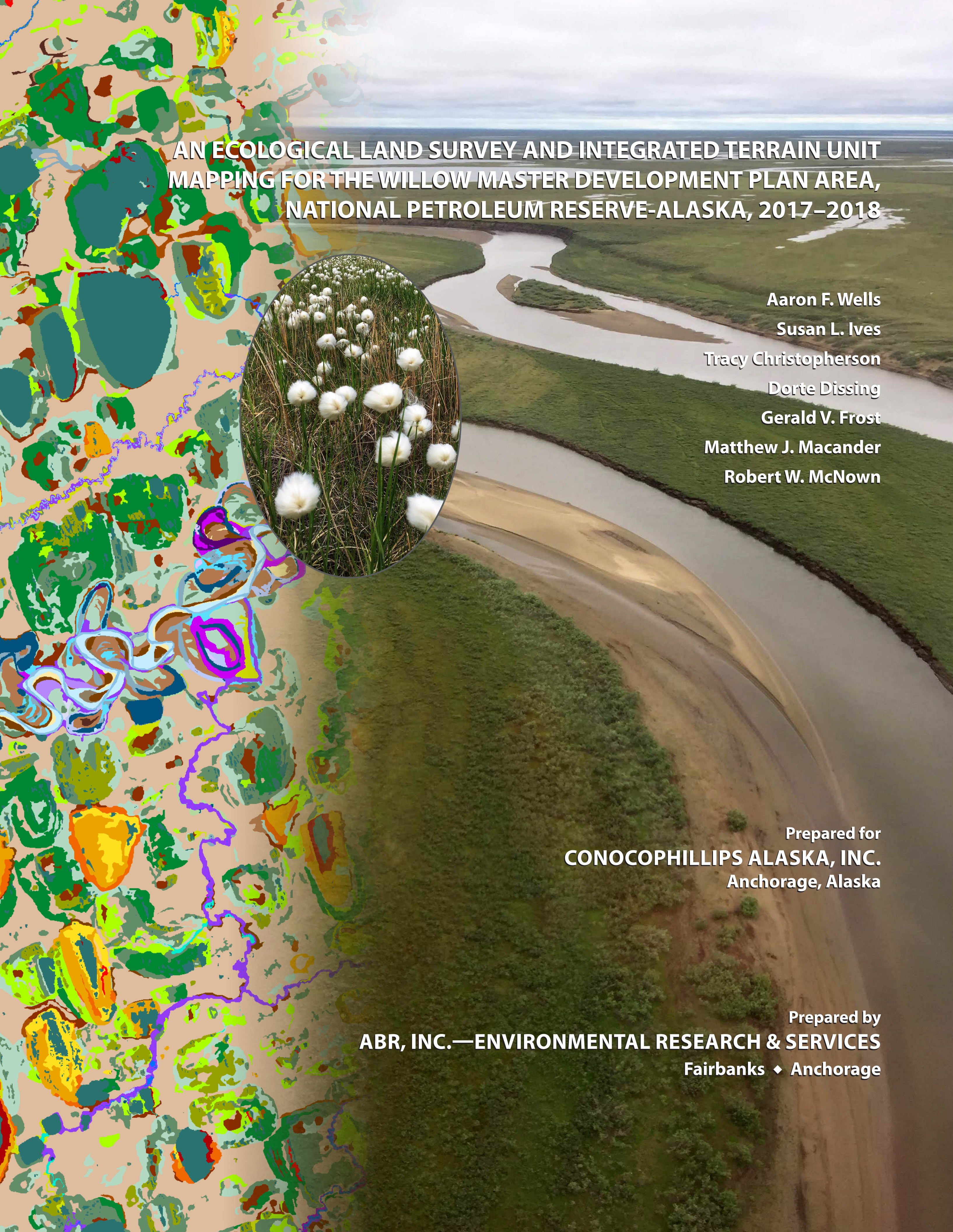
AN ECOLOGICAL LAND SURVEY AND INTEGRATED TERRAIN UNIT MAPPING FOR THE WILLOW MASTER DEVELOPMENT PLAN AREA, NATIONAL PETROLEUM RESERVE-ALASKA, 2017–2018



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Cover:

A sandbar and floodplain along Fish Creek with a section of the map showing ecotypes (local-scale ecosystems) in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska. Inset: *Eriophorum scheuchzeri* (white cottongrass) in a lake basin in the Willow Master Development Plan Area. Map produced by Dorte Dissing, ABR. Photos courtesy of ConocoPhillips Alaska, Inc.

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EXECUTIVE SUMMARY

Between 1992 and 2011, 279,830 ha of Integrated Terrain Unit (ITU) mapping was completed in areas of active drilling and ongoing oil exploration across the Beaufort Coastal Plain (BCP), including portions of the National Petroleum Reserve-Alaska (NPR-A) (Wells et al. in prep). In 2017 and 2018, field surveys and ITU mapping were expanded into the Willow Master Development Plan Area (Willow project area; 60,340 ha), on the western edge of the previously mapped area. The ITU mapping in the Willow project area has increased the total area mapped on the BCP to 340,170 ha, an area roughly the same size as the Hawaiian Islands of Maui and O'ahu, combined. The ITU classification and mapping is based on an Ecological Land Survey (ELS) approach, which divides and classifies the landscape into basic ecological units (e.g. geomorphic units) that can be aggregated into similarly functioning categories depending on the land management or regulatory questions of interest. The field, classification, and mapping products produced as part of the ELS are designed to address the following Best Management Practices from BLM (2013):

- E-12: Use ecological mapping as a tool to assess wildlife habitat before development of permanent facilities, to conserve important habitat types during development.
- M-3: Minimize loss of populations of, and habitat for, plant species designated as Sensitive by the BLM in Alaska.

Additionally, the products of the ELS classify and quantify current conditions and provide baseline mapping in advance of the proposed Willow development.

This report, in conjunction with Wells et al. (2018), summarizes the results of the 2017 and 2018 field, classification, and mapping efforts described above. We completed sensitive plant surveys and ELS field surveys in the Willow project area from 27 July to 7 August 2017, and on 1 August, 3 August, and 7–9 August 2018. We searched a total of 17 sensitive plant survey areas; 9 in 2017 and 8 in 2018. We recorded data describing and quantifying vegetation, soil, and environmental attributes at 198 field plots in 2017 and 124 plots in 2018. Of the field plots sampled in 2018, 98 were used to assess the accuracy of ITU mapping completed in 2017. Three BLM-listed sensitive grass species were identified in and adjacent to the Willow project area: *Koeleria asiatica* (28 occurrences), *Pleuropogon sabinei* (1), and *Poa hartzii* ssp. *alaskana* (4). We completed 60,340 ha of ITU mapping, which includes maps of geomorphology, surface form, vegetation, disturbance, and ecotypes (i.e., local-scale ecosystems). We then used the ITU mapping to evaluate and map ecosystem services, soil properties, and suitability measures of lands in the Willow project area: sensitive plant habitat suitability, wildlife habitats, wetlands, and soil great groups.

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ACKNOWLEDGMENTS

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1 INTRODUCTION

Between 1992 and 2011, ConocoPhillips Alaska, Inc. (CPAI) amassed a database that includes 279,830 ha of Integrated Terrain Unit (ITU) mapping and related field-verification data in areas of active drilling and ongoing oil exploration across the Beaufort Coastal Plain (BCP), including portions of the National Petroleum Reserve-Alaska (NPR-A) (Wells et al. in prep). The ITU mapping is based on an Ecological Land Survey (ELS) approach, which divides and classifies the landscape into basic ecological units (e.g., geomorphic units) that can be aggregated into similarly functioning categories depending on the land management or regulatory questions of interest. The map products are used to support environmental analysis and compliance requirements for proposed projects including Environmental Impact Statements (EIS), Section 7 Endangered Species Act (ESA) consultations, and permit applications under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. To add to this large mapping database described above, ABR, Inc.—Environmental Research & Services (ABR) worked with CPAI during 2017 and 2018 to expand the ITU mapping into the Willow Master Development Plan Area (Willow project area), a 60,340 ha area of NPR-A on the western edge of the previously existing ITU mapping (Figure 1). Nearly 45,000 ha of this ITU mapping was completed in 2017 (Wells et al. 2018), with the remaining area surveyed and mapped in 2018.

Wells et al. (2018) provides a detailed introduction to the ELS and ITU mapping approach. An ELS views landscapes as ecological systems with functionally related parts, and strives to provide a conceptual model for assessing and understanding ecosystems. An hierarchical approach was used to map landscape-soil-vegetation relationships using readily mapped and/or modeled landscape features. This approach allows for the classification and mapping of local-scale ecosystems (ecotypes), wildlife habitats, wetlands, and soil classes (aggregated soil great groups). The resulting ITU map can serve as the spatial database for land evaluations, such as avoiding sensitive terrain or high-value habitats for wildlife or sensitive plants, and for developing land-rehabilitation strategies appropriate for the landscape.

