Mapping Indicators of Groundwater Dependent Ecosystems in Nevada

Methods Report

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Authors:

Sarah Byer[1], Laurel Saito[1], Jinna Larkin[2], Kevin Badik[1], Louis Provencher[1], Ken McGwire[3], and Tanya Anderson[1]

Affiliations

1. The Nature Conservancy, Nevada
2. Nevada Department of Wildlife
3. Desert Research Institute

Corresponding author: Sarah Byer (sarah.byer@tnc.org)

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Spring Stewardship Institute Acknowledgement Statement regarding data for Springs layer:

This information is provided by the Springs Stewardship Institute (SpringStewardshipInstitute.org), a global initiative of the 501(c)3 nonprofit Museum of Northern Arizona, with the goal of improving understanding and management of these critical and endangered ecosystems. The schema of the Springs Online database (http://springsdata.org/), as well as relational geodatabases derived therefrom, are copyrighted© by the Springs Stewardship Institute of the Museum of Northern Arizona, Inc. Springs Online is a collaborative database that is continually being improved and refined. The data for this Project were acquired on May 5, 2019 and have not been updated since that time. For more current information visit SpringsData.org.

We also thank everyone who attended the workshops in 2018 and 2019 and reviewed the beta version of the story map. Thank you for your very helpful comments!

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Cover photo: Crescent Valley, Nevada by Sarah Byer (TNC)

Background

Groundwater dependent ecosystems (GDEs) are the natural communities including plants, animals, and microbes that rely on groundwater for all or part of their water needs. Groundwater is water that is stored below the soil surface as opposed to surface water, which is water available above ground. Some GDEs depend on surface expressions of groundwater such as stream baseflows, springs, and wetlands, whereas other GDEs primarily access groundwater below ground. GDEs host many of Nevada's endemic species, create valuable habitat for migratory and resident wildlife, and provide essential services to Nevada's people. GDEs store and purify water, preserve soils, sequester carbon, reduce flood risk, and offer recreational opportunities.

In cooperation with the Bureau of Land Management (BLM), the Nevada Water Program at The Nature Conservancy (TNC) has gathered data from multiple sources to assemble a state-wide database of indicators of GDEs (iGDEs) in Nevada. Identifying where GDEs are located requires detailed, local data about the land use, hydrology, and geology of a location. Because detailed local data are not available in all Nevada basins the database incorporates existing datasets to identify and map ecosystems that potentially rely on groundwater, hereafter known as indicators of GDEs (iGDEs; Klausmeyer et al. 2018). This concept originated from the California iGDE database, which provides a starting point for identifying and analyzing GDEs under California's Sustainable Groundwater Management Act.

The Nevada iGDE database includes phreatophytic communities, wetlands, springs, lakes and playas, rivers and streams, and groundwater-dependent species. In collaboration with the Nevada Department of Wildlife (NDOW) and Nevada Natural Heritage Program (NNHP), the database is available to the public and land managers as a downloadable file and Esri Story Map. GDEs represented in the Nevada iGDE database have not been field verified or do not have local hydrologic data. Additionally, expressions of groundwater at any location may change over time. The database provides spatial representation of where GDEs are likely located in Nevada based on best available data. The database provides a snapshot of where iGDEs are in Nevada and makes this information accessible to land stewards and scientists for managing and studying GDEs.

TNC anticipates that the database will be used for data exploration and simple, large-scale analyses as most of the data have not been field-verified for small-scale analyses. Creating the iGDE database and related products is the first step towards assessing the condition and future of GDEs in Nevada. Groundwater depletion, climate change, and water quality degradation can threaten the sustainability of GDEs, so resources like the iGDE database can be used with data on stressors and threats to GDEs to develop strategies to protect GDEs and the people, plants, and creatures that depend on them.

This report describes the methods used to develop and publish the Nevada iGDE story map and database. These methods were developed by TNC in collaboration with NDOW and with input from potential users of the database through two workshops and a beta testing period for the draft story map. The project team also consulted with data providers and partners to determine how to organize the database to ensure data integrity and ease-of-use. TNC included only information about GDEs that partners determined was useful to their work. All data providers and partners were invited to review the database throughout the data integration process.

The first workshop was held at the Desert Research Institute (DRI) North and South campuses on February 22, 2018 and was attended by 33 people[1]. The purposes of the workshop were to 1) provide an update of the Nevada GDE database effort; 2) find out how people might be interested in using the database; and 3) determine how to get additional data that were available for the database.

The beta version of the draft Nevada GDE story map was released on March 20, 2019 and coincided with the second workshop that was held on the same date at the DRI North and South campuses. This workshop was attended by 32 people[2] and its purposes were to 1) provide an update of the Nevada GDE database effort; 2) get feedback on the draft public story map of GDEs in Nevada; and 3) provide information about how to review and provide feedback on the draft public story map. Responses were collected through April 20, 2019. Please see Appendix A for a copy of the review form, and a summary of comments and responses. Revisions were made for final distribution of the Nevada iGDE story map and database on July 8, 2019.

This is a static geodatabase with no plans for update. Thus, data are current as of May 9, 2019. Although the data products used to create the database layers may be updated by their stewards, those updated products will not be integrated, so users seeking the most recent data products used in this database should contact the data providers (Appendix B, Table B1).

The Nevada iGDE database is available for download through NNHP by filling out a data request form to download the entire database or individual layers as shapefiles from this website: http://heritage.nv.gov/ecology. The public Nevada iGDE story map is located at https://arcg.is/qyj0v. Information about mapping resources are available at https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx.

Overview & Products

Nevada iGDE Database

The Nevada iGDE database was developed in a geodatabase format with each GDE type stored in spatial data layers. Tabular data about GDEs and metadata are stored in the geodatabase as tables. All layers and tables are also available in shapefile and comma-separated value format.

[1] Attendees at the first workshop represented the following organizations: Bureau of Land Management, Carson Water Subconservancy District, Desert Research Institute, Great Basin Water Network, National Park Service, Nevada Department of Wildlife, Nevada Division of Environmental Protection, Nevada Division of Water Resources, Nevada Natural Heritage Program, Pyramid Lake Paiute Tribe, Springs Stewardship Institute, The Nature Conservancy, US Fish and Wildlife Service, US Forest Service, and US Geological Survey.

[2] Attendees of the second workshop represented the following organizations: Bureau of Land Management, Center for Biological Diversity, Colorado State University (Center for Ecological Management of Military Lands), Desert Research Institute, Great Basin Water Network, National Park Service, Nevada Department of Transportation, Nevada Department of Wildlife, Nevada Division of Water Resources, Nevada Natural Heritage Program, Pyramid Lake Paiute Tribe, Springs Stewardship Institute, The Nature Conservancy, Truckee River Yacht Club, University of Nevada Reno, US Fish and Wildlife Service, US Forest Service

TNC developed a GIS using the arcpy module under Python 3.6 to integrate the spatial and non-spatial datasets. These scripts can be found on Github at https://github.com/sbyer-tnc/Nevada-iGDE. The GIS selects, prioritizes, combines, and summarizes GDE data from the original datasets to create both the Nevada iGDE Database and story map products (Figure 1).

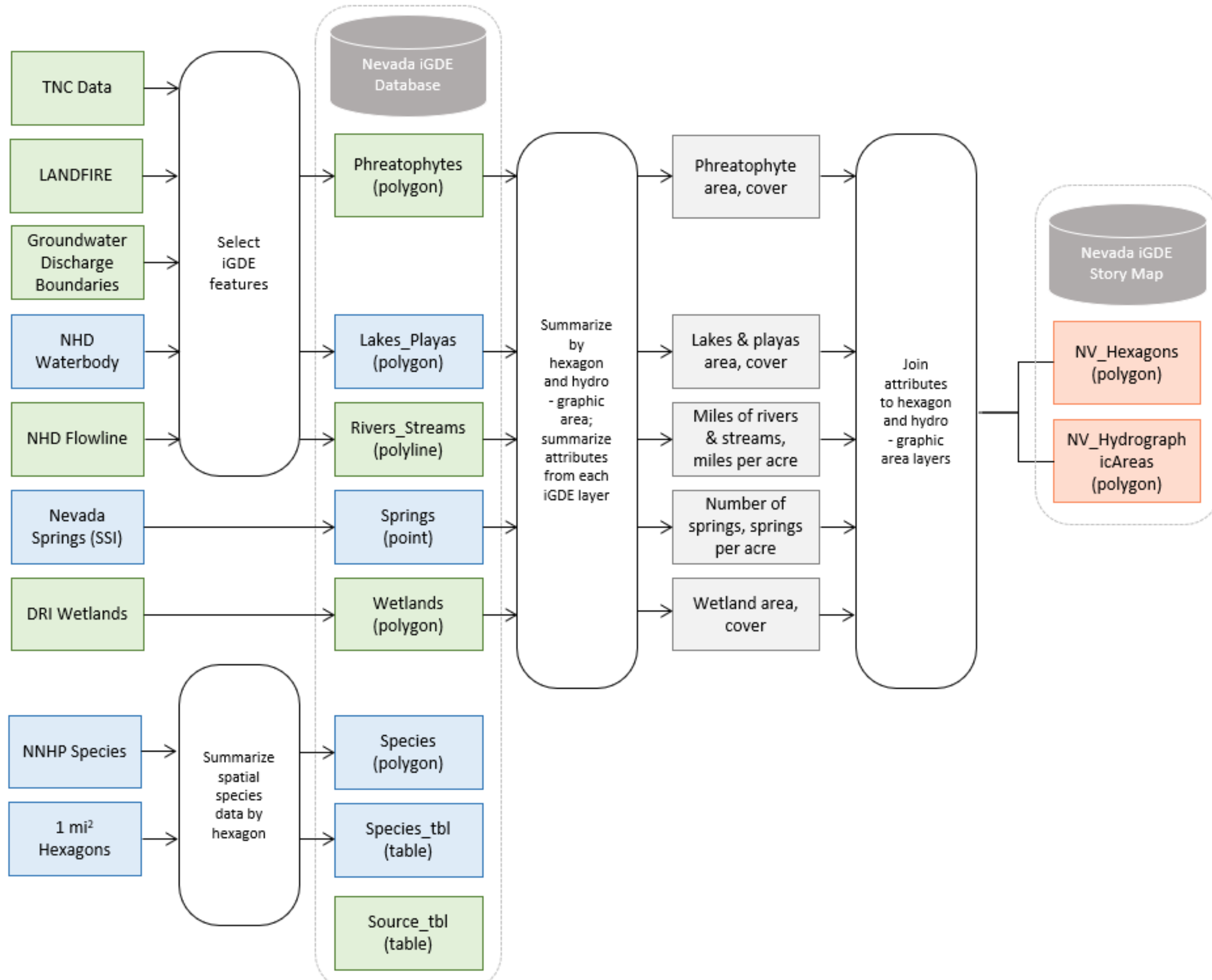


Figure 1. Overview of the datasets and processes used to create the iGDE database layers and story map layers.

TNC designed the database to integrate all available data that represent the presence of iGDEs. The geodatabase contains six spatial data layers and two tables (Table 1). Species, while not iGDEs themselves, are represented to describe what species use GDEs and where they have been recorded. A metadata table in the geodatabase describes the sources used to create each iGDE layer.

Table 1. Data layers and tables in the Nevada iGDE Database.

Geodatabase Layer	Format
Phreatophytes	Polygon
Lakes_Playas	Polygon
Rivers_Streams	Polyline
Springs	Point
Wetlands	Polygon
Species	Polygon
Species_tbl	Table
Source_tbl	Table

Story map of Groundwater Dependent Ecosystems in Nevada

NDOW and TNC created the GDE story map with Esri's ArcGIS Story Maps to visualize the information in the Nevada iGDE database. The story map displays summarized data from the following Nevada iGDE database layers: Phreatophyte Communities, Springs, Wetlands, Lakes and Playas, and Rivers and Streams. These layers are summarized by 1-mi^2 hexagons[3] and hydrographic areas[4]. Users can interact with the maps in the story map by navigating (e.g., panning, zooming) the maps and viewing iGDE statistics for a selected hexagon or hydrographic area. Additional information about the types of GDEs and their importance accompany the story map. Summarized data shown in the story map cannot be exported, but PDF and JPEG files of statewide maps are available on the story map.

