter resolution, historical black and white orthophotos collected in the summer of 1997.	UGRC	Summer 1993
NAIP 2011	1-meter resolution, 4-band aerial imagery collected during the summer of 2011.	USDA NAIP	8/6/2011
NAIP 2014	1-meter resolution, 4-band aerial imagery collected during the summer of 2014.	USDA NAIP	7/1/2014
NAIP 2016	1-meter resolution, 4-band aerial imagery collected during the summer of 2016	USDA NAIP	8/2/2016
NAIP 2018	1-meter resolution, 4-band aerial imagery collected during the summer of 2018.	USDA NAIP	9/11/2018 to 9/27/2018
Google Earth Imagery	Publicly available, true-color imagery from several years and sources. Imagery available in the project area includes NAIP imagery, Landsat imagery, and imagery collected by Google Imagery services.	Google Earth	Various
ESRI World Imagery	30-centimeter, true color imagery available as an ESRI service. Imagery mosaiced from several sources and collection dates.	ESRI	Various
Lidar and Elevation			
Heber Valley and Uinta Basin	0.5-meter resolution, bare earth lidar data of the Heber Valley collected during fall 2018	UGRC	Summer and fall 2018
2020 Northern and Central Utah	0.5-meter resolution, first return and bare earth lidar data of parts of Northern Utah collected during summer 2020	UGRC	Summer 2020
2020 Central and Southern Utah	1.0-meter resolution, first return and bare earth lidar data of parts of Central Utah collected during fall 2020	UGRC	Fall 2020
Existing Mapping			
NWI	Existing wetland mapping included in the NWI dataset.	USFWS	Summer 1984
NHD Flowlines	Centerlines of ephemeral, intermittent, seasonal, and perennial channels identified in the NHD.	USGS	2022
NHD Spring points	Point data of known springs and seeps identified in the NHD	USGS	2022
SSI Spring points	State-wide dataset depicting spring locations contained in the SSI database	SSI	2022
Utah Valley Bottoms	State-wide dataset depicting valley bottom areas for all perennial streams within the state of Utah	USU	Winter 2016
Land Use			
Water Related Land Use	Land use data showing the extent and type of irrigated crops, urban areas, and relatively natural landscapes.	UDWRi	2022
Water Points of Diversion	Agricultural irrigation and other diversion points along water features identifying wells, stock ponds, and springs.	UDWRI	2022
Fire Perimeters	Historical fire perimeters from 2011 to 2021 within project area	GeoMac	2022
Golf Courses	Known golf courses within the project area	UGRC	2022
Hot Springs	Known locations of selected geothermal springs and wells in project area	UGS	2022
Gravel Mines	Active, permitted gravel mine locations from the Utah Department of Oil, Gas and Mining	OGM	2022
Dam Inspection Points	Dam locations with dam size, type, and inspection agency information from the Utah Department of Water Rights	UDWRi	2022
Mineral Mines	Active and historical hard rock and mineral prospect claims from the Utah Department of Oil, Gas and Mining	OGM	2022
Restoration Sites	Restoration projects funded by the Watershed Restoration Initiative	WRI	2022

[1] Dataset abbreviations: National Agriculture Imagery Program (NAIP), Environmental Systems Research Institute (ESRI), National Wetland Inventory (NWI), National Hydrography Dataset (NHD), Spring Stewardship Institute (SSI)

[2] Source abbreviations: Utah Geospatial Resource Center (UGRC), U.S. Department of Agriculture National Agriculture Imagery Program (USDA NAIP), Environmental Systems Research Institute (ESRI), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), Spring Stewardship Institute (SSI), Utah State University (USU), Utah Department of Water Rights (UDWRi), Geospatial Multi-Agency Coordination (GeoMac), Utah Geological Survey (UGS), Department of Oil, Gas and Mining (OGM), Watershed Restoration Initiative (WRI).