Wells et al. (2018) provided detailed methods, results, and discussion for the work completed in 2017. This current report is a comprehensive summary of the ELS conducted in both 2017 and 2018 to classify and map the ecosystems and soils of the Willow project area. The specific objectives of the Willow project area studies were to:

1. Conduct ELS field surveys of vegetation, environmental, and soil characteristics.
2. In wetland focus areas identified by CPAI:
   a. Conduct wetland-determination field surveys
   b. Collect wetland functional assessment data
   c. Classify and map wetlands following National Wetlands Inventory (NWI) codes and hydrogeomorphic (HGM) classes
3. Conduct surveys for BLM Sensitive Plant Species to satisfy Best Management Practice M-3 (BLM 2013).
4. Review, analyze, and synthesize ELS and wetland data collected in 2017 and 2018.
5. Prepare an ecological land classification and ITU mapping products that dovetail with the existing BCP classification and mapping to satisfy Best Management Practice E-12 (BLM 2013).
6. Prepare maps of:
   a. Wildlife habitats soils, and wetlands (NWI)
   b. Habitat suitability for rare and sensitive plants

2 STUDY AREA

The Willow project area is located on Alaska's North Slope in the eastern portion of the NPR-A, approximately 150 km west of Deadhorse and 200 km southeast of Utqiaġvik (Figure 1). The study area lies about 15 km southwest of the Beaufort Sea coast and thus lacks coastal habitats;

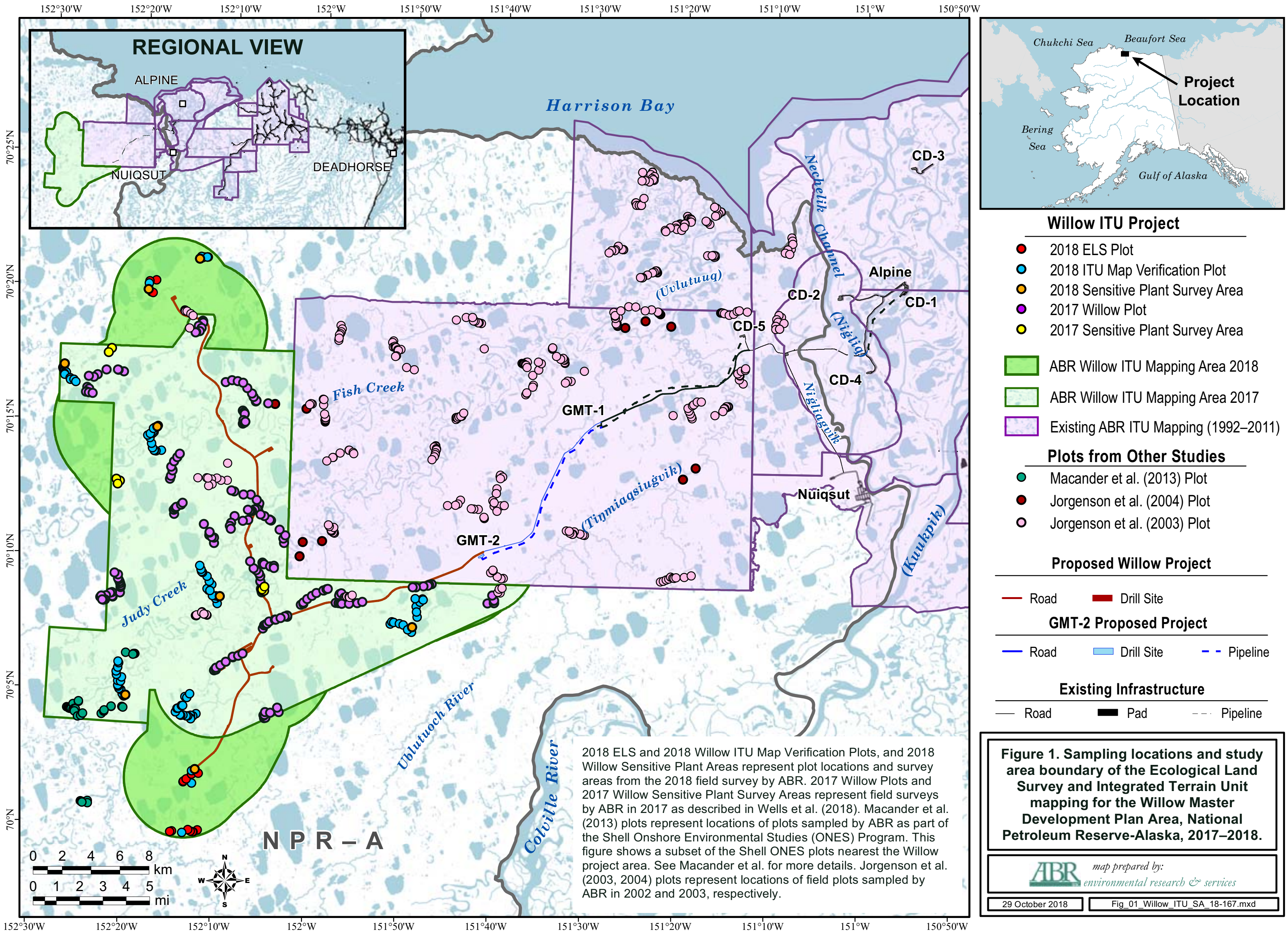


Figure 1. Sampling locations and study area boundary of the Ecological Land Survey and Integrated Terrain Unit mapping for the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

however, it does encompass sections of three major rivers: Judy Creek, Fish Creek, and the Kalikpik River.

Located on the Arctic Coastal Plain, the Willow study area experiences an Arctic climate with short, cool summers and long, cold winters with high winds. The entire study area is underlain by continuous permafrost estimated to be at least 330 m thick (Brown et al. 2002, Wahrhaftig 1965). The active layer—the surface layer of soil that thaws seasonally—is typically less than 0.5 meter thick, resulting in poorly drained soils. The landscape is dominated by permafrost-related landforms and oriented lakes, many of which originated due to thermokarst. The Arctic tundra is dominated by low-growing vegetation, with no trees and few shrubs exceeding 1 m in height (Walker et al. 2005). Tussock tundra is the dominant vegetation on old, stable landforms and wet sedge meadows are common on flat, poorly-drained lowlands and lake margins. A detailed discussion of the Willow study area environment is available in Wells et al. (2018).

3 METHODS

3.1 FIELD SURVEYS

We completed sensitive plant surveys and integrated ELS and wetland field surveys from 27 July to 7 August 2017, and on 1 August and 3 August 2018. Map accuracy assessment surveys were performed from 7 August to 9 August 2018. Three field crews were deployed in 2017 and 2 in 2018 for a total of 36 field crew days in 2017, and 10 field crew days in 2018. Each field crew was comprised of a botanist, a soil scientist, and a bear guard. Field crews were based at the Alpine Oil Facilities on the Colville River delta, and accessed the project area by helicopter.

3.1.1 SENSITIVE PLANT SURVEYS

Before field work began we compiled a list of sensitive plants for the NPR-A from BLM (2012). We located sensitive plant species in the project area using: (1) sensitive plant survey areas, i.e., surveys in habitats known from the literature and previous field surveys to be preferred by sensitive plants, and (2) sensitive plant searches at ELS and wetland plots. Detailed methods for each approach are provided in Wells et al. (2018). We searched 9 sensitive plant areas in 2017 and 8 areas in 2018 (Figure 1).

3.1.2 INTEGRATED ELS AND WETLAND FIELD SURVEYS

ELS and wetland surveys involve collecting many of the same types of field data, including information on landscape and environmental characteristics, vegetation, and soils. As described in Wells et al. (2018), we used these similarities to develop an integrated field sampling protocol to allow the concurrent collection of both ELS and wetland data collected during field sampling. ELS field protocols were combined with the U.S. Army Corps of Engineers (USACE) three-parameter approach, which involves collecting data on vegetation, soils, and hydrology (Environmental Laboratory 1987, USACE 2007), and the resulting data were used in ecological analyses, wetland determinations, and ITU map verification. Detailed methods for general environment, vegetation, soils, and wetlands data collection are provided in Wells et al. (2018).

We completed 11 ELS and 13 wetland transects in 2017, and 10 ELS transects in 2018. Transects were positioned along elevation gradients (toposequences) that were selected using a gradient-directed sampling scheme (Austin and Heyligers 1989). The sampling scheme was designed to sample the range of ecological conditions present within the Willow project area, providing the spatially related data needed to interpret ecosystem and soils development. In 2017, we sampled 69 ELS plots and 17 ITU map verification plots along ELS transects, and 86 wetland determination plots and 26 wetland verification plots along wetland transects for a total of 198 plots. In 2018, we sampled 20 ELS plots and 6 ITU map verification plots, for a total of 26 plots in the 2018 Willow ITU mapping area (Figure 1).

Data were collected using ABR-developed data-entry forms and mobile applications on ruggedized Android tablet computers. Geospatial coordinates (i.e. latitude/longitude) and approximate elevations were recorded on DeLORME Earthmate PN-60 recreation-grade GPS units, in the data collection forms on the tablet computers, and using a GIS (Geographc Information System) application (Collector for

ArcIGS: ESRI, Redlands CA) that displayed imagery for the project area on the tablet computers. Horizontal accuracy of plot locations was ±3–5 m. Field plots were circular, with an approximate radius of 10 m, and were situated entirely within a single distinct vegetation type or photo-signature identified on satellite imagery. Approximate plot locations were pre-selected, but exact placement was decided in the field by the field crew leader. Plots were placed in homogeneous patches of vegetation that were at least ½ ha in area, and not in transitional areas between distinct vegetation types (ecotones).

3.1.3 MAP ACCURACY ASSESSMENT SURVEYS

In 2018, we completed 98 ITU map verification plots in the 2017 Willow ITU mapping area for use in an accuracy assessment (Figure 1). Plots were positioned along toposequences to sample a range of environmental conditions and to maximize the number of mapped ecotypes that could be sampled by field crews traveling on foot. Data were collected at pre-selected sampling locations at the centroid of each sampled map unit polygons. Additional data points were collected at the discretion of the field crew leader, using a moving map on a tablet computer to place the plot at the approximate centroid of each map unit polygon. Rapid ITU map verification plots were designed for efficiency, so only the data necessary for the accuracy assessment were collected: location (latitude, longitude, elevation), geomorphic unit, surface form, Level IV vegetation class (Viereck et al. 1992), disturbance, water pH and EC, and percent cover of tussocks. In addition, percent foliar cover of 5–10 dominant plant species was recorded. Field crews had access to the mapped ecotypes, but to avoid biasing field decisions they did not have access to the mapped variables used to define an ecotype: geomorphic unit, surface form, Level IV vegetation class, and disturbance. Data at accuracy assessment plots was recorded using the same methods as described above for the integrated ELS and wetland surveys described.