Nevada iGDE Database Methods

This section of the report provides a description of the methods used to develop each layer of the Nevada iGDE database. Data dictionaries for all layers can be found in Appendix C.

Phreatophyte Communities

The Phreatophyte Communities layer is a polygon feature class showing where phreatophytes are located throughout Nevada. Multiple data sources were used to create this statewide layer as some data sources do not cover the entire state of Nevada. Data were prioritized by resolution and accuracy, with higher priority given to more accurate and higher resolution data (Table 2).

[3] . These hexagons were derived from the Nevada Critical Habitat Assessment Tool (NV CHAT) dataset (http://www.ndow.org/Nevada_Wildlife/Maps_and_Data/NVCHAT/Map_Data/) developed by the Nevada Department of Wildlife (NDOW).

[4] Hydrographic areas are the administrative groundwater basins in Nevada that are used by the Nevada Division of Water Resources to manage water rights

Table 2. Datasets used to create the Phreatophyte Communities layer in the iGDE database. Some datasets were created by classifying satellite imagery taken in different years, then mosaicked together to create one geography. "Date" indicates the year of the satellite image used to map most of each geography. More information on each data source can be found in Table B1. A map of areas covered by TNC can be found in Figure B1.

Priority	Source Code	Provider	Name	Resolution (m)	Date
1	nvtnc1	TNC	Cortez Range	1.5	2014
1	nvtnc2	TNC	7H Ranch	1.5	2014
1	nvtnc3	TNC	TJ Ranch	1.5	2014
1	nvtnc4	TNC	Great Basin National Park	2	2007
1	nvtnc5	TNC	IL Ranch	5	2013
1	nvtnc6	TNC	Mount Grant	4	2003
1	nvtnc7	TNC	Spring Mountains	2.4	2008
1	nvtnc8	TNC	TS HS Ranch	5	2013
1	nvtnc9	TNC	Upper Truckee Watershed	1.5	2016
1	nvtnc10	TNC	Ward Mountain	2	2009
1*	nvtnc11	TNC	Wassuk Range	10	2005
2	lf	LANDFIRE	LANDFIRE	30	2014
3	drip	Desert Research Institute	Phreatophyte groundwater discharge boundaries	NA	2019

* Mount Grant imagery and resolution takes priority where it overlaps with Wassuk Range

All datasets were combined to create one polygon feature class. At locations where multiple datasets occurred, only features from the highest priority dataset were retained. Vegetation types with phreatophytes were standardized to those used in the highest priority datasets and categorized into broad vegetation groups. Descriptions of phreatophyte community types can be found in Appendix D Phreatophyte cover data were further summarized into groups in the story map (Table 3).

Table 3. Phreatophyte Community types with groups.

Phreatophyte Community	Group
Aspen-Mixed Conifer	Forest
Aspen Woodland	Forest
Greasewood	Shrubland
Jeffrey Pine Riparian	Forest
Lodgepole Pine-Wet	Forest
Mesquite	Forest
Unknown Phreatophytes*	Unknown

**Unknown Phreatophytes are derived from DRI – Groundwater Discharge Boundaries (see text for explanation).*

TNC Vegetation Mapping

Land cover data provided by TNC have the highest-priority in the Phreatophyte Communities layer with one exception where two of the mapped areas overlap. These data products were derived from high resolution satellite imagery with substantial ground-truthed data collected to validate land cover classifications. TNC vegetation classifications are derived from LANDFIRE biophysical settings (BpS) which represent historically dominant vegetation on the landscape (https://www.landfire.gov/bps.php). The TNC data products contain more land cover classes beyond phreatophyte vegetation, but only the phreatophyte communities were added to the Phreatophyte Communities layer in the database. The vegetation classifications considered to be phreatophyte communities include: Aspen-Mixed Conifer, Aspen Woodland, Greasewood, Jeffrey Pine Riparian, Lodgepole Pine-Wet, and Mesquite (Table D1).

The TNC data products were converted from their original raster format to polygon features, then dissolved by their vegetation types and data sources. Of all TNC mapped areas, only the Mount Grant and Wassuk Range data products overlap. Mount Grant was given priority over Wassuk Range because it maps vegetation at a higher resolution (4 meters) than Wassuk Range (10 meters). Where the two areas overlap, features from Mount Grant were included and features from Wassuk Range were removed. The phreatophyte features with their source and land cover type attributes were then added to the Phreatophyte Communities layer. For more information about the TNC data products such as image capture dates and classification methods see https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx.

Landscape Fire and Resource Management Planning Tools (LANDFIRE) Vegetation Data

LANDFIRE Biophysical Setting (BpS) data were used wherever TNC data were not available in Nevada. The Bps product "represents the vegetation that may have been dominant on the landscape prior to Euro-American settlement and is based on both the current biophysical environment and an approximation of the historical disturbance regime" (https://www.landfire.gov/bps.php). At locations where both TNC and LANDFIRE data were present, only TNC data were used and all underlying LANDFIRE data were removed (Figure 2). LANDFIRE data were converted from the original raster format into polygons and dissolved by vegetation type. Only ecological systems with phreatophyte vegetation were included from the BpS product. Phreatophyte vegetation features were selected from the BpS product and assigned phreatophyte community names and groups to match those in the TNC data products based on shared BpS codes (Table 4).

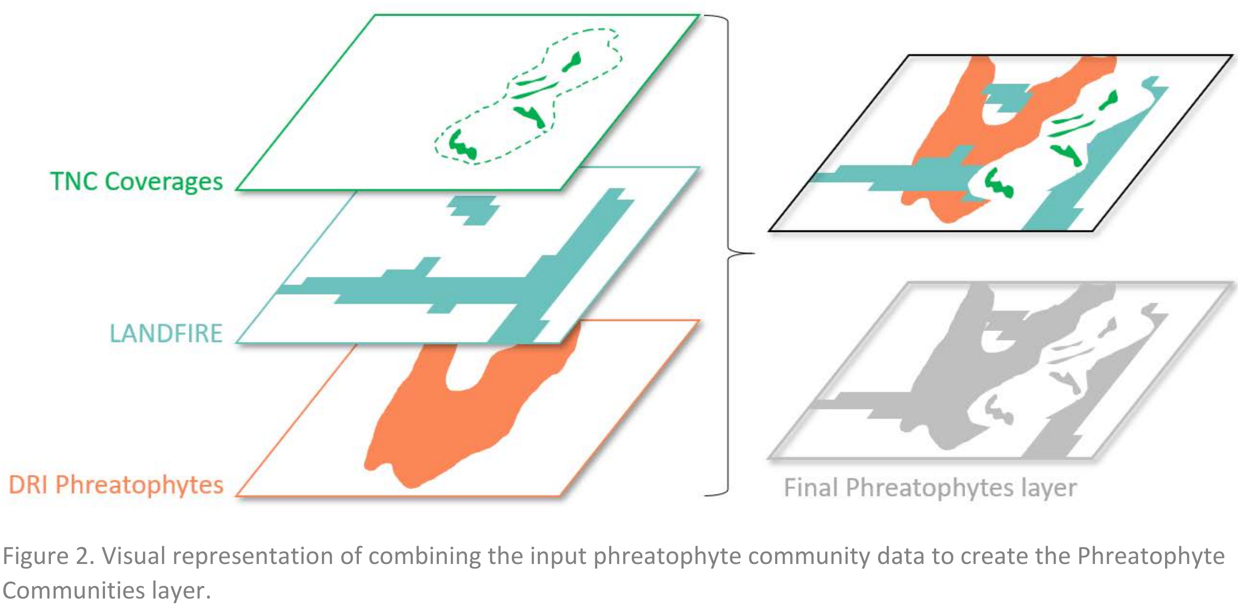


Figure 2. Visual representation of combining the input phreatophyte community data to create the Phreatophyte Communities layer.

Table 4. Original vegetation class names from LANDFIRE and their standardized names in the iGDE database.

LANDFIRE Class Name	BpS Code	Phreatophyte Community	Phreatophyte Group
Rocky Mountain Aspen Forest and Woodland	10110	Aspen Woodland	Forest
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	10610	Aspen-Mixed Conifer	Forest
Inter-Mountain Basins Greasewood Flat	11530	Greasewood	Shrubland
North American Warm Desert Riparian Systems	11551	Mesquite	Forest

Greasewood areas mapped by LANDFIRE were restricted to areas within the Groundwater Discharge Boundaries that contained phreatophytes (see *Desert Research Institute - Groundwater Discharge Boundaries*). We applied this rule because we noticed that greasewood from the LANDFIRE BpS product often fell outside of groundwater discharge boundaries; therefore, these more "upland" greasewood occurrences were not included as they presumably rely on surface water. The rule was informally tested by comparing TNC high-resolution and ground-truthed coverages to DRI's groundwater water discharge boundaries in areas we knew well (for example, Crescent Valley). We confirmed that TNC's coverages and DRI's groundwater discharge boundaries satisfactorily matched and that, perhaps, LANDFIRE coverages slightly overestimated the extent of greasewood by including more upland areas.

Desert Research Institute - Groundwater Discharge Boundaries

DRI provided groundwater discharge boundary data for 160 hydrographic areas in the Great Basin in Nevada. This data set contains polygons representing the potential groundwater discharge areas was delivered to TNC on May 3, 2019. Information on mapping methodology for the entire dataset or specific hydrographic areas can be found in this report: https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Documents/minor19_gwdischarge_boundaries_nv.pdf.

Boundary types such as irrigated cropland and bare soil were mapped in this dataset, but only "Phreatophyte" type boundaries were added to the Phreatophytes layer in the database. The phreatophyte boundaries were "restricted to the areas where shallow groundwater is available for consumption by greasewood, rabbitbrush, saltbush, saltgrass, and other phreatophyte species," where groundwater ranges from 10 to 50 feet (Minor et al. 2019; Plume and Smith, 2013). TNC and LANDFIRE data took priority where they overlapped with the boundary dataset. The phreatophyte groundwater discharge boundary features were erased in areas covered by all TNC data and wherever LANDFIRE phreatophyte classes occurred (Figure 2).

The discharge boundaries were carefully mapped but not all areas were field-verified. Photos and vegetation cover descriptions were recorded within some phreatophyte boundaries, but there was insufficient evidence to assign a phreatophyte community type (e.g., Greasewood or Mesquite) to an entire mapped area. All features in the groundwater discharge boundary dataset were therefore assigned “Unknown Phreatophytes” as the phreatophyte community type, and “Unknown” as the phreatophyte group.

Wetlands

Wetlands data were provided by DRI as part of grant from the EPA. DRI compiled existing geospatial and remote sensing data for Nevada into a statewide map of wetlands. Wetland boundaries and types are mapped and classified by intersecting multiple datasets. The statewide map of wetlands and information about this product can be found at this website: https://www.dri.edu/wetland-mapNV.

TNC provided DRI with polygons of wetland vegetation from TNC vegetation mapping for incorporation into the wetland map product. Using the same methods described in the Phreatophyte Communities section, wetland vegetation polygons were extracted from TNC map products. These wetland vegetation classes include: montane riparian, Ponderosa pine riparian, saline meadow, wet meadow – bottomland, wet meadow – montane, and wetland. These wetland vegetation types were cross-walked to match those in the other datasets used to create the statewide wetlands dataset (Table 5). Finally, DRI was given the TNC polygons to incorporate them with all other input datasets to create the final statewide map of wetlands.

Due to conflicting minimum mapping units and computational capacity, TNC polygons were not incorporated at their original resolution in the DRI wetlands dataset. DRI aggregated the resolution of the TNC polygons to 15 meter resolution during incorporation to reduce the data to a more consistent representation with fewer individual wetland polygons. The wetland vegetation type of the aggregated TNC data was determined by majority area covered within the 15 meter window. The final statewide map of wetlands provided by DRI was used as the iGDE Wetlands layer. Polygons representing lakes and dry playas were not included in the Wetlands layer to prevent duplicating data from the Lakes and Playas layer.

Table 5. Wetland types and subtypes included in the iGDE Wetlands layer. TNC wetland vegetation classes were cross-walked to the wetland types and subtypes.