Field Data

We conducted field surveys to visit problematic wetlands like irrigated fields or wetlands with seasonal hydrology where accurate mapping required assessing on-the-ground conditions. These surveys helped mappers correlate wetland vegetation types and water regimes to aerial imagery signatures. Surveys also focused on understanding the general distribution of wetlands within the project area, understanding which landscape features likely supported wetlands such as irrigated floodplains or slope breaks in the foothills above the Jordanelle Reservoir, and distinguishing between riparian areas, wetlands, and surrounding uplands. UGS mappers Elisabeth Stimmel, Grant Mauk, and Pete Goodwin conducted all surveys over several visits from May 16, 2022, to July 8, 2022, to best capture peak growing season and average high-water periods.

Field surveys followed typical UGS wetland mapping survey methods and consisted of visiting pre-identified sites that were either (1) representative of typical wetlands, (2) difficult to map based on aerial imagery alone, (3) located in a unique landscape or feature, or (4) had a unique aerial imagery signature (Goodwin and Molinari, 2022). This approach helped mappers adequately sample wetland types within the project area, while allowing focused effort on difficult wetlands. We selected sites either located on public land, easily viewed from public roads, or accessible through landowner permission.

For each site, we recorded the most appropriate wetland type and water regime with a representative photograph and GPS location using the Field Maps software application running on an Apple iPad Air 2 tablet. If access and conditions allowed, we collected additional information about flooding, saturation, or evidence of past flooding; presence or absence of soil features indicating persistent flooding or saturation, and the dominant herbaceous and woody vegetation species. These field data and photographs were especially useful for distinguishing irrigation-fed wetlands from surrounding uplands in Heber and Kamas Valleys.

We determined wetland types based on site characteristics visible in the field, including presence of wetland vegetation, vegetation growth form, and evidence of modification. We conducted field surveys during drought conditions and many sites lacked the expected flooding or saturation during our visit. Water regimes, as well as distinctions between wetlands, riparian areas, and uplands, were determined based on site characteristics and discussion of likely conditions throughout a normal year. Site characteristics assessed included characteristics possibly impacted by the drought (presence and extent of flooding or saturation) but also characteristics less affected by the drought such as soils, geomorphic setting, and vegetation communities. Discussion of likely conditions focused on landscape position, possible hydrology sources, seasonal water patterns, and site-specific drought impacts. These discussions helped mappers understand likely hydrology sources, typical duration and frequency of flooding or saturation, and typical wetland conditions.

NWI Wetland and Riparian Mapping

NWI mapping for this project was accomplished by hand digitizing polygons using ArcGIS software to establish boundaries and assign a wetland or riparian type according to USFWS guidelines to features visible in the source 2021 NAIP imagery (USFWS, 2019; Dahl and others, 2020). Kyle Lemaire and Sara Owen of the USFWS provided several clarifications and mapping reviews. Mapping of linear features, such as riverine channels, followed USFWS guidelines applicable to projects beginning before October 2022 to emphasize surface network connectivity while maintaining the priority of traditional polygonal wetlands (USFWS, 2021).

Wetland and riparian mapping were conducted concurrently, and all features were mapped at 1:3000 scale. Wetlands were mapped to a target mapping unit (TMU) of 0.1 acres (roughly 400 square meters). We mapped wetlands to a finer TMU than required by USFWS guidelines to provide greater detail about their location and distribution and better support expected uses of the mapping such as initial screening for development-related permitting issues or species-specific habitat inventories (Dahl and others, 2020). We expected riparian mapping to be applied at a broader, vegetation community scale and mapped riparian areas to a TMU of 0.5 acres (roughly 2000 square meters) to support expected uses like selecting treatment areas for salt cedar or Russian olive (*Elaeagnus angustifolia*) control, identifying habitats for nesting birds, or evaluating the presence and extent of riparian buffer around a stream or wetland.

NWI wetlands and riparian areas were mapped according to several broad conventions developed by the UGS to address problematic mapping situations and improve mapping consistency. Goodwin and Molinari (2022) described these broad conventions in detail as well as their application to NWI mapping. Several conventions specific to this project were developed to address issues unique to Heber Valley or specific stakeholder needs. These project-specific conventions include:

Riparian classification

- Forested or Scrub-shrub Riparian areas were classified to the Dominance Type level to help distinguish woody riparian areas dominated by non-native species such as Russian olive or provide additional detail for riparian habitats.