3.2 DATA ANALYSIS

Data management, data quality assurance and control, and use of supplementary field data followed methods described by Wells et al. (2018). Ecosystems in the Willow study area were classified at 2 levels. First, we classified 4 ecological components—geomorphology, surface form, vegetation, and disturbance—using standard classification systems developed for Alaska (Table 1). Second, we assessed patterns of correspondence among these ecological components to classify ecotypes (local-scale ecosystems) that best partitioned the range of variation for all the measured biological and physical components. The ultimate goal of the classification was to capture relationships between surficial geology, geomorphology, soils, vegetation and disturbance regime. These relationships can then be applied to address questions regarding ecosystem services (e.g., wildlife habitats).

3.3 GIS AND REMOTE SENSING

The GIS and remote sensing datasets used to support the mapping effort are summarized in Wells et al. (2018). An automated waterbody extraction was performed for the 2018 ITU mapping areas, following techniques described in Wells et al. (2018). Three image blocks were added to provide full coverage of the 2018 mapping areas (Figure 1). Although the new image blocks were based on the same 5 July 2015 WorldView-2 imagery as the original block used by Wells et al. (2018), the imagery provider independently color-balanced each block. Therefore the color interpretation was slightly different among the 4 (1 original and 3 new) image blocks.

3.3.1 INTEGRATED TERRAIN UNIT MAPPING

As described in Wells et al. (2018), map units were hand-digitized on-screen over multispectral satellite imagery. ITUs were mapped by assigning a four-parameter code to each map unit describing geomorphology, surface form, vegetation, and disturbance type (e.g., Eolian Inactive Sand Dune/Dune, undifferentiated/Dryas Dwarf Shrub Tundra/Eolian (Wind); Esdi/En/Sddt/Nge). Methods used to define map ecotypes and crosswalk wetland classes to ITU components are provided in Wells et al. (2018).

3.3.2 ACCURACY ASSESSMENT

We pooled data from the 98 ITU map verification plots from our 2018 map accuracy

Table 1. Coding system for classifying and mapping geomorphic units, surface forms, vegetation, and disturbance in the Willow project area, National Petroleum Reserve-Alaska, 2018.

Code	Class
	TERRESTRIAL GEOMORPHIC UNIT
cs	Solifluction Deposit
elu	Upland Loess*
esda	Eolian Active Sand Dune
esdb	Eolian Abandoned Sand Dune
esdi	Eolian Inactive Sand Dune
essl	Eolian Sand Sheet Lowland
essu	Eolian Sand Sheet Upland
fhl	Lowland Headwater Floodplain
fmoa	Meander Active Overbank Deposit
fmob	Meander Abandoned Overbank Deposit
fmoi	Meander Inactive Overbank Deposit
fmra	Meander Active Channel Deposit
fmraf	Meander Fine Active Channel Deposit*
fmrb	Meander Abandoned Channel Deposit
fmri	Meander Inactive Channel Deposit
fmrif	Meander Fine Inactive Channel Deposit*
fto	Old Alluvial Terrace
ftr	Recent Alluvial Terrace*
ldic	Drained Basin, ice-rich center
ldim	Drained Lake Basin, ice-rich margin
ldip	Drained Lake Basin, pingo
ldiu	Drained Lake Basin, ice-rich undifferentiated
ldnc	Drained Lake Basin, ice-poor center
ldnm	Drained Lake Basin, ice-poor margin
ldnu	Drained Lake Basin, ice-poor undifferentiated
mp	Alluvial-Marine Deposit
	WATERBODY GEOMORPHIC UNIT
wldc	Deep Connected Lake
wldcr	Deep Connected Riverine Lake
wldcrh	Deep Tapped Riverine Lake, High-water Connection
wldi	Deep Isolated Lake
wldir	Deep Isolated Riverine Lake
wldp	Deep Thermokarst Pit*
wlscr	Shallow Connected Riverine Lake
wlsi	Shallow Isolated Lake
wlsid	Shallow Isolated Dune Lake
wlsir	Shallow Isolated Riverine Lake
wlsp	Shallow Thermokarst Pit*
wrk	Thermokarst River
wrln	Lower Perennial River, non-glacial
	SURFACE FORM
d	Drainage
dr	Ripples*
ds	Scour Channels-Ridges*
dt	Water Tracks
e	Eolian Patterns*
eb	Scour Depressions*
ed	Erosion Pavements*
en	Dune, undifferentiated
es	Small Dunes*
fc	Channel
fh	Hummocks*
lp	Polygonized Pond Margins
m	Mounds (ide and peat related)*
mg	Gelifluction Lobes
mi	Ice-cored Mounds*
ms	Strang
mu	Undifferentiated Mounds
n	Nonpatterned
pd	Disjunct Polygon Rims
phh	High-centered, High-relief Polygons
phl	High-centered, Low-relief Polygons
plhh	Low-centered, High-relief, High-density Polygons
plhl	Low-centered, High-relief, Low-density Polygons
pllh	Low-centered, Low-relief, High-density Polygons
plll	Low-centered, Low-relief, Low-density Polygons
pm	Mixed High and Low-centered Polygons
pr	Polygon Rims*
sb	Bluffs or Banks

Table 1. Continued.

Code	Class
tb	Beads
tm	Mixed Thermokarst Pits and Polygons
tt	Thermokarst Troughs*
tw	Moats (linear, water filled)*
w	Water
wi	Lake with Islands
x	Complexes*
xb	Basin Complex
xd	Dune Complex
xr	Riverine Complex
	VEGETATION CLASS
bbg	Barren
bpv	Partially Vegetated
haa	Aquatic Algae
hafm	Common Marestail*
hfds	Seral Herbs
hfwfh	Fresh Herb Marsh*
hgmght	Moist Grass-Herb Meadow Tundra*
hgmsd	Moist Sedge-Dryas Tundra*
hgmss	Moist Sedge-Shrub Tundra
hgmst	Moist Sedge Meadow Tundra*
hgmswt	Moist Sedge-Willow Tundra*
hgmt	Tussock Tundra
hgmtd	Tussock Tundra-Dryas*
hgmte	Tussock Tundra-Ericaceous*
hgwfg	Fresh Grass Marsh
hgwfs	Fresh Sedge Marsh
hgwsbt	Wet Sedge-Birch Tundra*
hgwst	Wet Sedge Meadow Tundra
hgwswt	Wet Sedge-Willow Tundra
sddf	Dryas-Forb Dwarf Shrub Tundra*
sddl	Dryas-Lichen Dwarf Shrub Tundra*
sdds	Dryas-Sedge Dwarf Shrub Tundra*
sddt	Dryas Dwarf Shrub Tundra
sdeb	Bearberry Dwarf Shrub Tundra*
sdec	Cassiope Dwarf Shrub Tundra
sdet	Ericaceous Dwarf Shrub Tundra
sdwt	Willow Dwarf Shrub Tundra*
slcw	Closed Low Willow
slobe	Open Low Mesic Shrub Birch-Ericaceous Shrub*
slobw	Open Low Shrub Birch-Willow*
slobwe	Mesic Shrub Birch-Willow-Ericaceous
slott	Open Mixed Low Shrub-Sedge Tussock Tundra*
slow	Open Low Willow
slows	Open Low Willow-Sedge Shrub Tundra
stow	Open Tall Willow
wf	Fresh Water
xbo	Old Basin Wetland Complex
xby	Young Basin Wetland Complex
xd	Dune Complex
xr	Riverine Complex
	DISTURBANCE CLASS
a	Absent
hfgp	Gravel Pad
ht	Trail (undifferentiated)
n	Natural*
na	Animals, Wildlife*
name	Mammal excavations*
ng	Geomorphic Process*
nge	Eolian (Wind)
ngf	Fluvial (undifferentiated)
ngfd	Fluvial Deposition*
ngfe	Fluvial erosion/Channel migration
ngt	Thermokarst*

* Class described in field but not mapped.

assessment surveys, five 2018 rare plant survey areas located within the 2017 Willow ITU mapping area, and 37 plots from Jorgenson et al. (2003) for the purpose of performing a map accuracy assessment. These plots were not used as verification data by the mapping team in 2017, hence they represent an independent map validation dataset. The 140 accuracy assessment plots were each assigned a wildlife habitat class following the wildlife habitat classification of Wells et al. (2018), and then the plots were reviewed in a GIS with respect to the ITU mapping. Based on our review we excluded from further analysis 1) plots that resulted in 2 or more plots within a single map unit polygon and that represented small (i.e., less than minimum map unit area threshold) inclusions within the map unit, 2) plots sampled in vegetation type complexes, and 3) plots representing habitat classes with <3 plots. This filtering process reduced the accuracy assessment dataset to 120 plots. The accuracy assessment dataset was joined spatially to the ITU mapping in a GIS, and each plot was assigned the attributes of the map unit polygon within which it was located. The attribute table from the join was exported from the GIS software and used to create a confusion matrix to assess the accuracy of the wildlife habitat map.

3.4 LANDSCAPE EVALUATION AND MODELING

As in Wells et al. (2018), we present 4 applications of the ITU mapping in the Willow study area: wildlife habitats, wetlands, soil great groups, and sensitive plant habitat suitability. The wildlife habitat classification was was based on landscape properties considered most important to wildlife: shelter, security (or escape), and food. It focused on on (a) breeding waterbirds that primarily use waterbodies and wetland moist tundra types and (b) mammals and upland birds that use shrublands and dry tundra types. A broad-scale map of wetlands and waters within the Willow project area, consistent with the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) mapping, was developed by crosswalking the ITU classification to NWI types using field data obtained in summer 2017 and 2018. The soil great group classification relied on relating soil great groups to mapped ecotypes as described in Wells et al. (2018). The sensitive plant habitat suitability mapping was based on multiple data sources, including sensitive plant surveys in the Willow project area, observations of sensitive plants from Jorgenson et al. (2004) and Macander et al. (2013), herbarium records, and recorded habitat preferences in adjacent areas of the NPR-A.