Wetland Type	Wetland Subtype	TNC Wetland Vegetation Classes
Littoral	Aquatic bed	NA
Littoral	Emergent	NA
Littoral	Flooded	NA
Palustrine	Aquatic	Wet Meadow-bottomland
Palustrine	Emergent	Wet Meadow-montane
Palustrine	Flooded	NA
Palustrine	Forest	NA
Palustrine	Meadow	Saline Meadow, Wet Meadow-bottomland, Wet Meadow-montane, Wetland
Palustrine	Shoreline	NA
Palustrine	Shrub	NA
Palustrine	Undifferentiated	NA
Palustrine	Vegetated shoreline	NA
Playa	Intermittently flooded	NA
Playa	Seasonally flooded	NA
Riparian	Montane	Montane Riparian, Ponderosa Pine Riparian
Riparian	Undifferentiated	NA
Riparian	Valley	NA

Springs

Springs data were provided by the Springs Stewardship Institute (SSI), a non-profit organization of the Museum of Northern Arizona. SSI extracted data on all Nevada springs from their Springs Online database (http://springstewardshipinstitute.org/about-the-database/) and delivered this dataset to TNC on April 21, 2019. The Springs Online database is updated frequently as users add new spring survey information or location data, but the subset of data used in the iGDE database is static. Users seeking up-to-date data should contact SSI or visit the Springs Online database.

The Springs Online database contains spring locations and survey data. SSI summarized available survey data at spring locations including but not limited to water temperature, alkalinity, photographs, and observed species. SSI delivered this summarized data in a point feature class to TNC in addition to the survey data exported from their database.

A subset of available spring attributes was included in the iGDE Springs point layer. Summarized survey data were used where available to describe basic information about each spring (Table C3). Information about species recorded at springs was present in the summarized data layer, but this included incomplete species records. Only species records with a full scientific name (genus and species) were included in the species counts. Note that not all species recorded are groundwater-dependent. Many recorded species are facultative users of springs and other GDEs and will use them if given the opportunity. Not all springs were surveyed at the time of data publication and not all surveyed springs had species information. The presence of species information for a spring depends on the purpose of the survey or the surveyor's ability to identify certain species. Springs with no species data are not likely to be biologically barren. It is more likely that no survey was conducted at that spring or no species observations were recorded because it was not an objective of that survey. The following tables were used to calculate the number of species recorded at each spring in three groups: vertebrates, invertebrates, and plants:

Table 6. Species data recorded during spring surveys in the SSI data.

Table Name	Attribute Created
Nevada_Springs_Apr_21_2019_Summarized_TaxaVert_by_Site	VERT_COUNT
Nevada_Springs_Apr_21_2019_Summarized_TaxaInvert_by_Site	INVERT_COUNT
Nevada_Springs_Apr_21_2019_Summarized_TaxaFlora_by_Site	FLORA_COUNT

Once all attributes were calculated, the springs point data were added to the Springs layer in the iGDE database. Ten springs were removed from the iGDE database because the inventory status was recorded as "No Spring," indicating someone visited the location of a mapped spring but found no spring there. The 'SPRING_ID' field contains the unique Site ID of each spring from the SSI database which can be used to seek more information about a spring in the more comprehensive Springs Online database.

Lakes and Playas

National Hydrography Dataset (NHD) Waterbody data were used to create the Lakes and Playas layer. The NHD Waterbody feature class is part of the Hydrography feature dataset in the NHD, a product of the U.S. Geological Survey (https://www.usgs.gov/core-science-systems/ngp/national-hydrography/about-national-hydrography-products). The NHD Waterbody feature class contains surface water features across the continental U.S. including lakes, ponds, reservoirs, swamps, marshes, estuaries, and ice masses.

For the purpose of identifying iGDEs in Nevada, it was assumed that all natural lakes and playas in Nevada were iGDEs. Only playa and perennial lake/pond features were included in the database for the Lakes and Playas layer. A filter on the NHD 'FCode' attribute was used to include only perennial lake features (Table 7). This filter allowed for some reservoirs and human-modified lakes such as Lake Mead and Rye Patch Reservoir to be included in the layer. Although these features are heavily modified and controlled by humans, they are fed by groundwater via rivers, streams and springs. Lake Mead and Rye Patch Reservoir are primarily supported by the Colorado River and Humboldt River, respectively, both of which are perennial rivers that receive contributions from groundwater.

Table 7. FCodes used to filter for groundwater-dependent lakes and playas from the NHD

NHD FCode	NHD Feature Type	Description
36100	PLAYA	Playa
39004	LAKE/POND	Hydrographic Category|perennial
39009	LAKE/POND	Hydrographic Category|perennial; Stage|average water elevation
39011	LAKE/POND	Hydrographic Category|perennial; Stage|date of photography

Lake and playa features were clipped to the extent of Nevada and added to the iGDE database. The 'PERM_ID' field contains the unique Permanent Identifier of each waterbody from the NHD. Users that want more specific information about a waterbody can use this ID to find the waterbody in the full NHD.

Rivers and Streams

NHD Flowline data were used to create the Rivers and Streams layer. The NHD Flowline feature class is part of the Hydrography feature dataset in the NHD (https://www.usgs.gov/core-science-systems/ngp/national-hydrography/about-national-hydrography-products) and contains linear surface water features across the continental U.S. including pipelines, streams, rivers, canals, ditches, connectors, artificial paths, coastlines, and underground conduits.

Perennial streams and rivers were included as iGDEs because precipitation is not a reliable source of water throughout most of Nevada, so streams and rivers that rely solely on precipitation are likely to dry up periodically. Perennial reaches, parts of rivers and streams that contain water year-round, are iGDEs because groundwater is a consistent water source. FCode '46006' was used to filter for the perennial streams and rivers from the NHD flowline dataset.

Additional flowline sections of select streams and rivers that are classified as "artificial paths" (FCode '55800') were also included. These sections were modified by humans, but they are likely supported by groundwater as they include major perennial rivers and streams. The rivers and streams with "artificial paths" manually added to the Rivers and Streams layer include: Truckee River, Humboldt River, Virgin River, Carson River, White River, Walker River, Quinn River, Mary's River, Muddy River, Jarbidge River, Bruneau River, Owhyee River, Reese River, and Duck Creek. All groundwater-fed river and stream features were clipped to Nevada and added to the Rivers and Streams layer. The miles of each reach were also calculated. The 'PERM_ID' field contains the unique Permanent Identifier of each river or stream reach from the NHD. Users that want more specific information about a river or stream feature can use this ID to find the feature in the full NHD.

Species

Species data were provided by the NNHP (http://heritage.nv.gov/get_data). NNHP requested that their data be generalized to protect the location information of the sensitive species they track. Therefore, the species layer is a polygon feature class of uniform 1-mi^2 hexagons, the same used to summarize data in the public version of this database, to generalize the locations of rare or at-risk species.

NNHP provided a subset of spatial species data from their database of rare and at-risk species. NNHP selected wetland-dependent species in Nevada using their 'WETLAND' tag and exported these features as points, lines, and polygons on April 23, 2019. The species data in the iGDE database are static, but NNHP species data are being continually updated. Users seeking up-to-date species data should contact NNHP.

Points and lines were buffered by 5 meters on all sides and combined with the original species polygon data to create a combined polygon feature class of wetland species occurrences. Additional polygon features of data-sensitive species provided by NNHP were added to this polygon feature class. The locations of sensitive species were adjusted before being delivered to TNC by masking the last 4 digits of the UTM coordinates. All species location data have some degree of locational uncertainty which is reflected in the geometry of the feature or the coordinates in the attribute table. Therefore, features represent approximate locations of species occurrence (http://heritage.nv.gov/map_method). Information about the types of locational uncertainty of a mapped species, while present in the original NNHP data, was not included in the database because the species data have been further generalized by 1-mi^2 hexagons in the iGDE database.

A Spatial Join combined all NNHP species polygons with the hexagon layer to identify the species recorded in each hexagon. Because the 'Intersect' method was used in the spatial join, a species occurrence that spans multiple hexagons would be counted in all hexagons it touches. For example, a frog species that occurs within 500 meters along a stream is represented by a polygon that extends 500 meters on both sides of the stream (Figure 3). Overlaid by the hexagon layer, this polygon touches 7 hexagons. In the iGDE Species layer, all 7 hexagons will show occurrence of that frog. Summary Statistics were used to count the unique scientific names of species found within each hexagon after the Spatial Join to create the 'COUNT_NNHP' attribute. Counts of unique endemic species per hexagon ('COUNT_EN') were calculated by removing non-endemic species polygons from the NNHP data then running the Spatial Join and Summary Statistics tools with only endemic species polygons. The species count attributes were added to the hexagons to represent the number of mapped wetland-dependent species and endemic wetland-dependent species in each hexagon mapped by NNHP.

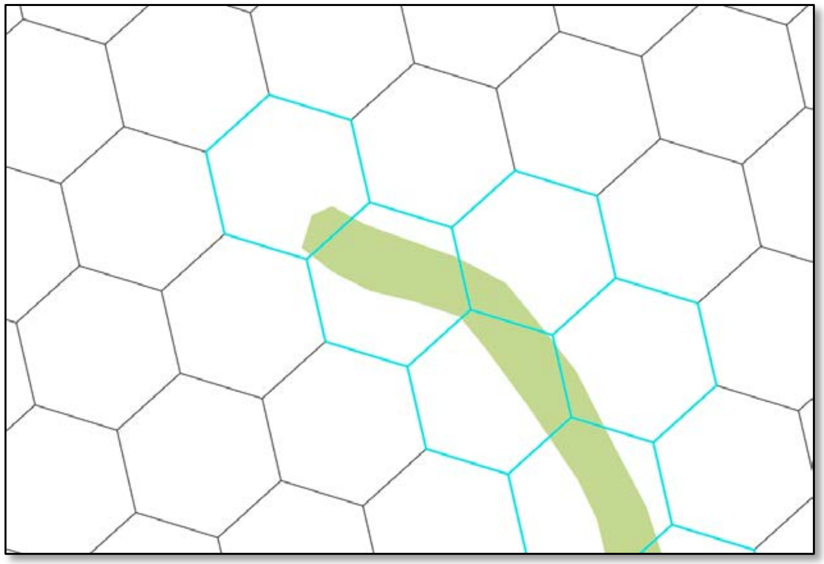


Figure 3. A linear species occurrence feature illustrates that a species can be found within 500 meters from a river or stream. This species would be considered present within all blue-highlighted hexagons.

A unique list of species was generated from the combined NNHP species polygon layer. This list, along with basic species attributes (scientific name, common name, conservation ranks, endemism, etc.), was added to the iGDE database as 'Species_tbl' (Figure 4). The data in this table are not spatial but provide information to users about wetland-dependent species that have been mapped by NNHP. A full list of species attributes is in Table D7. Definitions of attribute values describing species conservation ranks or taxonomic groups can be found at http://heritage.nv.gov/definitions.

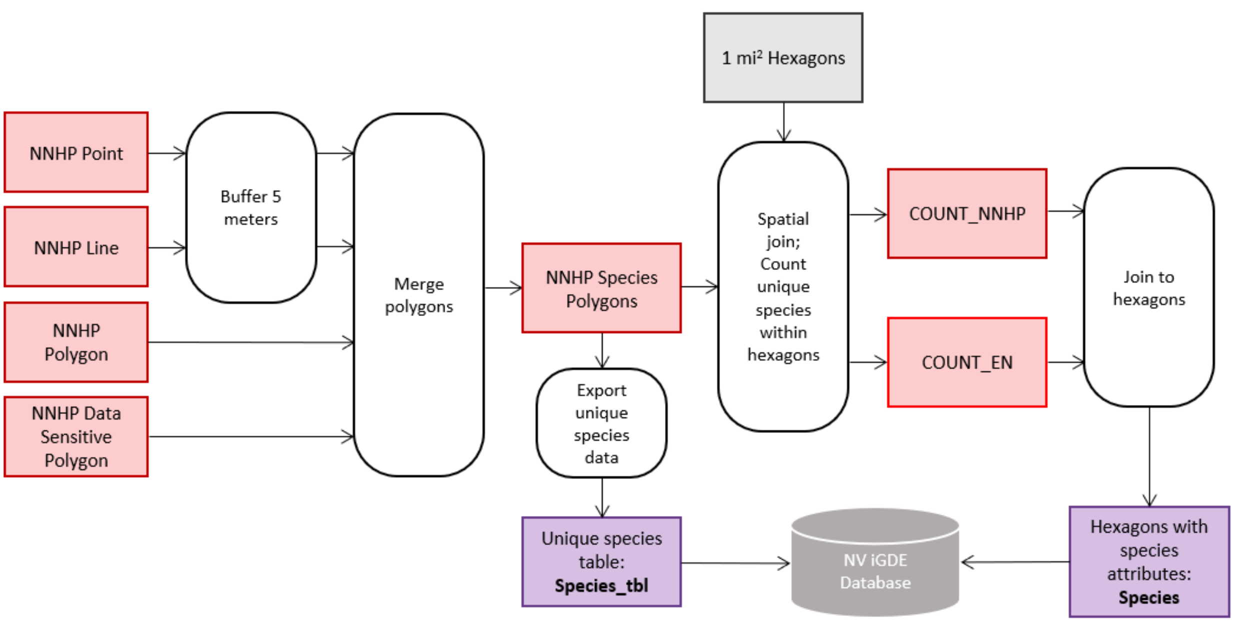


Figure 4. Processing steps for creating the 1-mi^2 hexagon Species layer and Species_tbl table from NNHP species data.