Excavations from the PRRP

- Pond features (PUB or PAB) on the Middle Provo River floodplain were assumed to be excavated during the PRRP and attributed with the excavated (x) modifier.
- Side channels on the Middle Provo River floodplain were attributed with the excavated (x) modifier only if the channels delivered water to or from features above the floodplain.

Irrigation

- Wetlands were mapped in irrigated areas if several years of imagery showed a consistently wet portion or core of the feature.
- Irrigation was considered to be temporary flooding and irrigated features were mapped with A water regimes.
- Features that were created from irrigation and would likely return to upland if irrigation were to stop were not mapped as wetlands unless field data or other supporting data confirmed persistent hydric soils, hydrophytic vegetation, or other wetland characteristics.

LLWW Mapping

We applied LLWW attributes to all wetland polygons within the project area following keys developed by Lemly and others (2018); these keys ignored riparian NWI features, and we did not apply LLWW attributes to these features. We mapped LLWW attributes with the semi-automated methods described by Goodwin and Molinari (2022) using the same source imagery and supporting data interpreted during NWI mapping (table 2).

Following the semi-automated approach, we manually assigned all mapped features one of eight water sources to provide input information to the LLWW automation process. Mappers assigned water source information to features by interpreting multiple years of imagery and lidar-derived DEMs and slope data sets to identify (1) patterns of inundation or saturation, (2) changing land uses, (3) surrounding terrain and shape of each mapped feature, and (4) possible relationships with other nearby mapped features (table 3).

LLWW attribute application followed several broad conventions developed by the UGS to address problematic situations and improve consistency (Goodwin and Molinari, 2022). However, we developed several conventions specific to this project to address issues unique to Heber Valley or stakeholder needs. These project-specific conventions include:

Lentic wetland flow paths

- Flow paths for wetlands with a Lentic (LE) landscape position were mapped according to the longest shared boundary, with features sharing their longest boundary with either the lake or other shoreline features assigned a bidirectional (BI) flow path and features sharing their longest boundary with either a river or lotic floodplain feature assigned a throughflow-bidirectional (TB) flow path.

Provo River Restoration Project

- All non-riverine lotic wetlands and waterbodies along the Middle Provo River were assumed to be created by the PRRP and assigned the restoration (re) modifier.

MAPPING COMPARISON

This 2023 mapping project replaces existing NWI mapping from a 1984 project that used imagery collected from 1981 to 1983 (USFWS, 1984). Wetland extents and distributions have changed over the past four decades, but changing mapping conventions and mapping technology advances complicate simple comparison between the two datasets. This 2023 project maps riparian areas and uses high-resolution imagery to identify small, isolated features that would not have been previously captured with the coarser 1980s imagery. These two changes affect how the mapping portrays wetlands in the project area and can apparently decrease wetland extent by reclassifying features from wetland to riparian or mapping features tighter to visible