4 RESULTS AND DISCUSSION

4.1 PLANT SPECIES SUMMARY

Comprehensive lists of vascular and non-vascular plants identified in the Willow project area are provided in Appendix A. Information provided includes the number of plots in which each taxon occurred, the Alaska state and global rankings for rare taxa (ACCS 2018), and the invasiveness rankings (AKEPIC 2018) for non-native taxa. Appendix B provides a synonymy table between plant taxonomic names used by ABR and those accepted by the National Plants Database (USDA NRCS 2018). Thirty-seven specimens of interest to the University of Alaska Museum of the North Herbarium (ALA) in Fairbanks, Alaska (e.g. collections of rare and sensitive plant species) were donated to ALA (Appendix C). All other specimens were donated to the University of Alaska Anchorage Herbarium (UAAH).

We encountered 377 plant taxa across all plots sampled in 2017 and 2018. Of this total, 255 were vascular plants, and 122 were non-vascular (Appendix A). We found no non-native species and 3 BLM sensitive plants in the Willow project area (see below, Sensitive Plant Surveys). The most commonly observed vascular plants, occurring in over 150 plots, were *Carex aquatilis* (180 plots), *Salix pulchra* (164), *Cassiope tetragona* (157), *Eriophorum angustifolium* (156), *Salix reticulata* (154), and *Dryas integrifolia* (153). These species have broad environmental tolerances, very effective reproductive strategies, and/or their preferred habitats are common in the study area. Sixty-one vascular species were limited to a single observation in the study area. This included species with strict environmental tolerances (e.g., the aquatic forb *Ranunculus confervoides*), sensitive plants (e.g., the grass *Pleuropogon sabinei*), and species whose preferred habitat is uncommon in the study area (e.g., the grass *Leymus mollis*). The most common non-vascular plants, those occurring at over 75 plots, are *Flavocetraria cucullata* (110 plots), *Aulacomnium turgidum* (105), *Hylocomium splendens* (99), and *Dactylina arctica* (85). The count of non-vascular species should be considered a low estimate; in accordance with the sampling protocol only dominant nonvascular plants were recorded. For a description of the commonly occurring species within each ecotype and plant association see the section Plot Ecotypes and Plant Associations, below.

4.1.1 SENSITIVE PLANT SURVEYS

No plant species occurring in the NPR-A are listed as Threatened or Endangered by the U.S. Fish and Wildlife Service (USFWS 2018). However, 50 plant species are listed as sensitive for Alaska by the BLM, and of these, 21 are known or suspected to occur in NPR-A (BLM 2012). We documented 3 BLM-listed sensitive grasses in the Willow project area and adjacent areas (Figure 2, Appendix A): *Koeleria asiatica* (28 occurrences), *Pleuropogon sabinei* (1), and *Poa hartzii* ssp. *alaskana* (4). Jorgenson et al. (2004) and Macander et al. (2013) also documented *Koeleria asiatica* (6 occurrences) and *Poa hartzii* ssp. *alaskana* (7) in and adjacent to the Willow project area (Figure 2). State and global rarity rankings, habitat preferences, and commonly associated species of *Koeleria asiatica*, *Pleuropogon sabinei*, and *Poa hartzii* ssp. *alaskana* are described in Wells et al. (2018).

As described in Wells et al. (2018), queries for the 21 sensitive plant species known or suspected to occur in NPR-A were made of the ARCTOS database using the locality search tool (ARCTOS 2018), and the Rare Plant Data Portal (ACCS 2018) mapping tool in 2017; no additional BLM sensitive species records were found within or adjacent to the Willow project area.

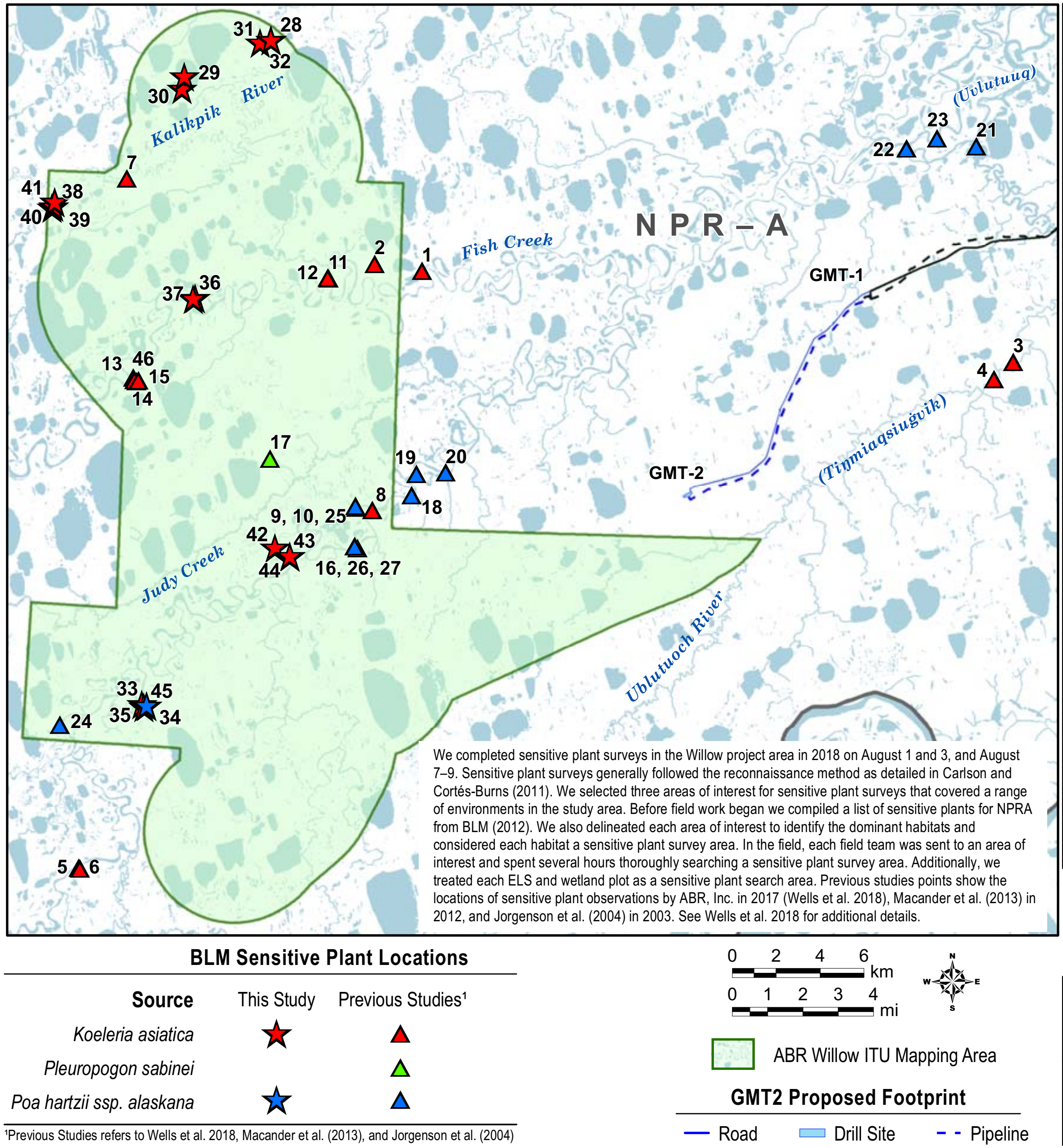
Three additional vascular plant species of possible conservation interest were observed in the study area. *Poa sublanata* and *Potamogeton subsibiricus* have state rarity rankings, but are not on the BLM sensitive species list; both species were recorded in both 2017 and 2018 (Appendix D), and are described in Wells et al. (2018). *Oxytropis campestris* was observed in 2017, but no specimen was collected. *O. campestris* includes within its taxonomic concept *O. tananensis,* which is on the BLM watch list and has a state ranking of S3S4Q. A state ranking of S3 means that this plant is considered rare within the state of Alaska, and at moderate risk of extirpation because of restricted range, narrow habitat specificity, recent population decline, small population sizes, and/or a moderate number of occurrences. A state ranking of S4 means that this plant is apparently secure, but uncommon, within the state and may be a long-term conservation concern. However, the “Q” in the state ranking indicates that the taxonomic classification of *O. tananensis* as a separate species, and its taxonomic relationship to *Oxytropis campestris*, are questionable or uncertain as currently defined. To help resolve these uncertainties any future field studies should focus on searching for and collecting specimens from the *O. campestris* taxonomic group. The one record of *O. campestris* in the Willow project area was encountered on the banks of Judy Creek, and Cortés-Burns et al. (2009) describes this species as occurring in rocky, *Dryas* heath tundra with scattered shrubs and forbs on river bluffs and limestone knobs above floodplains.

Two BLM-listed sensitive species that we expected to find, but did not, were *Mertensia drummondii* and *Potentilla stipularis*. *M. drummondii* is known in Alaska from the Meade and Kogosukruk River areas (Cortés-Burns et al. 2009, ARCTOS 2018), where it occurs on sparsely vegetated, active sand dunes and blowouts. *P. stipularis* is known in NPR-A from 1 location at the confluence of the Etivluk and Colville rivers (Cortés-Burns et al. 2009).

4.1.2 PLOT ECOTYPES AND PLANT ASSOCIATIONS

We identified a total of 36 plot ecotypes in the Willow project area; 36 plant associations were represented within those plot ecotypes (Appendix E).