Sources

'Source_tbl' contains information about the source(s) used to create each feature in the database. All layers contain a 'SOURCE_CODE' field, which contains an abbreviated code of the source dataset used to create that feature. The source table contains these source codes, in addition to information about that source including the full name, originating organization, date last updated, links to sites about the layer, and more. The source table is found in Table B1.

Public Story Map

Information from all layers in the iGDE database are summarized by 1-mi^2 hexagons from the NV CHAT (http://www.ndow.org/Nevada_Wildlife/Maps_and_Data/NVCHAT/Map_Data/) and by hydrographic areas from the Nevada Division of Water Resources (NDWR) (http://water.nv.gov/gisdata.aspx). In the hydrographic area boundary file downloaded from the NDWR site there are 261 features. These features were dissolved by their 'HYD_AREA' IDs to create the 256 hydrographic basins within the boundary of Nevada. The public story map only contains two feature classes: hexagons and hydrographic areas with iGDE attributes calculated for each feature based on the data in the layers from the private database. A list of all attributes for each feature class can be found in Tables C1 – C10.

These layers were symbolized and published to TNC's ArcGIS Online server to be presented in a Story Map in cooperation with NDOW. The story map is available to the public: https://ndow.maps.arcgis.com/apps/MapSeries/index.html?appid=936d34302dff4e6d9d6d42a3d478024b

Phreatophyte Communities

A 'PER_PHR' attribute stores the percent cover of phreatophyte communities of each feature in both feature classes. Percent phreatophyte cover was calculated by intersecting the Phreatophyte Communities layer's polygons with the summarizing feature class (i.e., hexagons or hydrographic areas). The intersected phreatophyte community features were dissolved by the summarizing feature to create sections of phreatophytes in each hexagon or hydrographic area. The area in acres of each phreatophyte community section was calculated to create the 'AREA_PHR' attribute. This attribute represents the area covered by phreatophyte communities in each summarizing feature. Percent phreatophyte community cover ('PER_PHR') was calculated by dividing the area of phreatophyte communities in a section by the summarizing feature's total area (Figure 5).

PER_PHR = 100(Area covered by phreatophyte communities / total area of summarizing feature)* (1)

Additional attributes were created to represent the phreatophyte community groups in each summarizing feature. Individual phreatophyte community types from the private database's Phreatophyte Communities layer were categorized into the following groups: forest, shrubland and unknown (Table 4). Groups were assigned based on how each phreatophyte community type would be described by the general public. The following attributes were calculated to represent the proportion of a summarizing feature covered by each phreatophyte group: area/percent forest cover ('AREA_FRST'/'PER_FRST'), area/percent shrubland cover ('AREA_SHRUB'/'PER_SHRUB'), area/percent unknown cover ('AREA_UNK'/'PER_UNK'). These attributes were calculated using the same methods described above to calculate 'AREA_PHR' and 'PER_PHR', but only the group's features were included in the calculation (i.e. only forest features were used to calculated 'AREA_FRST' and 'PER_FRST').

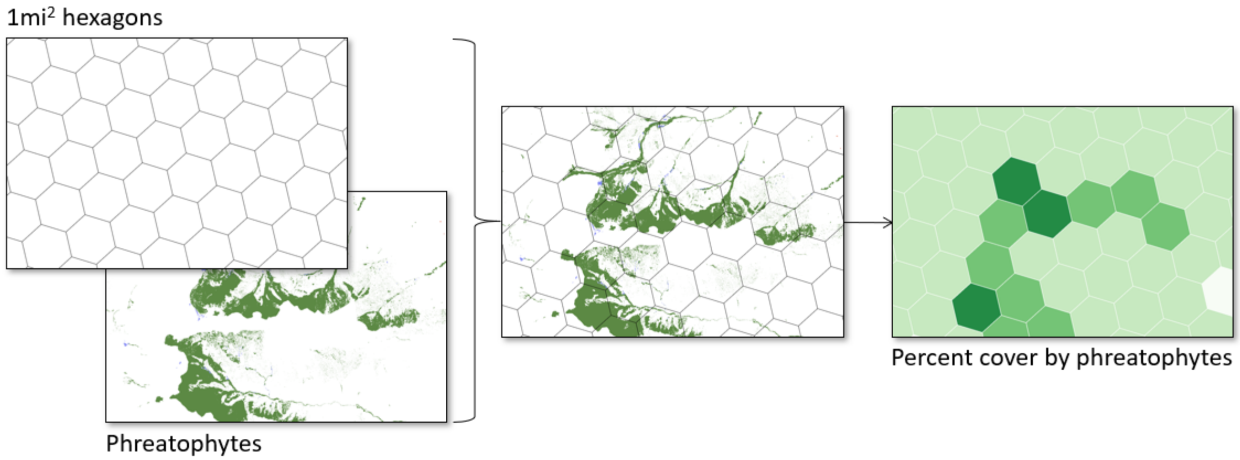


Figure 5. Illustration of how the Phreatophyte Community layer is summarized by 1 mi^2 hexagons.

Wetlands

A 'PER_WET' attribute stores the percent of each feature covered by wetlands. Percent wetland was calculated by intersecting the Wetland layer's polygons with the summarizing feature class. The intersected wetland features were dissolved by the summarizing feature ID to create sections of wetlands. The area in acres of each wetland section was calculated to create the 'AREA_WET' attribute. 'PER_WET' was calculated by dividing the area of wetlands in a section by the summarizing feature's total area.

PER_WET = 100(Area covered by wetlands / total area of summarizing feature)* (2)

Springs

A 'COUNT_SPR' attribute stores the number of springs in each summarizing feature. A spatial join between the summarizing feature layers and the iGDE Springs point feature class identified all springs that intersect each summarizing feature. The resulting attribute table was summarized by unique feature IDs to count the number of springs that intersected each feature. These values were joined to their corresponding feature classes to create the 'COUNT_SPR' attribute.

For the hydrographic areas an additional attribute was calculated to scale the number of springs to the size of each summarizing feature. Larger hydrographic areas could appear to have more springs because of their larger area, but the density of springs might actually be smaller than for smaller hydrographic areas. Thus, the 'AREA_SPR' attribute normalizes the number of springs to the size of the summarizing feature by calculating the number of springs per acre. Due to the relatively small number of springs in larger hydrographic areas, spring density ('AREA_SPR') is represented as the number of springs per 10,000 acres (Figure 6).

*Springs per 10,000 acres =10,000 * (Number of springs / Total area of hydrographic area)* (3)

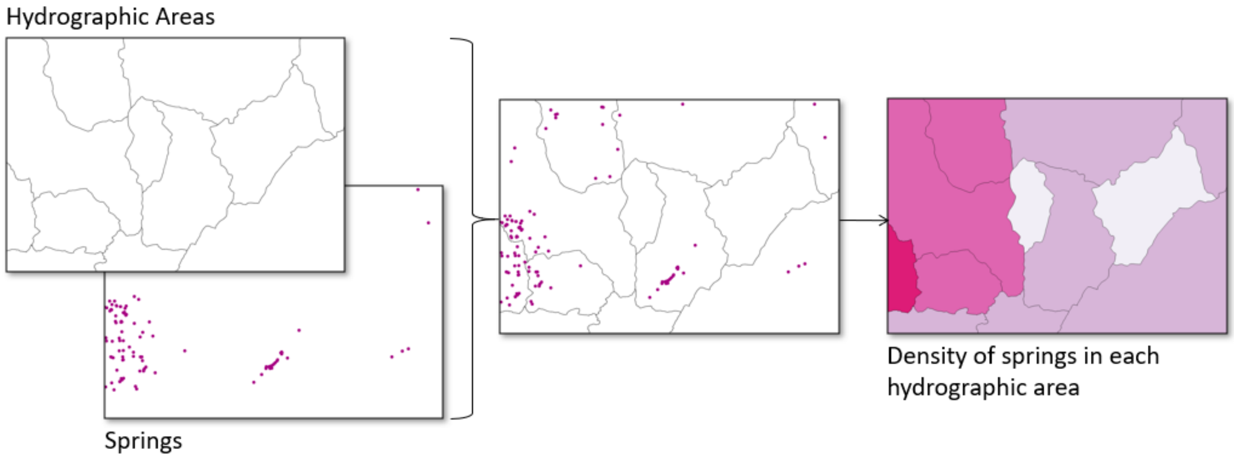


Figure 6. Illustration of how the Springs layer is summarized by hydrographic areas.

Lakes and Playas

A 'PER_LKPL' attribute stores the percent of each feature covered by both lakes and playas. Percent lake-playa was calculated by intersecting the Lakes and Playas polygons with the summarizing feature class. The intersected lake-playa features were dissolved by the summarizing feature ID to create sections of lakes and playas. The area in acres of each lake-playa section was calculated to create the 'AREA_LKPL' attribute. 'PER_LKPL' was calculated by dividing the area of lake-playa in a section by the summarizing feature's total area.

Percent cover by lakes-playas = 100(Area covered by lakes or playas /total area of summarizing feature)*(4)

Additional attributes were created to represent the percent and area of each summarizing feature covered by either lakes ('AREA_LAKE' and 'PER_LAKE') or playas ('AREA_PLAYA' and 'PER_PLAYA'). These attributes were calculated using the same methods described above to calculate 'AREA_LKPL' and 'PER_LKPL', but only lake or playa features were included in the calculation (e.g., playa features were removed from the calculation of 'AREA_LKPL' and 'PER_LKPL').

Rivers and Streams

A 'MILES_RIVST' attribute stores the miles of rivers and streams within each summarizing feature. All river and stream polylines were dissolved to create a single feature class, then intersected with the summarizing feature layer. The intersection identifies the collection of rivers and streams in each summarizing feature. The miles of rivers and streams per summarizing feature were calculated as 'MILES_RIVST'. This attribute was joined to the corresponding summary feature class. Hydrographic areas or hexagons that did not contain iGDE rivers or streams were given a 'MILES_RIVST' value of 0.

For the hydrographic areas an additional attribute was calculated to scale the miles of rivers and streams to the size of each summarizing feature. It is generally expected that larger hydrographic areas are likely to have more miles of rivers and streams. The 'AREA_RIVST' attribute normalizes the length of rivers and streams to the size of the summarizing feature by calculating the miles of rivers and streams per 10,000 acres (Figure 7). This attribute was only calculated for the hydrographic area summary feature class as all hexagons are the same size.

*Miles of rivers and streams per 10,000 acres = 10,000 * (Miles of rivers and streams / Total area of hydrographic area)* (5)

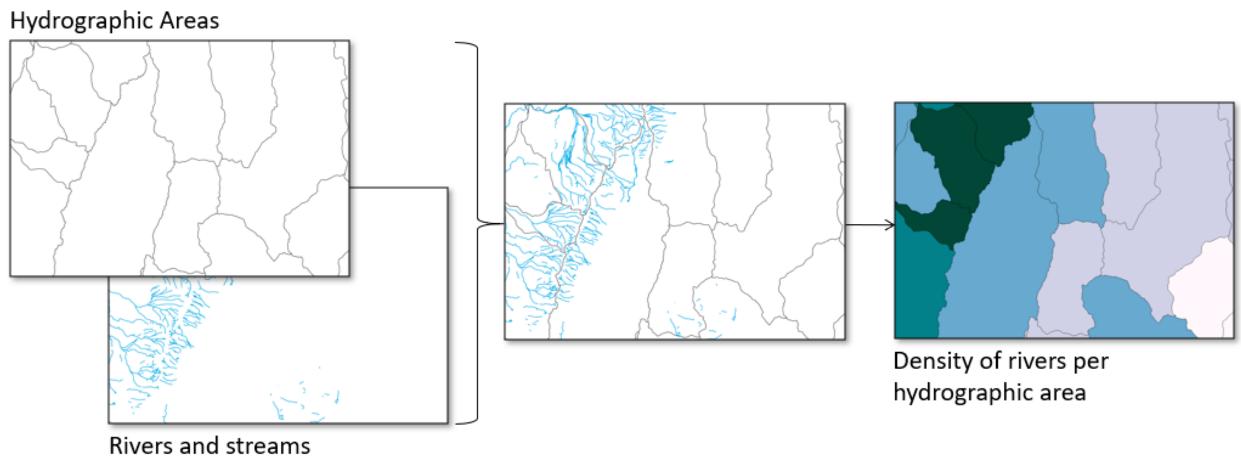


Figure 7. Illustration of how the Rivers and Streams layer is summarized by hydrographic areas.