Table 3. *Water sources assigned for automating LLWW attribution.*

Water Source	General Description	Geomorphic Setting	Imagery Signature	Applied To
Overbank flooding	Feature has surface water connection when nearby river or lake is flooded.	Adjacent to creeks, rivers, lakes. Features are typically flat floodplains and small depressions.	Variable and affected by location on floodplain and extent of recent flooding. Higher floodplain wetlands typically vegetated, and water absent from most images. Lower floodplain wetlands vegetated or not, water present in many or most images.	Fringe-like features, stream-bank shrub wetlands, gravel bars and shores, floodplain wetlands.
Alluvial aquifer	Feature seems to be connected to the river or lake water table–as the river and associated water table rises, feature is flooded. Direct surface connection rare.	On the floodplains of larger creeks, rivers, or lakes. Features are generally depressions, ponds, and basins well removed from typical flooding extent.	Surface water in ponds generally present in most images but appears to raise or lower with amount of water in nearby river or lake. Vegetated features have more robust vegetation than surrounding areas and may occasionally appear saturated or flooded.	Floodplain depressions, oxbows, areas on the floodplain not directly adjacent to the river.
Precipitation accumulation	Feature collects water from non-channelized runoff, snow melt, or is part of a stormwater system.	Topographic low points without clear surface water inputs. Features are typically shallow depressions or basins or isolated, excavated pits.	Variable. Montane basins usually barren with surface water present only in spring/early imagery. Low-lying areas may be vegetated or not and typically dry in most imagery.	Playas, stormwater retention ponds, flats, shallow montane depressions.
Stream flow accumulation	Feature that collects water from a stream (ephemeral to perennial) or is a flowing stream itself, includes canals.	Located within, or includes, part of a stream channel. Features are streams, rivers, canals, or basins and ponds interrupting the channel.	Channels with or without water depending on the size of the stream and timing of imagery. Basins and impoundments variously dry, drying, or flooded depending on the size of the channel feeding them and timing of imagery.	Impoundments built across the stream, lakes with an obvious inlet, reservoirs, streams, canals.
Irrigation	Feature fed by canals, diversions outside the floodplain, runoff from irrigated fields.	Level, agricultural areas outside of river floodplains with clear signs of canals or ditches. Features are typically flat or gently sloping fields and pastures without extensive crops.	Natural vegetation without distinct rows or lines indicating crops or plowing. Water usually present as saturation or shallow flooding; the total extent of wet area changes drastically between years of imagery and often appears wet during dry parts of the year.	Irrigation retention ponds, irrigated pastures and fields, features collecting irrigation runoff.
Artificial	Areas that have been obviously constructed and water source seems to be entirely removed from any natural system.	Areas that have been obviously constructed and water source seems to be entirely removed from any natural system.	Water typically present in most images. If vegetated, usually supports dense emergent vegetation or floating algal mats typical of high-nutrient systems.	Sewage lagoons, constructed ponds with no clear water source.
Groundwater	Features supported by groundwater emergence or shallow groundwater creating saturated conditions. Features generally lack obvious surface water inputs, are unlikely to be affected by rivers, don't exist in a distinct depression collecting surface water, and were not identified as a spring.	Topographic low areas in valley bottoms, toes and slopes of alluvial fans and deltaic deposits, bases of cliffs, terraces, and other steep slope breaks. Features are variable but generally lack obvious surface water inputs, are unlikely to be affected by rivers, and do not exist in a distinct depression collecting surface water.	Variable and depends on the amount of groundwater as well as the supported vegetation. Emergent vegetation supported by shallow groundwater typically appears saturated in spring or early summer imagery or unusually robust in later imagery but may be indistinct from surrounding uplands in other images. When wet, the total extent of wet area remains roughly similar across multiple years of imagery. Areas with greater amounts of groundwater appear saturated or flooded, or support robust vegetation in most imagery, with the total extent of the wetted area remaining similar across multiple years of imagery.	Big emergent flats, disconnected oxbows, areas downstream of springs but not obviously flooded or connected via surface water
Spring	Groundwater-fed features identified as springs in the NHD, WRPOD, SSI or other layers.	Same as groundwater features.	Similar to groundwater-fed features, but spring-fed features usually have surface water present as pools or small rills in most years of imagery.	Spring pools, adjacent areas with surface water supplied by that spring, or single pond containing springhead.

boundaries. Conversely, these changes can also drive apparent increases in the extent and count of features by including drier riparian features or smaller, isolated features that may not have been captured in the initial 1984 mapping. When combined, these apparent increases and decreases make it difficult to meaningfully summarize wetland change within the project area without a detailed feature-by-feature analysis.

Though comparing the datasets does not allow us to quantify wetland change in the study, comparing the two datasets can still yield useful information about differences in the two datasets (table 4).