Twenty-three ecotypes corresponded to one or two plant associations, and fifteen plant associations occurred in only one ecotype (Appendix E). These primarily represent narrowly defined ecotypes (based on vegetation), with low within-ecotype variability in species composition, and plant associations that correspond to unique



We completed sensitive plant surveys in the Willow project area in 2018 on August 1 and 3, and August 7–9. Sensitive plant surveys generally followed the reconnaissance method as detailed in Carlson and Cortés-Burns (2011). We selected three areas of interest for sensitive plant surveys that covered a range of environments in the study area. Before field work began we compiled a list of sensitive plants for NPRA from BLM (2012). We also delineated each area of interest to identify the dominant habitats and considered each habitat a sensitive plant survey area. In the field, each field team was sent to an area of interest and spent several hours thoroughly searching a sensitive plant survey area. Additionally, we treated each ELS and wetland plot as a sensitive plant search area. Previous studies points show the locations of sensitive plant observations by ABR, Inc. in 2017 (Wells et al. 2018), Macander et al. (2013) in 2012, and Jorgenson et al. (2004) in 2003. See Wells et al. 2018 for additional details.

ID	Species code	Latitude	Longitude
1	koeasi[3]	70.261117	-152.020316
2	koeasi[3]	70.263351	-152.078049
3	koeasi[3]	70.230634	-151.304699
4	koeasi[3]	70.223467	-151.327166
5	koeasi[2]	70.012964	-152.406123
6	koeasi[2]	70.012675	-152.404895
7	koeasi[1]	70.294385	-152.380991
8	koeasi[1]	70.162967	-152.070524
9	koeasi[1]	70.16375	-152.089964
10	koeasi[1]	70.164372	-152.09095
11	koeasi[1]	70.25672	-152.133076
12	koeasi[1]	70.257099	-152.133679
13	koeasi[1]	70.21346	-152.363723
14	koeasi[1]	70.212056	-152.359941
15	koeasi[1]	70.212328	-152.35723
16	koeasi[1]	70.148094	-152.090452
17	plesab[1]	70.182567	-152.195632
18	poaala[3]	70.169534	-152.024249
19	poaala[3]	70.178367	-152.019249
20	poaala[3]	70.179317	-151.984216
21	poaala[3]	70.318184	-151.355
22	poaala[3]	70.316751	-151.439333
23	poaala[3]	70.321067	-151.402433
24	poaala[2]	70.07087	-152.435582
25	poaala[1]	70.164372	-152.09095
26	poaala[1]	70.147249	-152.086895
27	poaala[1]	70.148094	-152.090452
28	koeasi[4]	70.353021	-152.212373
29	koeasi[4]	70.3318076	-152.3179891
30	koeasi[4]	70.3368777	-152.3158063
31	koeasi[4]	70.3518341	-152.225577
32	koeasi[4]	70.3529904	-152.2123772
33	koeasi[4]	70.0805571	-152.3379191
34	koeasi[4]	70.0793461	-152.3357831
35	koeasi[4]	70.0798559	-152.3323926
36	koeasi[4]	70.2467128	-152.292719
37	koeasi[4]	70.2464001	-152.2948341
38	koeasi[4]	70.2812952	-152.4695039
39	koeasi[4]	70.2817532	-152.4679012
40	koeasi[4]	70.2837775	-152.466645
41	koeasi[4]	70.2836782	-152.4666759
42	koeasi[4]	70.1462721	-152.185674
43	koeasi[4]	70.142971	-152.16719
44	koeasi[4]	70.1430134	-152.1673037
45	poaala[4]	70.0798559	-152.3323926
46	koeasi[3]	70.212492	-152.362091

Notes: Latitudes and Longitudes are given in WGS84. Plant species codes are: 'koeasi' - 'Koeleria asiatica', 'plesab' - 'Pleuropogon sabinei' and 'poaala' - 'Poa hartzii ssp. alaskana. Source of locations listed in table from [1] Wells et al. 2018, [2] Macander et al. 2013, and [3] Jorgenson et al. 2004, [4] This Study

Figure 2. Locations of BLM sensitive plants found in and adjacent to the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

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environmental conditions. For instance, the ecotype Upland Dry Tall Willow Shrub, and the plant association *Salix alaxensis-Chrysanthemum bipinnatum*, represent a unique combination of ecotype and plant association. This ecotype occurs almost exclusively on active dunes near rivers and features an assemblage of species unique to these environments.

Seven ecotypes had high within-ecotype variability in species composition, and corresponded to five or more plant associations (Appendix E). Several of these ecotypes were aggregated at the vegetation series level, and thus have similar dominant species but differ in understory species composition. For example, the Upland Moist Tussock Meadow ecotype is associated with 4 plant associations: (Appendix E). Tussock cottongrass, *Eriophorum vaginatum*, is dominant or codominant in all of these associations, but the remaining species vary among associations.

Twelve plant associations occurred in 3 or more ecotypes, these were primarily associations that occur in a variety of environments and are dominated by species tolerant of a diversity of environmental conditions. For example, the plant association *Carex aquatilis-Salix richardsonii-Equisetum variegatum* occurs in 5 ecotypes (Appendix E). The co-dominant species in this association, *C. aquatilis* and *S. richardsonii*, thrive in a variety of wet and saturated environments and tolerate periodic disturbances.

4.2 LANDSCAPE RELATIONSHIPS

The classification and mapping of ecotypes (local-scale ecosystems) was based on the survey of ecological components (topography, geomorphology, soil, hydrology, permafrost, and vegetation) along toposequences. Ordination analysis was also used to understand floristic relationships within and between plot ecotypes. The toposequences were selected to be representative of the landscape-soil-vegetation relationships in the Willow project area, and were used as the basis for classification and mapping. Wells et al. (2018) presents diagrams and descriptions of three toposequences and ordination diagrams that represent some of the common landscape and floristic relationships within the Willow project area.

Hierarchical relationships among ecological components were developed by successively grouping data from the ELS and wetland determination plots sampled in 2017–2018 by physiography, soil texture, geomorphology, slope position, surface form, drainage, soil chemistry, vegetation structure, and plant association (Table 2, Appendix E).

4.3 INTEGRATED TERRAIN UNIT MAPPING

4.3.1 ECOLOGICAL COMPONENTS

4.3.1.a Geomorphology

Twenty-two terrestrial geomorphic units were mapped (Appendix F), comprising 79.5% of the Willow study area (Table 3). The study area is dominated by ice-rich and ice-poor drained lake basin deposits (Figure 3). The 7 units in this group accounted for 33.0% of the mapped area, with Drained Lake Basin, ice-rich margin the most widespread (22.0%). Other common terrestrial geomorphic units included Alluvial-Marine Deposit (17.1%) and Eolian Sand Sheet Upland (15.4%).

Twelve waterbody classes were mapped (Appendix G), comprising 20.6% of the Willow study area (Table 3). The most prevalent waterbody class was Deep Isolated Lake (8.8%), which most often occurred on Alluvial-Marine and Eolian Sand Sheet deposits, and in Drained Lake Basins (Figure 4). Deep Connected Lakes (6.9%) and Shallow Isolated Lakes (2.6%), which are also associated with drained lake basins, were also common. See Wells et al. (2018) for a detailed discussion regarding the geomorphology and waterbody classification and mapping with respect to ecological processes and wildlife habitat.

4.3.1.b Surface Form

Twenty-five surface forms were mapped in the Willow study area (Appendix H). The most common ice-related surface forms were High-centered, Low-relief Polygons (18.2%); Mixed Thermokarst Pits and Polygons (12.1%); Mixed High- and Low-Centered Polygons (6.2%); and Disjunct Polygon Rims (6.6%) (Table 4, Figure 5). The least common ice-related surface form was Gelifluction Lobes (0.1%), which occur on Solifluction Deposit geomorphic units. Two surface forms specific to water were differentiated

Table 2. Relationships among ecological components of ecosystems in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Lacustrine	Lacustrine Grass Marsh	Graminoid Emergent	Deep Isolated Lake	Water
			Drained Lake Basin, ice-poor margin	Nonpatterned
	Lacustrine Moist Barrens	Barrens or Partially Vegetated		
	Lacustrine Moist Low Willow Shrub	Low Shrub	Drained Lake Basin, ice-poor center	
			Drained Lake Basin, ice-poor margin	
	Lacustrine Moist Sedge-Shrub Meadow	Dwarf Shrub		Ice-cored Mounds
				Nonpatterned
		Sedge Meadow		
	Lacustrine Wet Sedge Meadow			
				Strang
			Drained Lake Basin, ice-poor undifferentiated	Disjunct Polygon Rims
				Nonpatterned
Lowland	Lacustrine Aquatic Barrens	Lake Water	Drained Lake Basin, ice-rich undifferentiated	
	Lowland Lake		Deep Connected Lake	Water
			Deep Thermokarst Pit	
			Shallow Isolated Lake	
			Shallow Thermokarst Pit	
		Open Water	Shallow Isolated Lake	
			Shallow Thermokarst Pit	Thermokarst Troughs

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Lowland, continued	Lowland Moist Birch-Willow-Ericaceous Low Shrub	Low Shrub	Meander Abandoned Overbank Deposit	Bluffs or Banks
	Lowland Moist Low Willow Shrub		Drained Lake Basin, ice-poor margin	Undifferentiated mounds
			Drained Lake Basin, ice-rich margin	High-centered, Low-relief Polygons
				Nonpatterned
				Strang
			Drained Lake Basin, ice-rich undifferentiated	Nonpatterned
			Meander Abandoned Overbank Deposit	Bluffs or Banks
	Lowland Moist Sedge-Shrub Meadow	Dwarf Shrub	Alluvial-Marine Deposit	High-centered, Low-relief Polygons
			Drained Lake Basin, ice-rich margin	Strang
			Meander Abandoned Overbank Deposit	Mixed High and Low-centered Polygons
			Old Alluvial Terrace	Nonpatterned
			Solifluction Deposit	High-centered, Low-relief Polygons
		Sedge Meadow	Drained Lake Basin, ice-rich margin	Disjunct Polygon Rims
				Mixed High and Low-centered Polygons
				Nonpatterned
	Lowland Sedge Marsh	Sedge Emergent	Drained Lake Basin, ice-rich margin	Disjunct Polygon Rims
				Low-centered, Low-relief, Low-density Polygons