Species

Species data were not summarized for the story map to prevent misinterpretations of where groundwater dependent species are present or absent. The NNHP species data are restricted to areas that have surveyed for species by NNHP and other agencies that provide data to NNHP. Therefore, a summarized dataset might show an absence of species in an area just because someone has not yet surveyed there. The absence of groundwater dependent species at any location does not mean that a species cannot or does not exist there, but it may mean that there are no data for that location.

To protect sensitive species, detailed species data with locations can only be acquired from the original NNHP datasets. Information about the species mapped such as name and conservation status can be found in the private database's 'Species_tbl' table. More species information can be found through NNHP on their website: http://heritage.nv.gov/species/.

GDE Count

An attribute called 'GDE_COUNT' was created to show the number of unique physical iGDE types present in a hexagon or hydrographic area according to the available data. Species data were not included in this count because the occurrence of a species that uses GDEs is not necessarily indicative of GDE presence (see Species section above). A value of '0' means that no iGDE types are present and a value of '1' means there is one iGDE type present. A maximum value of '5' indicates that all 5 iGDE types are present: Phreatophyte Communities, Wetlands, Springs, Lakes and Playas, and Rivers and Streams. The summarizing attributes for these 5 iGDE types were used to calculate 'iGDE_COUNT'. A value of '1' was added to the 'iGDE_COUNT' when an attribute indicated that an iGDE was present. The following criteria were used to determine whether each iGDE type was present in a hexagon or hydrographic basin:

- More than 0% of the feature is covered by phreatophyte communities (PER_PHR > 0)
- More than 0% of the feature is covered by wetlands (PER_WET > 0)

- At least one spring (COUNT_SPR > 0)
- More than 0% of the feature is covered by lakes or playas (PER_LKPL > 0)
- At least one river or stream feature (MILES_RIVST > 0)

Limitations of the Nevada iGDE database and story map

Limitations in the use of this database were identified throughout its development. The database utilized the best available data and methods at the time of publication, but it is possible that useful datasets were not made available to the project team during the study.

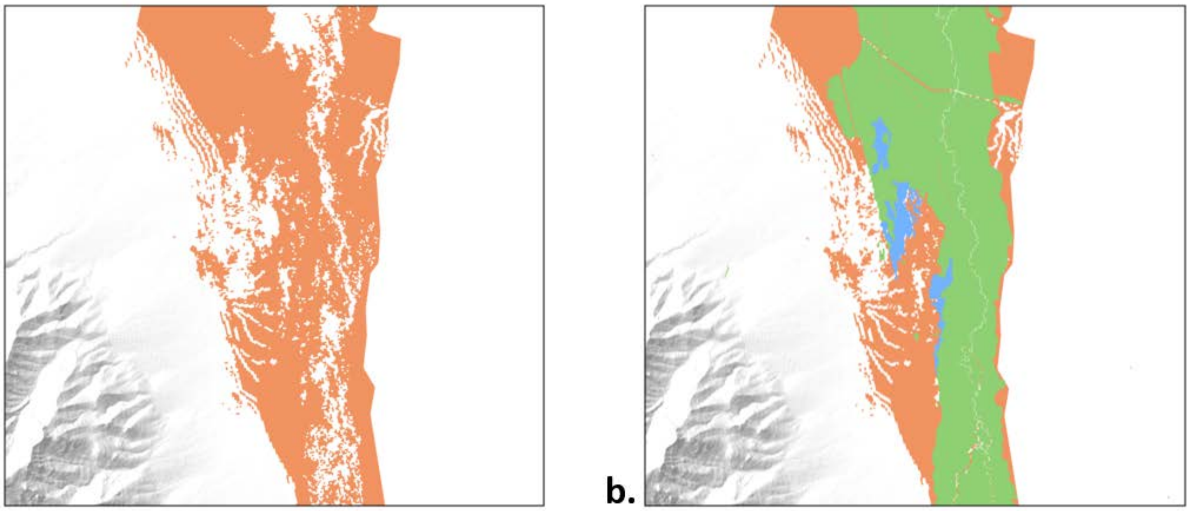
All data in the database are static although the input datasets and the GDEs themselves may change. The database provides a snapshot of indicators of GDEs in Nevada at of the time of publication (May 9, 2019). There are currently no plans to update this database although the individual datasets used to create the database may be updated (e.g. SSI spring data, NNHP species data, etc.). As more data are collected, these sources will become more representative of GDEs and species that rely on them. Additionally, GDEs are dynamic and cannot be entirely represented by static data. In time, springs may become dry during drought cycles, or waterways may be altered by people for irrigation or flood management.

It is possible that the database did not capture all GDEs or species. Some GDEs are very small and may be too small-scale to be mapped by any of the original datasets. Depending on the resolution of the dataset, small-scale features may take on different shapes and sizes from their real dimensions, or they may disappear entirely. A small wet meadow less than 10 meters in width or length may not be captured by remote sensing data from LANDFIRE or older satellite imagery with minimum mapping units greater than 10 meters. Similarly, riparian stringers – long, thin vegetation features along streams – may not be captured by satellite imagery with coarser resolutions. Additionally, all of Nevada has not been surveyed for species, which are incredibly dynamic. Spatial species data from NNHP represent where species have been found or observed. The absence of a species at any location does not mean that a species cannot or does not exist there.

The NHD provides comprehensive information about hydrographic features nationwide. At this scale, many features are outdated or may have become inaccurate because the lakes, playas, rivers, and streams mapped in the NHD are dynamic landscape features. The sizes and shores of lakes may change with drought cycles, rivers may form new channels, and streams may be diverted into different channels. The USGS is working on the NHDPlus HR dataset, an updated, quality-controlled version of the NHD. Volunteers can review and quality-control features from the NHD to bring them up-to-date for the NHDPlus HR. Currently, this is an ongoing effort. NHD data were used in the iGDE database as the best available data until the NHDPlus HR is more complete. More information about the NHDPlus HR and corrections made to the NHD can be found here: https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution

We acknowledge the existence of overlapping data between some of the database layers, most notably the Phreatophyte Communities and Wetlands layers. Not all wetlands have phreatophytes, but many wetland communities are composed of both phreatophytes and non-phreatophytic vegetation. Therefore, it is difficult to separate wetlands from phreatophyte communities. Aspen Woodland features from the Phreatophyte Communities layer and Riparian features from the Wetlands layers commonly overlap. Some phreatophytic plants do not live in wetlands, and these are easier to classify as

Phreatophyte Communities. Greasewood, for example, composes phreatophyte-dominated communities in drier areas and would not usually be considered “wetland”. But due to differences in mapping methods between the input datasets to the Phreatophyte Communities and Wetlands layers, some phreatophytes like greasewood communities may be represented by both layers (Figure 8).



a. b.

Figure 8. (a) Greasewood mapped in orange in the Phreatophytes Communities layer in Steptoe Valley in eastern Nevada. (b) Features from the Wetlands layer mapped over the greasewood. According to the Wetlands layer, some of the area mapped as greasewood may also be considered palustrine (green) or playa (blue) wetland.

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Appendix A – Nevada GDE Story Map Review Form and Responses

The review form used to solicit responses during the beta testing of the Nevada GDE Story Map review is shown followed by a summary of feedback provided and associated responses from the project team. We appreciate the comments provided, which helped to greatly improve the functionality and content of the story map and database.

Nevada Groundwater Dependent Ecosystems Story Map: Feedback Form

Link to story map: https://arcg.is/qyj0v

Please provide feedback to Sarah Byer (sarah.byer@tnc.org, *775-322-4990 Ext.3124*). The best way is to email Sarah this form with your answers by April 12, 2019. After this date the database will be pulled offline.

Name: ______________________________

Organization: ______________________________

Contact info: ______________________________

1. What internet browser are you using?

2. Please describe any instances when the story map did not function as you expected. Was anything you tried (links, navigating the web maps, etc.) broken?

3. Are there functions you'd like to see that the story map currently doesn't support?

4. What content did not load in a reasonable amount of time?

5. Please provide links to any other story maps that you particularly like. What do you like about them?

6. Please provide a description of any statewide statistics you'd like to see in the story map for any layer.

7. The Phreatophytes section is the most built-out. What do you think about the map design and functionality? The side-bar text? The photos?

8. Please provide any additional feedback here. Please be as specific as possible.

Requests for information/content:

- If you have photos of GDEs that you can share, please contact Sarah. Credit will be given.
- Let us know if you have good graphics that we can use to explain any of the GDEs.

Thank you!

Feedback and Responses on Draft Nevada GDE Story Map

Table A1. Content

Comment	Response
Suggested link: Southern Nevada Fire Management Plan (not live yet)	We did not add this link because we did not receive it by the time the Story Map was published
Add more photo points	We added many more photo points to the final product
Revise summary statistics for rivers as using number of reaches is misleading	We changed the approach to reflect river miles and normalized for size of hydrographic areas
Fix photo points that are not working	We have tried to catch all of these in the final product
Revise summary statistics for springs as just counting can be misleading for small hydrographic areas	We changed the approach to reflect number of springs per 1-mi^2 for hexagons, and per 10,000 acres for hydrographic areas
Species data should include a disclaimer that species data only represent incidental observations or specific studies at limited sites and not fully representative or are likely an underestimation	We removed species data from the public story map because of the limitations pointed out by this comment
Include a map with project partner office locations	We did not include this as this information is likely on the project partner websites and we do have links to the project partner websites
Add statistics about Nevada (i.e., driest state in the nation, amt of precipitation) and why groundwater is important	We added this information to the story map
Add links to websites for Nevada Division of Water Resources and Nevada Division of Environmental Protection	We added a link to NDWR because we used some of their resources, but we did not include a link to NDEP.
Include information about the hydrologic or geologic setting for a particular site (i.e., is it supported by a basin- or subbasin-scale water table or a more locally perched system, is it groundwater-dependent year round or intermittently, is it supported by seasonal mountain block runoff?)	We were unable to include this information in the Story Map, but it will likely be a part of follow-on work by TNC using data from the Nevada iGDE database.
Text regarding phreatophytes needs modification because forests, meadows and shrublands are not phreatophytes themselves, but rather vegetation-types (or classes) that may be composed of phreatophytes an non-phreatophytes	We changed the layer name to Phreatophyte Communities
The data for springs and streams shown on the story map is broader than what we would typically use	The only statewide map of rivers and streams that indicate perennial or intermittent reaches we were able to obtain was the NHD dataset. The SSI dataset was the best available dataset for springs that we were able to obtain.