Table 4. *Summary of 1984 and 2023 mapping data.*

Broad Wetland Type	2023 Mapping[1]			1984 Mapping[1]		
	Cowardin Codes	Features	Acres	Cowardin Codes	Features	Acres
Lacustrine Systems						
Deep Water	L1UBHh	2	2174.4		0	0.0
Aquatic Bed		0	0.0		0	0.0
Shallow Water		0	0.0	L2UBFh, L2UBGh, L2USCx	5	445.7
Lacustrine Shore	L2USCh	18	1262.7	L2USCh	7	73.6
Artificially Flooded	L2UBKx	2	68.4		0	0.0
Lacustrine Total		22	3505.4		12	519.3
Palustrine Systems						
Aquatic Bed	PABF, PABFb, PABFh, PABFx, PABGh, PABGx	121	46.1	PABGx, PABF, PABFh, PABFx, PABG, PABGb, PABGh	84	57.4
Emergent Meadow	PEM1A, PEM1Ah, PEM1Ax, PEM1B, PEM1Bx, PEM1C, PEM1Cb, PEM1Ch, PEM1Cx, PEM1D, PEM1Jx	596	2173.3	PEM1A, PEM1Ah, PEM1C, PEM1/SSC, PEM1/USC, PEM1B, PEM1Ch, PEM1Cx	447	2836.6
Emergent Marsh	PEM1E, PEM1Eb, PEM1Ex, PEM1F, PEM1Fh, PEM1Fx	66	74.2	PEM1F, PEM1Fh	50	175.2
Farmed		0	0.0		0	0.0
Forested	PFO1A, PFO1Ah, PFO1Ax, PFO1B, PFO1Bb, PFO1C, PFO1Cb, PFO1Cx, PFO5F	55	54.3	PFOA, PFO/EM1A, PFO/SSA, PFO/SSC, PFOAx, PFOC	103	393.3
Scrub Shrub	PSS1A, PSS1Ab, PSS1Ah, PSS1Ax, PSS1B, PSS1Bb, PSS1Bx, PSS1C, PSS1Cb, PSS1Ch, PSS1Cx, PSS1Eb, PSS1Fh	388	390.5	PSS/EM1C, PSS/USC, PSSC, PSSCh, PSSCx	141	341.9
Permanent Pond	PUBF, PUBFb, PUBFh, PUBFx, PUBG, PUBGh, PUBGx	224	99.2		0	0.0
Seasonal Pond	PUSA, PUSAh, PUSAx, PUSC, PUSCh, PUSCx, PUSJx	18	6.7	PUS/SSAh, PUSA, PUSAx, PUSC, PUSCh, PUSCx	23	47.5
Artificially Flooded	PUBKx	7	32.0		0	0.0
Palustrine Total		1475	2876.3		848	3852.0
Riverine Systems						
Lower Perennial	R2UBF	11	20.9	R2UBH, R2USA, R2USC	50	286.2
Upper Perennial	R3RBF, R3RBG, R3RBH, R3RBHr, R3RSC	152	253.2		0	0.0
Intermittent Streambed	R4SBA, R4SBAx, R4SBC, R4SBCx	259	389.5	R4SBC, R4SBCx	169	262.0
Unknown Perennial		0	0.0	R5UBH, R5UBFx	203	89.7
Riverine Total		422	663.6		422	637.8
Riparian Systems						
Riparian Emergent	Rp1EM, Rp2EM	167	409.5			
Riparian Forested	Rp1FO6CW, Rp1FO6MD, Rp2FO6CW	294	748.7			
Riparian Scrub Shrub	Rp1SS6MD	115	168.5			
Riparian Total		576	1326.7		0	0.0
Total Mapping		2495	8372.0		1282	5009.0

[1]Mapping conventions have changed drastically between 1984 and 2023 and care should be taken when comparing the two datasets.

Excluding riparian areas, the 2023 update maps an additional 2000 acres of wetland, pond, riverine, or lacustrine habitat and approximately 600 additional features. Increases in lakes and shoreline habitats account for the largest difference between the two datasets. The 2023 update captured more vegetated wetlands (emergent meadow, emergent marsh, scrub-shrub and forested) but fewer acres than the initial mapping. However, the 2023 update includes approximately 1300 acres of vegetated riparian features not captured in the initial mapping. Both datasets capture riverine features similarly, in both the number of features captured and the total extent.