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Lowland, continued	Lowland Sedge Marsh, continued	Sedge Emergent, continued	Drained Lake Basin, ice-rich margin, continued	Nonpatterned
				Undifferentiated mounds
			Drained Lake Basin, ice-rich undifferentiated	Nonpatterned
			Shallow Thermokarst Pit	Water
	Lowland Wet Sedge Meadow	Sedge Meadow	Alluvial-Marine Deposit	Disjunct Polygon Rims
				Nonpatterned
			Drained Lake Basin, ice-poor margin	
			Drained Lake Basin, ice-rich margin	Disjunct Polygon Rims
				Low-centered, High-relief, Low-density Polygons
				Low-centered, Low-relief, High-density Polygons
				Low-centered, Low-relief, Low-density Polygons
				Mixed High and Low-centered Polygons
				Nonpatterned
				Strang
				Undifferentiated mounds
				Water tracks (non-incised drainages)
			Drained Lake Basin, ice-rich undifferentiated	Disjunct Polygon Rims
				Low-centered, Low-relief, Low-density Polygons
				Nonpatterned
				Undifferentiated mounds

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Lowland, continued	Lowland Wet Sedge Meadow, continued	Sedge Meadow, continued	Eolian Sand Sheet Lowland	Mixed pits and polygons
				Nonpatterned
				Strang
			Meander Abandoned Overbank Deposit	Low-centered, High-relief, High-density Polygons
				Low-centered, Low-relief, High-density Polygons
	Lowland Wet Sedge-Willow Meadow	Low Shrub	Drained Lake Basin, ice-rich margin	Polygon Troughs
		Sedge Meadow		Disjunct Polygon Rims
				Strang
			Drained Lake Basin, ice-rich undifferentiated	Nonpatterned
			Meander Abandoned Overbank Deposit	Mixed High and Low-centered Polygons
Riverine	Beaded Stream	Forb Emergent	Thermokarst River	Water
		River Water		
	Lower Perennial River		Lower Perennial River, non-glacial	Water
	Riverine Dry Dryas Dwarf Shrub	Dwarf Shrub	Meander Fine Inactive Channel Deposit	Nonpatterned
			Meander Inactive Overbank Deposit	Complexes
	Riverine Grass Marsh	Graminoid Emergent	Deep Isolated Riverine Lake	Water
	Riverine Lake	Lake Water	Shallow Isolated Riverine Lake	
	Riverine Moist Barrens	Barrens or Partially Vegetated	Meander Active Channel Deposit	Ripples
			Meander Fine Active Channel Deposit	Nonpatterned

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Riverine, continued	Riverine Moist Barrens, continued	Barrens or Partially Vegetated, continued	Meander Fine Active Channel Deposit, continued	Ripples
	Riverine Moist Low Willow-Sedge Meadow	Low Shrub	Meander Active Overbank Deposit	Nonpatterned
			Meander Fine Inactive Channel Deposit	
			Meander Inactive Channel Deposit	
			Meander Inactive Overbank Deposit	
	Riverine Moist Low Willow Shrub		Lowland Headwater Floodplain	
			Meander Active Overbank Deposit	
			Meander Fine Inactive Channel Deposit	
			Meander Inactive Overbank Deposit	Bluffs or Banks
				Nonpatterned
	Riverine Moist Sedge-Shrub Meadow	Sedge Meadow		
	Riverine Moist Tall Willow Shrub	Tall Shrub	Lowland Headwater Floodplain	Bluffs or Banks
			Meander Fine Inactive Channel Deposit	Nonpatterned
	Riverine Sedge Marsh	Sedge Emergent	Meander Active Overbank Deposit	Mixed pits and polygons
			Meander Fine Active Channel Deposit	Nonpatterned
			Meander Fine Inactive Channel Deposit	

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Riverine, continued	Riverine Wet Sedge Meadow	Sedge Meadow	Lowland Headwater Floodplain	Nonpatterned, continued
			Lowland Headwater Floodplain, continued	Water tracks (non-incised drainages)
			Meander Active Overbank Deposit	Nonpatterned
			Meander Fine Inactive Channel Deposit	
			Meander Inactive Overbank Deposit	Complexes
			Meander Inactive Overbank Deposit, continued	Low-centered, Low-relief, High-density Polygons
				Strang
	Riverine Wet Sedge-Willow Meadow	Low Shrub	Meander Fine Inactive Channel Deposit	Nonpatterned
		Sedge Meadow		
			Meander Inactive Overbank Deposit	Low-centered, Low-relief, Low-density Polygons
Upland	Upland Dry Barrens	Barrens or Partially Vegetated	Eolian Active Sand Dune	Crescent Dunes
	Upland Dry Dryas Dwarf Shrub	Dwarf Shrub	Eolian Abandoned Sand Dune	Dune, undifferentiated
				Linear Dunes
			Eolian Inactive Sand Dune	Dune, undifferentiated
				Linear Dunes
			Meander Abandoned Overbank Deposit	High-centered, Low-relief Polygons
			Old Alluvial Terrace	High-centered, High-relief Polygons

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Upland, continued	Upland Dry Grass Meadow	Grass Meadow	Old Alluvial Terrace, continued	High-centered, Low-relief Polygons
			Eolian Inactive Sand Dune	Crescent Dunes
	Upland Dry Tall Willow Shrub	Low Shrub	Eolian Active Sand Dune	
				Dune, undifferentiated
				Small Dunes
	Upland Moist Birch-Willow-Ericaceous Dwarf Shrub	Dwarf Shrub	Alluvial-Marine Deposit	Hummocks
				Mixed pits and polygons
			Drained Lake Basin, ice-rich margin	Polygon Rims
			Drained Lake Basin, pingo	High-centered, High-relief Polygons
				High-centered, Low-relief Polygons, continued
		Low Shrub	Alluvial-Marine Deposit	Bluffs or Banks
				High-centered, High-relief Polygons
			Drained Basin, ice-rich center	
				Mixed pits and polygons
			Upland Loess	Bluffs or Banks
	Upland Moist Cassiope Dwarf Shrub	Dwarf Shrub	Alluvial-Marine Deposit	High-centered, Low-relief Polygons
				Nonpatterned
			Drained Basin, ice-rich center	
			Eolian Abandoned Sand Dune	Dune, undifferentiated
				Linear Dunes

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Upland, continued	Upland Moist Cassiope Dwarf Shrub, continued	Dwarf Shrub, continued	Eolian Sand Sheet Upland	Bluffs or Banks
			Meander Abandoned Overbank Deposit	
			Solifluction Deposit	Gelifluction lobes
	Upland Moist Ericaceous Dwarf Shrub		Alluvial-Marine Deposit	Bluffs or Banks
	Upland Moist Ericaceous Dwarf Shrub, continued		Drained Basin, ice-rich center	High-centered, High-relief Polygons
			Drained Lake Basin, ice-rich margin	Low-centered, Low-relief, High-density Polygons
			Eolian Inactive Sand Dune	Dune, undifferentiated
			Upland Loess	High-centered, High-relief Polygons
	Upland Moist Low Willow Shrub	Low Shrub	Eolian Inactive Sand Dune	Dune, undifferentiated
	Upland Moist Shrub-Tussock Meadow	Tussock Meadow	Alluvial-Marine Deposit	High-centered, Low-relief Polygons
				Hummocks
				Mixed High and Low-centered Polygons
				Mixed pits and polygons
				Nonpatterned
			Drained Basin, ice-rich center	High-centered, High-relief Polygons
				Mixed High and Low-centered Polygons
				Mixed pits and polygons
			Drained Lake Basin, ice-rich margin	High-centered, Low-relief Polygons

Table 2. Continued.

Physiography	Plot Ecotype	Vegetation Structure	Geomorphic Unit	Surface Form
Upland, continued	Upland Moist Shrub-Tussock Meadow, continued	Tussock Meadow, continued	Drained Lake Basin, ice-rich margin, continued	Nonpatterned
			Drained Lake Basin, ice-rich undifferentiated	Disjunct Polygon Rims
			Drained Lake Basin, pingo	High-centered, High-relief Polygons
			Eolian Sand Sheet Upland	High-centered, Low-relief Polygons
			Eolian Sand Sheet Upland, continued	Mixed pits and polygons
				Nonpatterned
			Upland Loess	High-centered, High-relief Polygons
				High-centered, Low-relief Polygons
				Mixed pits and polygons
	Upland Moist Tussock Meadow		Alluvial-Marine Deposit	High-centered, Low-relief Polygons
				Mixed pits and polygons
				Nonpatterned
			Drained Basin, ice-rich center	Mixed pits and polygons
				Nonpatterned
			Drained Lake Basin, ice-rich margin	
			Eolian Sand Sheet Upland	High-centered, Low-relief Polygons
				Nonpatterned
			Upland Loess	High-centered, Low-relief Polygons
				Nonpatterned

Table 3. Areal extent of terrestrial and aquatic geomorphic units in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