Table A2. Appearance and Functionality

Comment	Response
It would be nice to view a list of GDE species found in each basin and not just a count	Species maps and counts were removed from the story map because of limitations in interpretation of the data
Zooming issues with locating which hydrographic area one was looking at or locating where the hexagon was in Nevada. Maybe toggle map on and off so you can see what's under the hydrographic basin or hexagon.	We modified the presentation of the basemap to include identifying locations like major highways and towns, and made the display layer transparent so that the locating items could still be seen. We also included the hydrographic area(s) associated with a 1-mi^2 hexagon to the information included when it is clicked. Toggling was not possible.
The navigation scroll bars for the story map are not intuitive and easy to use, and look different in different browsers. Have the next section automatically expand when you scroll to the bottom of the section.	The navigation scroll bars are a feature of the ArcGIS Online story map layout we used, and this layout did not have the automatic expansion feature. We considered alternate layouts but felt the one we used was the most effective for this content.
Have a way to get back to the content sections if you click on a link for a definition	We included links to the different sections in the Definitions section
Consider a general title for the GDE type section with subtitles for the specific types. Suggestions were made on order of sections and topics.	We incorporated some of these suggestions, but we are unable to create "sub-sections" with the story map layout we are using.
Change colors for legend on Phreatophytes section and consider using symbols for those who are color blind	The colors are automatic and can't be controlled. We were also not able to use symbols instead of colors.
Maybe display aerial imagery instead of only the basin map or hillshade.	ArcGIS Online only allows one basemap to be used per story map.
Put photo credits on the photos	We weren't able to put photo credits on the photos themselves without investing a lot of time in editing each photo. Photo credits are included on the data that come up with each photo point and on the story map in the text.
Links for some of the GDE types go to the wrong places	We fixed the links.
Increase the font size of the text a bit to make it look less textbooky	We had limited control on font size and tried to balance the sizes available with the content.
As you scroll through the text, have some of the images and photos appear on the right side	This was not possible with the story map format we used.
Have any species mentioned hyperlinked to a pop-up of a photo of that species	We did do this for some of the species in the Species section
Remove the saguaro cactus photo	That photo was a placeholder for the beta version and was removed

Table A3. Other Comments

Comment	Response
Write up a methodology that can be accessed on the website	We are preparing a methods report that will be available by September 2019 and will be linked to the story map and where the database is downloaded
TNC California mapped indicators of GDEs as opposed to GDEs. I wonder if that applies to your work	We used iGDEs for "indicators of GDEs" when referring to the data shown in the maps as was done for the California database
Links were provided to other story maps reviewers liked	We looked at the story maps to examine other ways of presenting our data

Appendix B – Data Sources and Providers

Table B1. Data sources and providers. Users seeking more reliably up-to-date datasets should visit these data sites or contact the data provider. 'Source_tbl' contains more information about data sources.

Source Name	Layer	Citation and/or URL	Data Provider	Date
Cortez Range biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2014 - 2018
7H Ranch biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2014
TJ Ranch biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2014
Great Basin National Park biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2007
IL Ranch biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2013
Mount Grant biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2003
Spring Mountains biophysical	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStat	The Nature Conservancy	2008

settings and classes		es/nevada/water/Pages/database-collaboration.aspx		
TS HS Ranch biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2013
Upper Truckee Watershed biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2016
Ward Mountain biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2009
Wassuk Range biophysical settings and classes	Phreatophyte Communities, Wetlands	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	The Nature Conservancy	2005
LANDFIRE Phreatophyte Cover	Phreatophyte Communities	Landfire (2014); https://www.landfire.gov/bps.php	United States Geological Survey	Accessed 20 June 2018
Desert Research Institute Phreatophyte Boundaries	Phreatophyte Communities	Minor et al. (2019); https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/nevada/water/Pages/database-collaboration.aspx	Desert Research Institute	Updated May 2019
Desert Research Institute Wetlands	Wetlands	McGwire (2019); https://www.dri.edu/wetland-mapNV	Desert Research Institute	Acquired 15 May 2019
Springs Stewardship Institute summarized spring data	Springs	Ledbetter et al. (2019); https://springsdata.org	Springs Stewardship Institute	Acquired 21 April 2019

National Hydrography Dataset waterbodies	Lakes and Playas	NHD (2019); ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Hydrography/NHD/State/HighResolution/GDB/NHD_H_Nevada_State_GDB.zip	United States Geological Survey, National Geospatial Program	Accessed 16 February 2019
National Hydrography Dataset flowline	Rivers and Streams	NHD (2019); ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Hydrography/NHD/State/HighResolution/GDB/NHD_H_Nevada_State_GDB.zip	United States Geological Survey, National Geospatial Program	Accessed 16 February 2019
Nevada Natural Heritage Program	Species, Species_tbl	NNHP (2019); http://heritage.nv.gov/get_data	Nevada Natural Heritage Program	Exported April 2019
Nevada Department of Wildlife NVCHAT hexagons	All layers	NDOW (2019); http://www.ndow.org/Nevada_Wildlife/Maps_and_Data/NVCHAT/Map_Data/	Nevada Crucial Habitat Assessment	Acquired January 2019
Nevada Division of Water Resources Hydrographic Areas	All layers	NDWR (2018); http://water.nv.gov/gisdata.aspx	State Engineer's Administrative Hydrographic Areas, or Groundwater Basin Boundaries	Acquired December 2018

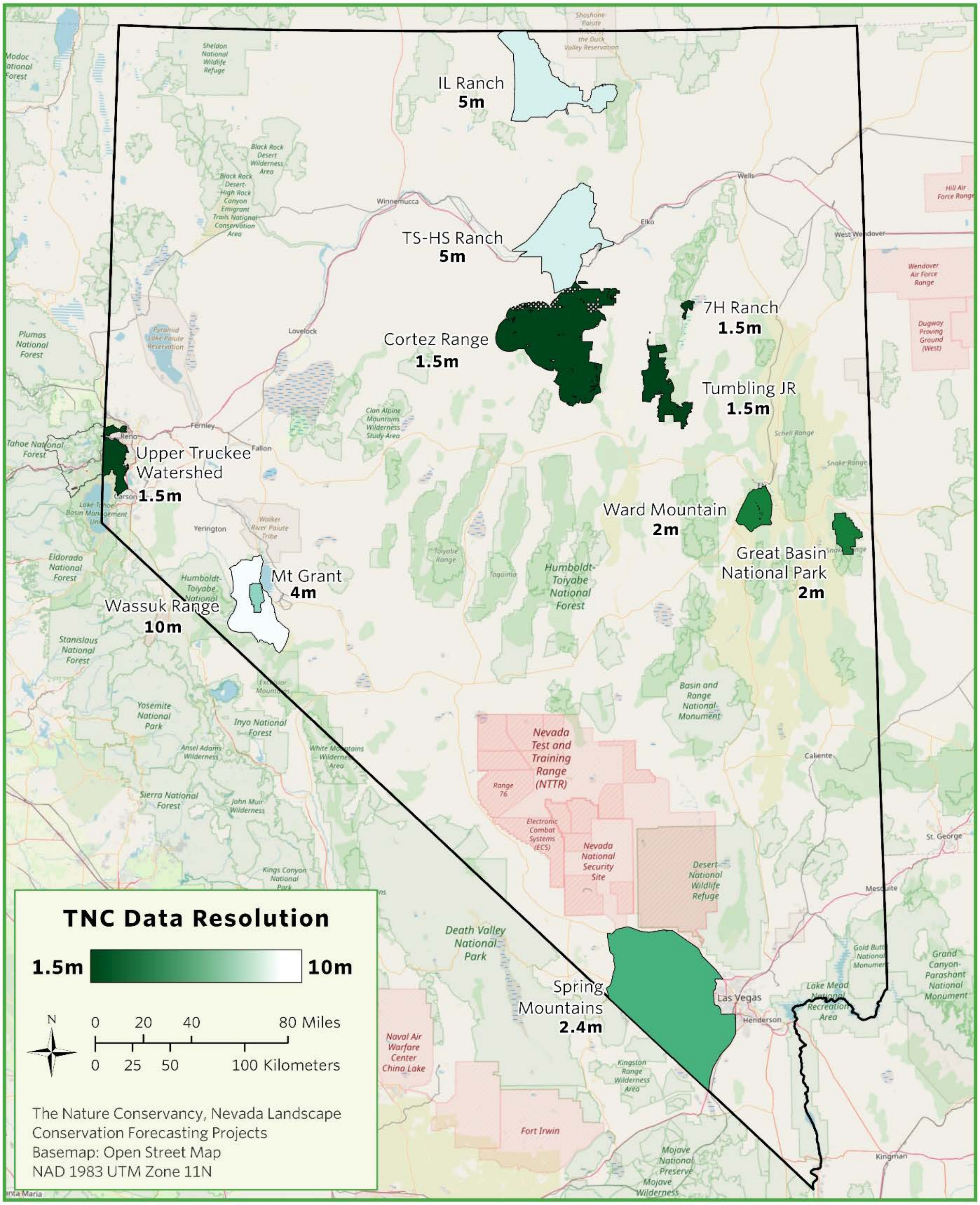

Figure B1. TNC coverages for iGDE database with map resolutions.

Appendix C– Data dictionaries

Table C1. Phreatophyte Communities feature class attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
Shape_Length	Shape_Length	Double	Shape length
Shape_Area	Shape_Area	Double	Shape area
SOURCE_CODE	Source Code	Text	Unique code used to match source information to each iGDE feature in Source_tbl
PHR_TYPE	Phreatophyte Type	Text	Name of the type of phreatophyte community
PHR_GROUP	Phreatophyte Group	Text	Generalized group of phreatophytes (Forest, Shrubland, Meadow)
COMMENTS	Comments	Text	Additional comments about the feature

Table C2. Wetlands feature class attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
Shape_Length	Shape_Length	Double	Shape length
Shape_Area	Shape_Area	Double	Shape area
SOURCE_CODE	Source Code	Text	Unique code used to match source information to each iGDE
WET_TYPE	Wetland Type	Text	Description of the wetland type
WET_SUBTYPE	Wetland Subtype	Text	Description of the vegetation, topography, or hydrology in each wetland type
COMMENTS	Comments	Text	Additional comments about the feature

Table C3. Springs feature class attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
SOURCE_CODE	Source Code	Text	Unique code used to match source information to each iGDE
SPRING_ID	Spring ID	Numeric	Unique spring ID used to match with the source data
SPRING_NAME	Spring Name	Text	Name of the spring
SPRING_TYPE1	Spring Type 1	Text	The primary spring type according to SSI (http://springstewardshipinstitute.org/cave)
SPRING_TYPE2	Spring Type 2	Text	The secondary spring type according to SSI (http://springstewardshipinstitute.org/cave)

IMAGE_LINK	Image Hyperlink	Text	Hyperlink to a photo of the spring on the SSI website
SKETCH_LINK	Sketch Hyperlink	Text	Hyperlink to a sketch of the spring on the SSI website
LATITUDE	Latitude	Numeric	Latitude where spring occurs in decimal degrees as determined by the field team using a GPS or map or imported from a named database
LONGITUDE	Longitude	Numeric	Longitude where spring occurs in decimal degrees as determined by the field team using a GPS or map or imported from a named database
ELEVATION	Elevation (m)	Numeric	Elevation of the spring site as determined by field surveyors using a GPS or map (meters)
INV_STAT	Inventory Status	Text	Indicates whether a spring has been surveyed or its location verified
SURV_COUNT	Survey Count	Short	Number of surveys conducted at the spring
FLOW_MEAN	Flow Mean (L/s)	Double	The amount of flow measured in liters per second (L/s) averaged for all available flow data from surveys at the spring
PH_MEAN	pH Mean	Double	pH value averaged for all pH values from surveys conducted at the spring (tbl_WQData; WQ_Measurement)
WATER_TEMP_MEAN	Water Temperature Mean (C)	Double	Water temperature in degrees Celsius averaged for all temperatures from surveys conducted at the spring (tbl_WQData; WQ_Measurement)
SPEC_COND_MEAN	Specific Conductance Mean (uS/cm)	Double	Specific conductance measured in uS/cm averaged for all values from surveys conducted at the spring (tbl_WQData; WQ_Measurement)
ALKALINITY_MEAN	Alkalinity Mean (mg/L)	Double	Alkalinity measured in mg/L averaged for all values from surveys conducted at the spring (tbl_WQData; WQ_Measurement)
AREA	Area (m2)	Double	Total area in square meters of all distinct habitats surrounding the spring (tbl_PolygonSurvey; AreaSqM)
VERT_COUNT	Vertebrate Species Count	Long	Number of vertebrate species observed at the spring (Nevada_July_5_2018_Springs_Summarized_TaxaVert_by_Site)
INVERT_COUNT	Invertebrate Species Count	Long	Number of invertebrate species observed at the spring (Nevada_July_5_2018_Springs_Summarized_TaxaInvert_by_Site)
FLORA_COUNT	Plant Species Count	Long	Number of plant species observed at the spring (Nevada_July_5_2018_Springs_Summarized_TaxaFlora_by_Site)
COMMENTS	Comments	Text	Additional comments about the feature