Two large, landscape-altering projects have occurred within the project area between 1984 and 2023: creation of the Jordanelle Reservoir in 1993 and the completion of the PRRP in 2008. Both projects substantially impacted wetlands within the project area and contribute to differences between the 2023 and 1984 dataset. Jordanelle Dam construction and subsequent filling of the reservoir created nearly 3000 acres of lacustrine deepwater and shoreline features and is the largest contributor to the increased wetland extent in the 2023 update (table 4). PRRP efforts to restore wetland hydrology to floodplains along the Middle Provo River through constructing numerous small ponds contribute to more than 250 new pond features included in the 2023 mapping. Both projects also affected vegetated wetlands (emergent meadow, emergent marsh, scrub-shrub and forested), with the Jordanelle flooding approximately 350 acres of vegetated wetland included in the initial 1984 mapping. That loss may be offset by the vegetated wetlands created by PRRP along the Middle Provo but project-wide shifts in the extent and distribution of vegetated wetlands obscure any such offset.

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REFERENCES

American West Center, 2023, Utah Indian curriculum project—Ute lands and sovereignty: University of Utah, accessed May 2023.

Bell, T.M., 1997, Provo River Project: Denver, Colorado, Bureau of Reclamation History Program, 38 p.

Dahl, T.E., Dick, J., Swords, J., and Wilen, B., 2020, Data collection requirements and procedures for mapping wetland, deepwater and related habitats of the United States (version 3): Madison, Wisconsin, U.S. Fish and Wildlife Service Division of Habitat and Resource Conservation, National Standards and Support Team, 91 p.

Goodwin, P., and Molinari, R., 2022, Cache Valley wetland mapping—supplemental report: Utah Geological Survey Open File Report 744, 28 p., 2 appendices, https://doi.org/10.34191/OFR-744.

Lemly, J., Marshall, S., Stark, K., Lindquist, E., Robertson A., Hutchins, H., 2018, Keys to LLWW for inland wetlands of the western United States: Fort Collins, Colorado, Colorado Natural Heritage Program, 39 p.

PRISM Climate Group, 2014, PRISM gridded climate data—30 year normal precipitation: Oregon State University, https://prism.oregonstate.edu/normals/, accessed May 25, 2023.

Raty, L.S, 1954, A history of Wasatch County—1859–1899: Provo, Brigham Young University, M.S. thesis, 117 p.

Tiner, R.W., 2014, Dichotomous keys and mapping codes for wetland landscape positions, landform water flow path and waterbody type descriptors, Version 3.0: Hadley, Massachusetts, U.S. Fish and Wildlife Service, 65 p.

U.S. Fish and Wildlife Service [USFWS], 1984, National wetlands inventory map report for Salt Lake study 2: Denver, Colorado, U.S. Fish and Wildlife Service, 5 p.

U.S. Fish and Wildlife Service [USFWS], 2019, A system for mapping riparian areas in the western United States: Falls Church, Virginia, U.S. Fish and Wildlife Service Ecological Services, 36 p.

U.S. Fish and Wildlife Service [USFWS], 2021, Incorporating buffered linears into the NWI polygonal data layer: Madison, Wisconsin, U.S. Fish and Wildlife Service, National Wetlands Inventory, 16 p.

Utah Reclamation Mitigation and Conservation Commission [URMCC], 1997, Provo River Restoration Project [PRRP]—Final environmental impact statement summary: Salt Lake City, Utah, U.S. Department of Interior, 30 p.

Western Regional Climate Center, 2023, Utah climate summaries: https://wrcc.dri.edu/summary/climsmut.html, accessed May 2023.

Woods, A.J., Lammers, D.A., Bryce, S.A., Omernik, J.M., Denton, R.L., Domeier, M., and Comstock, J.A., 2001, Ecoregions of Utah (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey, map scale 1:1,175,000.