	Area*		
Geomorphic Unit	Acres	Hectares	Percent
Terrestrial			
Alluvial-Marine Deposit	25,490	10,315	17.1
Drained Basin, ice-rich center	6,912	2,797	4.6
Drained Lake Basin, ice-poor center	924	374	0.6
Drained Lake Basin, ice-poor margin	5,029	2,035	3.4
Drained Lake Basin, ice-poor undifferentiated	1,308	529	0.9
Drained Lake Basin, ice-rich margin	32,789	13,269	22.0
Drained Lake Basin, ice-rich undifferentiated	2,124	859	1.4
Drained Lake Basin, pingo	114	46	0.1
Eolian Abandoned Sand Dune	1,221	494	0.8
Eolian Active Sand Dune	659	267	0.4
Eolian Inactive Sand Dune	2,961	1,198	2.0
Eolian Sand Sheet Lowland	3,709	1,501	2.5
Eolian Sand Sheet Upland	22,896	9,266	15.4
Lowland Headwater Floodplain	1,159	469	0.8
Meander Abandoned Channel Deposit	720	291	0.5
Meander Abandoned Overbank Deposit	3,107	1,257	2.1
Meander Fine Active Channel Deposit	1,163	471	0.8
Meander Active Overbank Deposit	556	225	0.4
Meander Fine Inactive Channel Deposit	1,155	468	0.8
Meander Inactive Overbank Deposit	2,513	1,017	1.7
Old Alluvial Terrace	1,378	558	0.9
Solifluction Deposit	297	120	0.2
Aquatic			
Shallow Isolated Lake	3,925	1,588	2.6
Deep Isolated Lake	13,121	5,310	8.8
Shallow Isolated Riverine Lake	247	100	0.2
Deep Connected Lake	10,259	4,152	6.9
Deep Isolated Riverine Lake	1,553	628	1.0
Deep Connected Riverine Lake	151	61	0.1
Lower Perennial River, non-glacial	1,204	487	0.8
Shallow Isolated Dune Lake	16	6	<0.1
Deep Tapped Riverine Lake, High-water Connection	53	21	<0.1
Thermokarst River	226	91	0.2
Shallow Connected Riverine Lake	165	67	0.1
Shallow Tapped Riverine Lake, High-water	7	3	<0.1
Total	149,111	60,343	100.0
Aggregated Subtotals			
Terrestrial	118,391	47,909	79.5
Aquatic	30,721	12,431	20.6

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

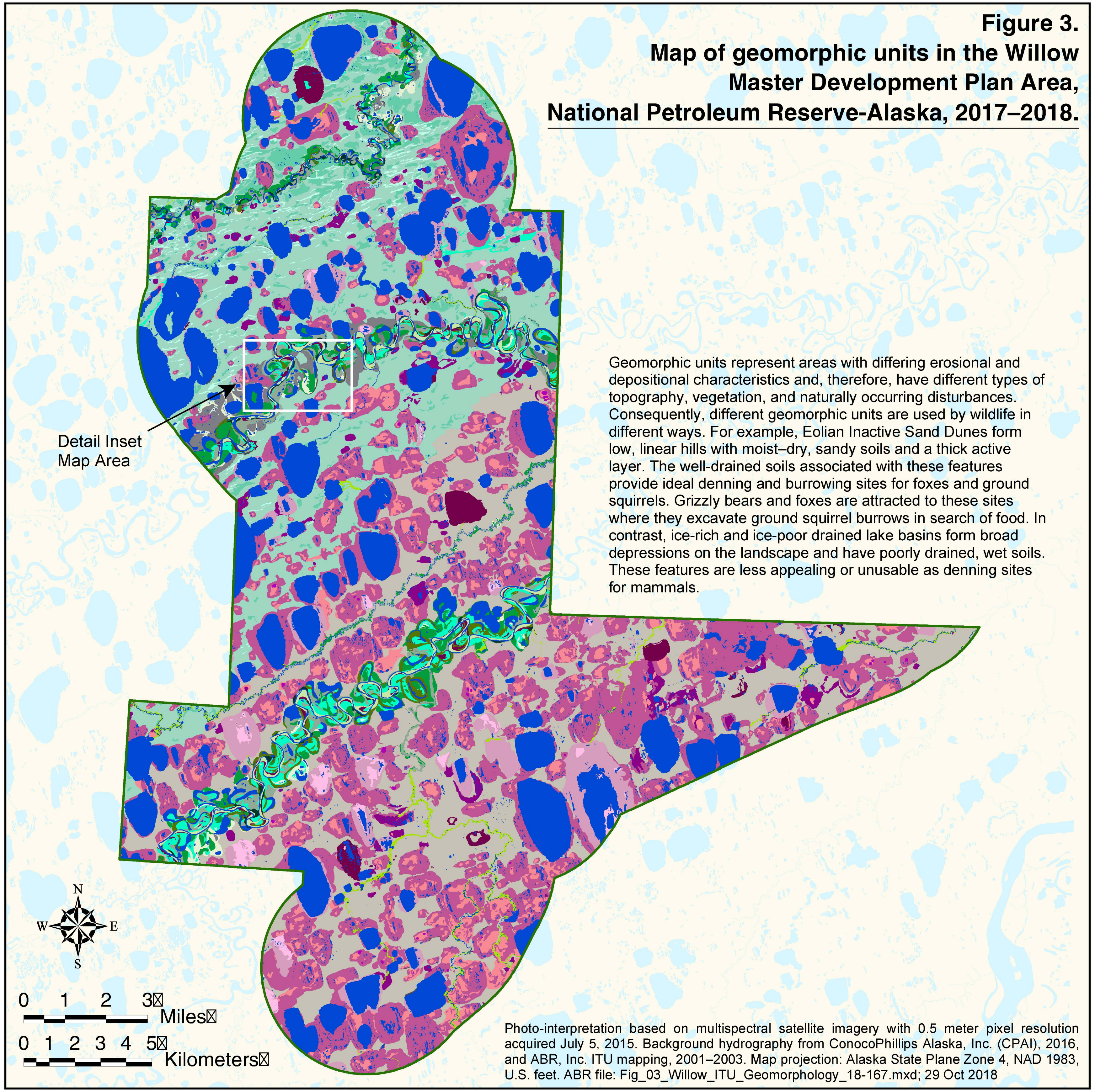
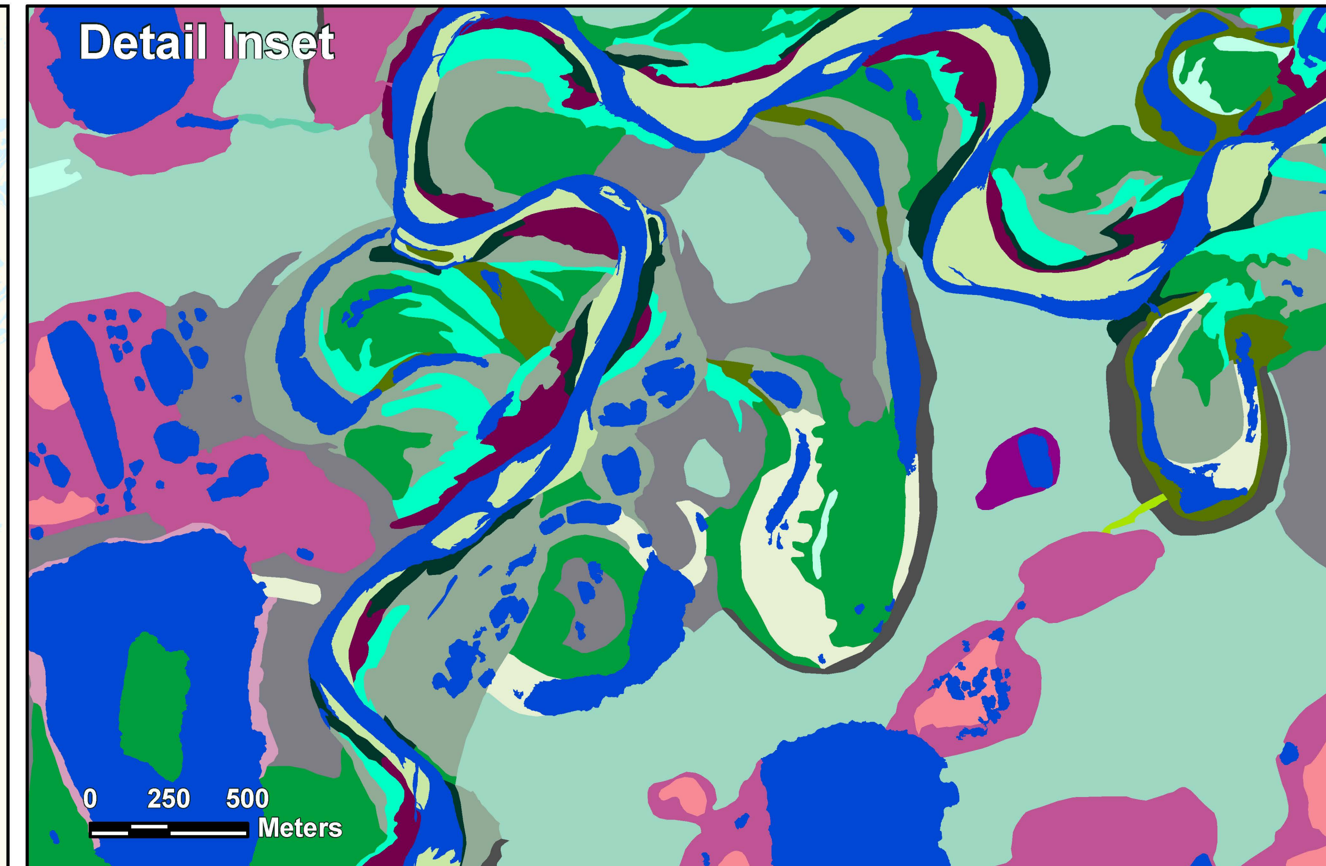


Figure 3.
Map of geomorphic units in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Geomorphic units represent areas with differing erosional and depositional characteristics and, therefore, have different types of topography, vegetation, and naturally occurring disturbances. Consequently, different geomorphic units are used by wildlife in different ways. For example, Eolian Inactive Sand Dunes form low, linear hills with moist–dry, sandy soils and a thick active layer. The well-drained soils associated with these features provide ideal denning and burrowing sites for foxes and ground squirrels. Grizzly bears and foxes are attracted to these sites where they excavate ground squirrel burrows in search of food. In contrast, ice-rich and ice-poor drained lake basins form broad depressions on the landscape and have poorly drained, wet soils. These features are less appealing or unusable as denning sites for mammals.