Table C4. Lakes and Playas feature class attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
Shape_Length	Shape_Length	Double	Shape length
Shape_Area	Shape_Area	Double	Shape area
PERM_ID	Permanent Identifier	Text	Unique ID used to link the feature in the iGDE database with the corresponding feature in the NHD database
BODY_NAME	Waterbody Name	Text	GNIS name of the waterbody
BODY_TYPE	Waterbody Type	Text	Type of waterbody, lake or playa
BODY_CODE	Waterbody Code	Long	Code used to identify the type of waterbody and how the feature was mapped in the NHD
BODY_DESC	Waterbody Description	Text	Description of the waterbody and mapping method from NHD
AREA_ACRES	Area (acres)	Double	Calculated area of the feature in acres
SOURCE_CODE	Source Code	Text	Unique code used to match source information to each iGDE
COMMENTS	Comments	Text	Additional comments about the feature

Table C5. Rivers and Streams feature class attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
Shape_Length	Shape_Length	Double	Shape length
Shape_Area	Shape_Area	Double	Shape area
PERM_ID	Permanent Identifier	Text	Unique ID used to link the feature in the iGDE database with the corresponding feature in the NHD database
RIVER_NAME	River Name	Text	GNIS name of the river or stream
RIVER_TYPE	River Type	Text	Type of river or stream
RIVER_CODE	River Code	Long	Code used to identify the type of river or stream
LENGTH_M	Length (m)	Double	Length of the river or stream reach in meters
SOURCE_CODE	Source Code	Text	Unique code used to match source information to each iGDE
COMMENTS	Comments	Text	Additional comments about the feature

Table C6. Species feature class attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
Shape_Length	Shape_Length	Double	Shape length
Shape_Area	Shape_Area	Double	Shape area
HEX_ID	Hexagon ID	Long	Unique ID for the hexagon feature
COUNT_NNHP	NNHP Species Count	Long	Number of unique species mapped by NNHP in the hexagon
COUNT_EN	Endemic Species Count	Long	Number of unique endemic species mapped by NNHP in the hexagon
COMMENTS	Comments	Text	Additional comments about the feature

Table C7. Species table ('Species_tbl') attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique row ID
SCI_NAME	Scientific Name	Text	Scientific (Latin) name of the species provided. Usually consists of Genus and species, but may contain additional identifiers for subspecies
COM_NAME	Common Name	Text	Common name of the species
MAJOR_GROUP	Major Taxonomic Group	Text	Major taxonomic group to which the species belongs (e.g. Vertebrate Animal, Vascular Plant, etc.). Codes are interpreted by NNHP: http://heritage.nv.gov/definitions
MINOR_GROUP	Minor Taxonomic Group	Text	Major taxonomic group to which the species belongs (e.g. Amphibian, Mammal, Fern, Monocot, etc.). Codes are interpreted by NNHP: http://heritage.nv.gov/definitions
NV_RANK	Nevada Conservation Status	Text	State rank indicator, based on distribution within Nevada at the lowest taxonomic level
G_RANK	Global Conservation Status	Text	Global conservation rank indicator, based on distribution globally at the lowest taxonomic level
NV_STATUS	Nevada Protection Status	Text	State of Nevada Protection and Designations (NAC 503). Codes are interpreted by NNHP: http://heritage.nv.gov/definitions
ESA_STATUS	ESA Conservation Status	Text	U.S. Fish and Wildlife Service (USFWS) Categories for Listing under the Endangered Species Act. Codes are interpreted by NNHP: http://heritage.nv.gov/definitions
BLM_STATUS	BLM Conservation Status	Text	U.S. Bureau of Land Management (BLM) Status. Codes are interpreted by NNHP: http://heritage.nv.gov/definitions
USFS_STATUS	USFS Conservation Status	Text	U.S. Forest Service (FS) Status. Codes are interpreted by NNHP: http://heritage.nv.gov/definitions
NNPS_STATUS	NNPS Conservation Status	Text	Conservation Status as determined by the Rare Plant Working Group of the Nevada Native Plant Society. Codes are interpreted by NNHP: http://heritage.nv.gov/definitions

WAP2012	Wildlife Action Plan	Text	Identified as a Species of Conservation Priority (SCP) in the Nevada Wildlife Action Plan (2012)
ENDEMISM	Endemism	Text	Indicates that the species is endemic to the state of Nevada (Y/N/P)
NNHP_LIST	NNHP List	Text	Indicates whether the species is on NNHP's at-risk (tracking) list or watch list
COMMENTS	Comments	Text	Additional comments about the source

Table C8. Source table ('Source_tbl') attributes from the full iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique row ID
SOURCE_CODE	Source Code	Text	Unique code used to match source information to each iGDE feature
SOURCE_DATE	Source Date	Date	Year in which most of the data were acquired. For satellite remote sensing data inputs, the date refers to image capture date. For other data inputs, the date refers to the year that the most recent version of the dataset was available
SOURCE_GROUP	Source Group	Text	Name of the layer(s) in which the source is used
SOURCE_PROVIDER	Source Provider	Text	Standardized name of the provider of the data source
SOURCE_NAME	Source Name	Text	Given name of the dataset
SOURCE_LINK	Source Link	Text	Link to the report or website that describes the data source, and where the original data may be accessed
SOURCE_CITE	Source Citation	Text	Citation for the data source
MAP_METHOD	Mapping Method	Text	Abbreviated description of the method used to collect or map the iGDE data
MAP_UNIT	Minimum Mapping Unit	Numeric	Minimum mapping unit of the source data, the minimum threshold for mapping a feature or, if the source is a raster file, the resolution in meters
COMMENTS	Comments	Text	Additional comments about the source

Table C9. NV_Hexagons attributes from the public iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
Hex_ID	Hexagon ID	Long	Unique ID for each hexagon, retained from original hexagons downloaded from the CHAT
POLY_AREA	Hexagon Area (acres)	Double	Area of each hexagon in acres
AREA_PHR	Acres of Phreatophytes	Double	Acres of phreatophytes in the hexagon
PER_PHR	Percent Phreatophytes	Double	Percent area of each hexagon covered by phreatophyte data
AREA_FRST	Acres of Forest Phreatophytes	Double	Acres of forest phreatophytes in the hexagon
PER_FRST	Percent Forest Phreatophytes	Double	Percent area of each hexagon covered by forest phreatophytes
AREA_SHRUB	Acres of Shrubland Phreatophytes	Double	Acres of shrubland phreatophytes in the hexagon
PER_SHRUB	Percent Shrubland Phreatophytes	Double	Percent area of each hexagon covered by shrubland phreatophytes
AREA_UNK	Acres of Unknown Phreatophytes	Double	Acres of unknown phreatophytes in the hexagon
PER_UNK	Percent Unknown Phreatophytes	Double	Percent area of each hexagon covered by unknown phreatophytes
AREA_WET	Acres of Wetlands	Double	Acres of wetlands in each hexagon
PER_WET	Percent Wetlands	Double	Percent area of each hexagon covered by wetlands
COUNT_SPR	Spring Count	Long	Number of springs that occur in each hexagon
AREA_LKPL	Acres of Lakes and Playas	Double	Acres of lakes and playas in each hexagon
PER_LKPL	Percent Lakes and Playas	Double	Percent area of each hexagon covered by lakes/playas
AREA_LAKE	Acres of Lakes	Double	Acres of lakes in each hexagon
PER_LAKE	Percent Lakes	Double	Percent area of each hexagon covered by lake
AREA_PLAYA	Acres of Playas	Double	Acres of playas in each hexagon
PER_PLAYA	Percent Playas	Double	Percent area of each hexagon covered by playa
MILES_RVST	Miles of Rivers and Streams	Long	Total miles of rivers/streams that occur in each hexagon
COUNT_NNHP	Species Count	Long	Number of unique species that occur in each hexagon from NNHP data
COUNT_EN	Endemic Species Count	Long	Number of unique endemic species that occur in each hexagon from NNHP data
GDE_COUNT	Number of iGDE Types	Long	Number of types of physical GDE features in each hexagon. The maximum value is 5, which indicates that a hexagon

			contains all of the following features: phreatophytes, wetlands, springs, lakes/playas, rivers/streams.

Table C10. NV_HydrographicAreas attributes from the public iGDE database.

Field	Alias	Type	Description
OBJECTID	OBJECTID	Numeric	Unique feature ID
Shape	Shape	Geometry	Geometry type
HYD_AREA	Hydrographic Area ID	Text	Hydrographic Area ID
HYD_AREA_N	Hydrographic Area Name	Text	Hydrographic Area Name
SUBAREA_NA	Subarea Name	Test	Subarea Name
HYD_REGION	Hydrographic Region ID	Double	Hydrographic Region ID
HYD_REGI_1	Hydrographic Region Name	Text	Hydrographic Region Name
POLY_AREA	Hydrographic Area (acres)	Double	Area of hydrographic area in acres
AREA_PHR	Acres of Phreatophytes	Double	Acres of phreatophytes in the hydrographic area
PER_PHR	Percent Phreatophytes	Double	Percent area of each hydrographic area covered by phreatophyte data
AREA_FRST	Acres of Forest Phreatophytes	Double	Acres of forest phreatophytes in the hydrographic area
PER_FRST	Percent Forest Phreatophytes	Double	Percent area of each hydrographic area covered by forest phreatophytes
AREA_SHRUB	Acres of Shrubland Phreatophytes	Double	Acres of shrubland phreatophytes in the hydrographic area
PER_SHRUB	Percent Shrubland Phreatophytes	Double	Percent area of each hydrographic area covered by shrubland phreatophytes
AREA_UNK	Acres of Unknown Phreatophytes	Double	Acres of unknown phreatophytes in the hydrographic area
PER_UNK	Percent Unknown Phreatophytes	Double	Percent area of each hydrographic area covered by unknown phreatophytes
AREA_WET	Acres of Wetlands	Double	Acres of wetlands in each hydrographic area
AREA_WET	Percent Wetlands	Double	Percent area of each hydrographic area covered by wetlands
COUNT_SPR	Spring Count	Long	Number of springs that occur in each hydrographic area
AREA_SPR	Springs per Acre	Long	Number of springs per acre in each hydrographic area
AREA_LKPL	Acres of Lakes and Playas	Double	Acres of lakes and playas in each hydrographic area
PER_LKPL	Percent Lakes and Playas	Double	Percent area of each hydrographic area covered by lakes/playas

AREA_LAKE	Acres of Lakes	Double	Acres of lakes in each hydrographic area
PER_LAKE	Percent Lakes	Double	Percent area of each hydrographic area covered by lake
AREA_PLAYA	Acres of Playas	Double	Acres of playas in each hydrographic area
PER_PLAYA	Percent Playas	Double	Percent area of each hydrographic area covered by playa
MILES_RVST	Miles of Rivers and Streams	Long	Total miles of rivers/streams that occur in each hydrographic area
AREA_RVST	Miles of Rivers and Streams per Acre	Long	Miles of rivers/streams per acre that occur in each hydrographic area
COUNT_NNHP	Species Count	Long	Number of unique species that occur in each hydrographic area from NNHP data
COUNT_EN	Endemic Species Count	Long	Number of unique endemic species that occur in each hydrographic area from NNHP data
GDE_COUNT	Number of iGDE Types	Long	Number of types of physical GDE features in each hydrographic area. The maximum value is 5, which indicates that a hexagon contains all of the following features: phreatophytes, wetlands, springs, lakes/playas, rivers/streams.

Appendix D – Vegetation Community Descriptions

Table D1. Descriptions of phreatophyte communities and wetlands.

Vegetation Community	Description
Aspen-Mixed Conifer	Aspen-Mixed Conifer is commonly called "seral aspen." Quacking aspen (*Populus tremuloides*) is the dominant tree species, except in late succession where prolonged fire exclusion and ungulate herbivory allow dominance by mixed conifers, such as white fir (*Abies concolor*) and limber pine (*Pinus flexis*). The presence of even a single aspen tree in a stand provides strong evidence that the area historically supported aspen clones. The aspen-mixed conifer system typically occurs on flat to steep terrain (<80%) on all aspects. Elevation ranges from 1,700 m to 2,800 m (5,600' to 9,200'). Soils are highly variable, but generally cool. This type occurs above the juniper and/or sagebrush zones. Aspen stands that are difficult to "see through" are considered healthy. Shrub, forb, and grass species typical of mesic sites are very diverse and plant cover is very high before conifers dominate in late succession. Fire is a key disturbance.
Aspen Woodland	The Aspen Woodland system is dominated by quacking aspen (*Populus tremuloides*) and is commonly called "stable aspen." It is hypothesized, but not proven, that soils prevent encroachment of conifers even with fire exclusion, therefore maintaining the relative cover of conifers to <25%. Where aspen woodland is adjacent to conifers, an occasional conifer seedling may occur, but conifers do not drive the fire regime. Elevations generally range from 1,981 m to 2,743 m (6,500'-9,000'), but occurrences can be found at lower elevations, and average annual precipitation ranges from 36 cm to >51 cm (14" to >20"). Distribution of this ecological system is limited primarily by adequate soil moisture required to meet its high evapotranspiration demand, and secondarily by the length of the growing season or low temperatures. The aspen woodland system occurs commonly as multi-storied stands and it has been shown that regeneration can occur in gaps where older trees have died of senescence. Stands are usually closed. Aspen suckers 1.5 m to 4.6 m (5-15') tall will be present in all classes (min. 500 stems/acre). The system also includes aspen thickets that occur on concave shoulders of mountains and plateaus on northerly aspects or on the lee-side of snow-blown plateau and mountain summits where snow accumulation prevents full development of aspen as tall trees. The aspen woodland system typically occurs above juniper and adjacent to mountain big sagebrush. At elevations below 6,500 feet this group grades into black (*Populus balsamifera*) and narrowleaf cottonwood (*Populus angustifolia*) types along riparian corridors. Understory consists of abundant herbaceous and shrub components. Often species of tall forbs, perennial grasses and shrubs are found in the understory. The herbaceous layer may be lush and diverse. The primary natural disturbances affecting aspen woodlands are fire, disease and insect outbreaks, and herbivory. While fire is important, it has been recently shown that aspen stands can persist without fire.
Greasewood	Greasewood occurs on alluvial flats or lake plains usually adjacent to playas. Sites typically have saline to sodic soils, shallow water table, and flood intermittently, but remain dry for most growing seasons. The water table remains high enough to maintain vegetation, despite salt accumulations. Slope gradients of less than 2 percent are most typical. Elevations range from 1,067 to 1,768 m (3,500' to 5,800'). Average annual precipitation is 13 to 25 cm (5" to 10"); and average growing season is 100 to 120 days. The surface layer normally crusts over, inhibiting water infiltration and seedling emergence. This system sometimes occurs as a mosaic of multiple communities, with open to moderately-dense shrublands dominated or co-dominated by greasewood (*Sarcobatus vermiculatus*). Basin big sagebrush (*Artemesia tridentata* spp. *tridentata*), shadscale (*Atriplex confertifolia*) may be present or co-dominant. An herbaceous layer, if present, is usually dominated by salt-tolerant graminoids. There may be inclusions of alkali sacaton (*Sporobolus airoides),* saltgrass (*Distichilis spicata*), and basin

	wildrye (*Leymus cinereus)* in areas where the groundwater is closer to the surface during the growing season. Vegetation on this site is normally restricted to coppice mound areas that are surrounded by playa-like depressions or nearly level, usually barren, inner spaces. As ecological condition declines, herbaceous understory is reduced or eliminated and the site becomes a community of halophytic shrubs dominated by greasewood. Fire was historically absent but occurs today in greasewood communities invaded by non-native annual species. Flooding events is the more common natural disturbance.
Jeffrey Pine Riparian	The Jeffrey Pine Riparian system is unique to the Sierra Nevada ecoregion and is relatively restricted in its landscape position, where it is found along channels where intermittent flow can occur above 1,220 m (4,000'). It is dominated by Jeffrey pine (*Pinus jeffreyi* Balf.). Because of soil moisture and cold air movement associated with drainages, the system can reach lower elevations than upland Jeffrey pine forests. Due to the increased moisture, individuals are often considerably larger than similar aged trees in the drier, adjacent forest. The canopy is generally closed. This system is often more productive than adjacent forests and may have species associated with riparian communities in the understory (willow, aspen, chokecherry, sumac, Wood's rose, currant, and white fir). Like all Jeffrey pine forests, fire historically was an important ecological process, which was a relatively frequent disturbance. Flooding events are also important in this system.
Lodgepole Pine - Wet	Stands of inundated Sierran lodgepole pine (*P. contorta* spp. *murrayana* (Balf.) Engelm.) in the Sierra Nevada are dense with smaller diameter trunks than lodgepole pines in drier areas. These stands are found between 2000 m to 3,200 m (6,500'-10,500') on gentle slopes or in drainage bottoms where the pines have encroached into wet meadows. Soils are often saturated with water. Western hemlock (*Tsuga heterophylla*), California red fir (*Abies magnifica*), white fir (*A. concolor*), and western white pine (*P. monticola*) may be present in the canopy. Unlike the drier stands of lodgepole pines, wetter sites support a more productive understory with shrubs such as pinemat manzanita (*Arctostaphylos nevadensis*), purple mountainheath (*Phyllodoce breweri*), and *Salix lemmonii*. Generally bole density and canopy cover is high. The natural wet/dry cycles were important factors in the dynamics of these forests as was infrequent fire.
Mesquite	Groundwater dependent mesquite is found in the warm desert drainages of southern Nevada. These communities are often called mesquite Bosque. Mesquite plants have deep roots and very hard wood that withstands periodic flooding. The system is found in at least three different types of communities. Mesquite woodlands often occupy the 500-year floodplain terrace of larger warm desert riparian systems away from the wetter willow and cottonwood. Mesquite can be mixed in with willows and cottonwood in riparian woodlands along smaller perennial streams. Mesquite Bosque can occupy sand dunes systems near playas or dry lake beds where groundwater percolates through the sand towards the surface. While fire is infrequent, flooding, severe drought periods, and hard freezes are factors limiting mesquite. The greatest threats to Mesquite Bosque today are wood cutting and off-road vehicle driving.
Montane Riparian	The Montane Riparian system is found within a broad elevation range above 1,220 m (4,000'). Riparian communities require flooding and gravel for reestablishment. The system is found in low- to mid-elevation canyons and draws, on montane floodplains, in steep-sided canyons, or narrow V-shaped valleys with rocky substrates. Sites are subject to temporary flooding during spring runoff, although summer flash floods can have dramatic effects on succession. Rivers and streams of the Sierra Nevada can experience severe flood events during winter rain-on-snow storms associated with atmospheric rivers of rain. Underlying gravels may keep the water table just below ground surface, and are favored substrates for cottonwood and willow regeneration. In steep-sided canyons, streams typically have perennial flow on intermediate

	to high gradients. Surface water is generally high for variable periods. Soils are typically alluvial deposits of sand, clays, silts and cobbles that are highly stratified with depth due to flood scour and deposition. Codominant and diagnostic species include willow (*Salix* spp.), cottonwood (*Populus* spp.), chokecherry (*Prunus virginiana*), sumac (*Rhus* spp.), Wood's rose (*Rosa woodsia*), currant (*Ribes* spp.), occasional aspen (*Populus tremuloides*), and conifers. Vegetation is very heterogeneous and diverse along river reaches. Some reaches will be dominated by cottonwood, whereas others are completely occupied by willow, and even cinquefoil and sagebrush on natural stream terraces (not due to incision). Lower slopes <6% favor cottonwood, whereas willow is more typically found on steeper slopes.
Saline Meadow	The Saline Meadow system is found at the bottom of broad valleys or axial valleys, and on alluvial flats at elevations of 1,219 m to 1,829 m (4,000' to 6,000') with slopes between 0-4%, although more typically <2%, usually surrounded by salt tolerant plant communities. The system is wetted by an elevated water table at a depth of 102 cm (40") on saline soils and between 51-102 cm (20" to 40") on sodic floodplains that periodically rise to the surface during the spring or is spring-fed in broad valley bottoms. Saturated soils support graminoid dominance. Soils are deep saline and often calcareous or sodic and made of alluvium of mixed origins. Average annual precipitation ranges from 15 to 25 cm (6" to 10"). Alkali sacaton (*Sporobolus airoides*) and alkali muhly (*Muhlenbergia asperifolia*) dominate, although inland saltgrass (*Distichlis spicata*), and alkali cordgrass (*Spartina gracilis*) may co-dominate. Inland saltgrass dominates on sodic soils. Black greasewood (*Sarcobatus vermiculatus*), iodine bush (*Allenrolfea occidentalis*), silver buffaloberry (*Shepherdia argentea*), alkali rabbitbrush (*Chrysothamnus albidus*), and willow (*Salix* spp.) may be present at low abundance. As the sodium concentration in the soil increases, vegetation cover decreases from <70% to <15%. The wet/dry cycle is an important dynamic affecting woody succession. Non-native grazing and non-native plants are current threats.
Unknown Phreatophytes	Large areas with observed phreatophytic plants that have not been classified as one of the other phreatophyte communities.
Wet Meadow-montane	The Wet Meadow system is wetted by an elevated water table about 51 cm (20") from the surface during the growing season and adjacent to creeks or rivers, or is spring-fed. Three types are included here: (i) Perennially wet meadows close to mountain streams and around or below seeps and springs, (ii) clay seeps dominated by grasses and mules' ears wyethia, and (iii) dry "wet" meadows that dry out during the hot season. Saturated soils support graminoid dominance. Elevation ranges from 1,524 m to 2,896 m (5,000' to 9,500') and annual precipitation is between 25 cm and 41 cm (10" and 16"). Tufted hairgrass (*Deschampia cespitosa*) dominates and Nevada bluegrass (*Poa nevadensis*) codominates in true wet meadows, whereas Nevada bluegrass dominates in dry meadows. Alpine timothy (*Phleum alpinum*) and sedges (*Carex* spp.) are also common in both types of wet meadows. Clay seeps are dominated by Idaho fescue (*Festuca idahoensis*), mountain brome (*Bromus marginatus*), mules' ears wyethia (*Wyethia amplexicaulis*), and whitehead wyethia (*Wyethia helenioides*). The presence of shrubs (willow [*Salix* spp.], Wood's rose [*Rosa woodsii*], silver sagebrush [*Artemisia cana*]) at the meadow's edge increases during consecutive drought years and decreases during consecutive high-water years.
Wet Meadow-bottomland	The Wet Meadow-bottomland system is found in bottomland floodplains or adjacent to valley axial streams. Slope is typically less than 2%. The system is wetted by an elevated water table about 51 cm (20") from the surface during the growing season and adjacent to rivers or is spring-fed. Saturated soils support graminoid dominance. Elevation is generally below 1,524 m (5,000') and annual precipitation is between 15 cm and 25 cm (6" and 10"). Being in a floodplain away from the main channel, bottomland wet meadows can experience large flood events and fine sediment accumulation. Above 20 cm (8") of annual precipitation, tufted

	hairgrass (*Deschampia cespitosa*) dominates and Nevada bluegrass (*Poa nevadensis*) codominates, whereas Alkali bluegrass (*Poa juncifolia*) dominates and alkali sacaton (*Sporobolus airoides*) codominates below 20 cm (8") of annual precipitation. Baltic rush (*Juncus balticus*), inland saltgrass (*Distichlis spicata*), and alkali cordgrass (*Spartina gracilis*) are also common, especially as soil become more saline or sodic. The presence of shrubs such as willow (*Salix* spp.), Wood's rose (*Rosa woodsia*), silver buffaloberry (*Shepherdia argenta*) at the meadow's edge increases during consecutive drought years and decreases during consecutive high-water years. Non-native plants, especially saltcedar (*Tamarix ramosissima*), is a frequent cause of degradation of these wet meadows. Due to the low-elevation and concave landform position, the development of stream channels (i.e. headcuts, channelization, etc.) is less frequent than in montane wet meadows. Channelization can lower the water table and shift the plant community from phreatophytes to more upland species. Bank slumping and hummocking from non-native grazing is a common form of degradation.
Wetlands	Wetlands are found in bottomland floodplains or adjacent to valley streams. Wetlands are generally formed by flood events cutting river meanders, creating backwater wetlands set apart from the main river channel. Beaver activity in wooded areas can also create wetlands. Vegetation in this system is dominated by helophytes like cattail (*Typha* spp.), bulrush (*Scirpus* spp.), and tule (*Schoenoplectus* spp.). Non-native grazing and non-native plants are likely the causes of degradation.