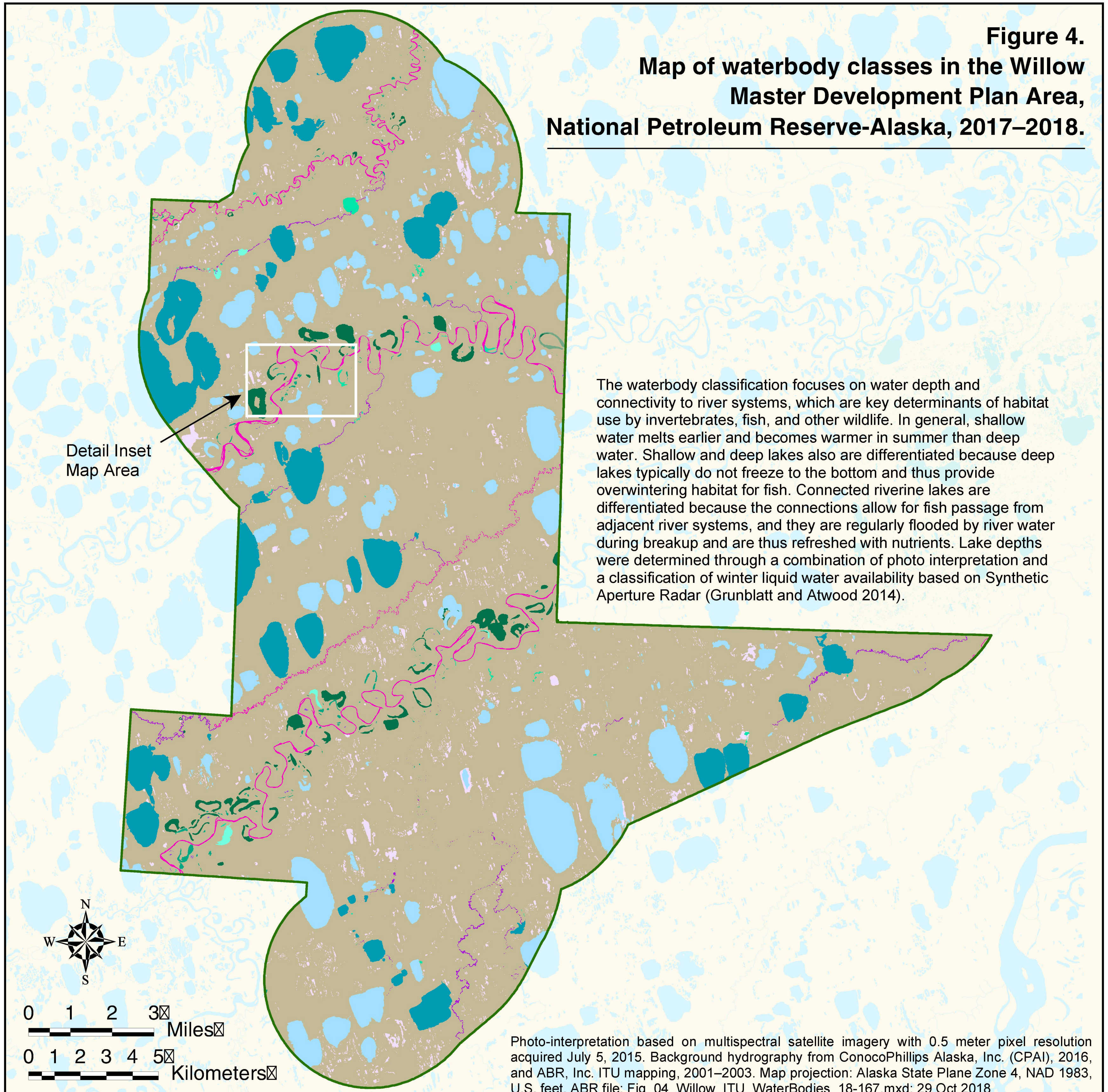
Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_03_Willow_ITU_Geomorphology_18-167.mxd; 29 Oct 2018



Terrestrial Geomorphic Unit

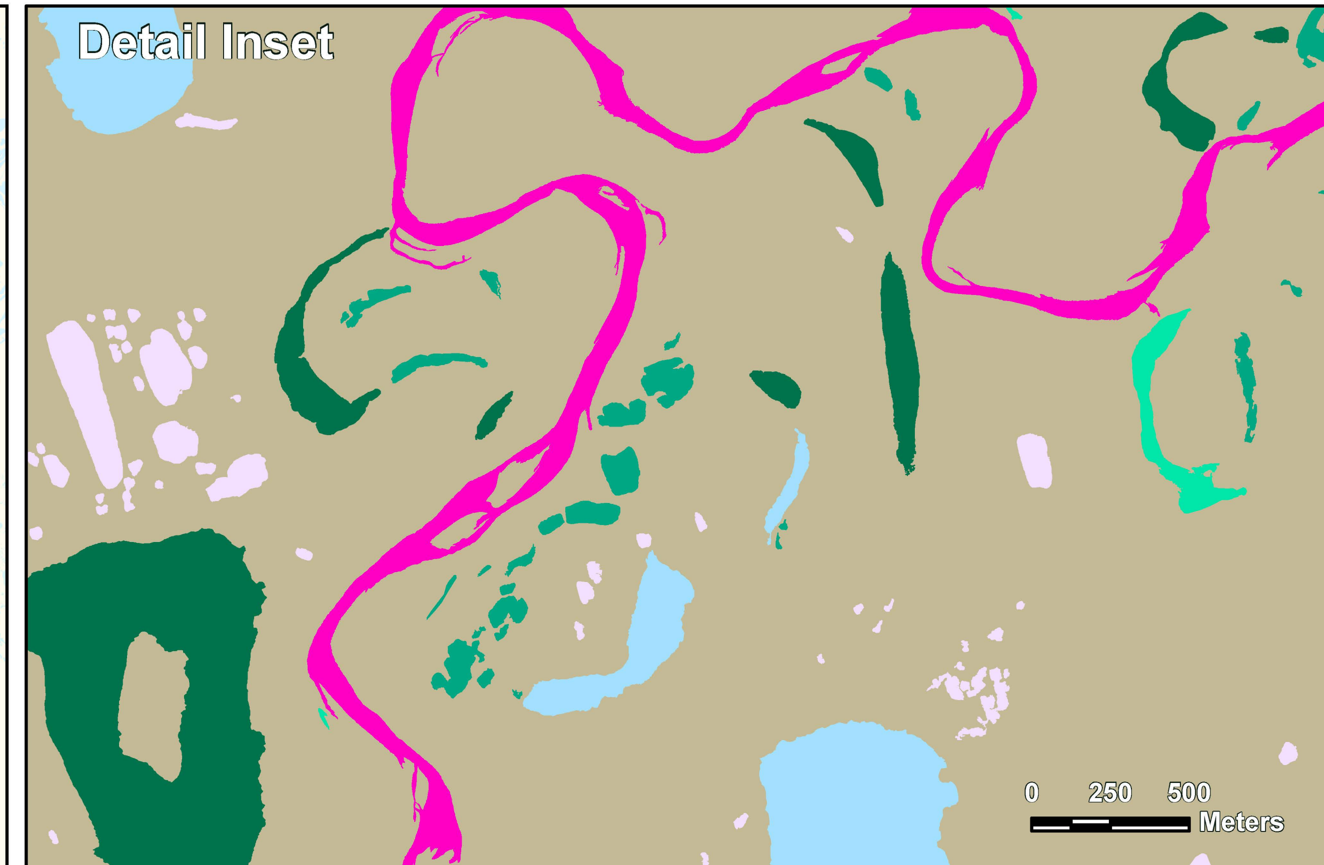
- Solifluction Deposit
- Eolian Active Sand Dune
- Eolian Inactive Sand Dune
- Eolian Abandoned Sand Dune
- Eolian Sand Sheet Upland
- Eolian Sand Sheet Lowland
- Lowland Headwater Floodplain
- Meander Active Channel Deposit
- Meander Inactive Channel Deposit
- Meander Abandoned Channel Deposit
- Meander Active Overbank Deposit
- Meander Inactive Overbank Deposit
- Meander Abandoned Overbank Deposit
- Old Alluvial Terrace
- Alluvial-Marine Deposit
- Drained Lake Basin, ice-poor center
- Drained Lake Basin, ice-poor margin
- Drained Lake Basin, ice-poor undifferentiated
- Drained Basin, ice-rich center
- Drained Lake Basin, ice-rich margin
- Drained Lake Basin, pingo
- Drained Lake Basin, ice-rich undifferentiated
- Aquatic Geomorphic Unit, Fresh

Figure 4.
Map of waterbody classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



The waterbody classification focuses on water depth and connectivity to river systems, which are key determinants of habitat use by invertebrates, fish, and other wildlife. In general, shallow water melts earlier and becomes warmer in summer than deep water. Shallow and deep lakes also are differentiated because deep lakes typically do not freeze to the bottom and thus provide overwintering habitat for fish. Connected riverine lakes are differentiated because the connections allow for fish passage from adjacent river systems, and they are regularly flooded by river water during breakup and are thus refreshed with nutrients. Lake depths were determined through a combination of photo interpretation and a classification of winter liquid water availability based on Synthetic Aperture Radar (Grunblatt and Atwood 2014).

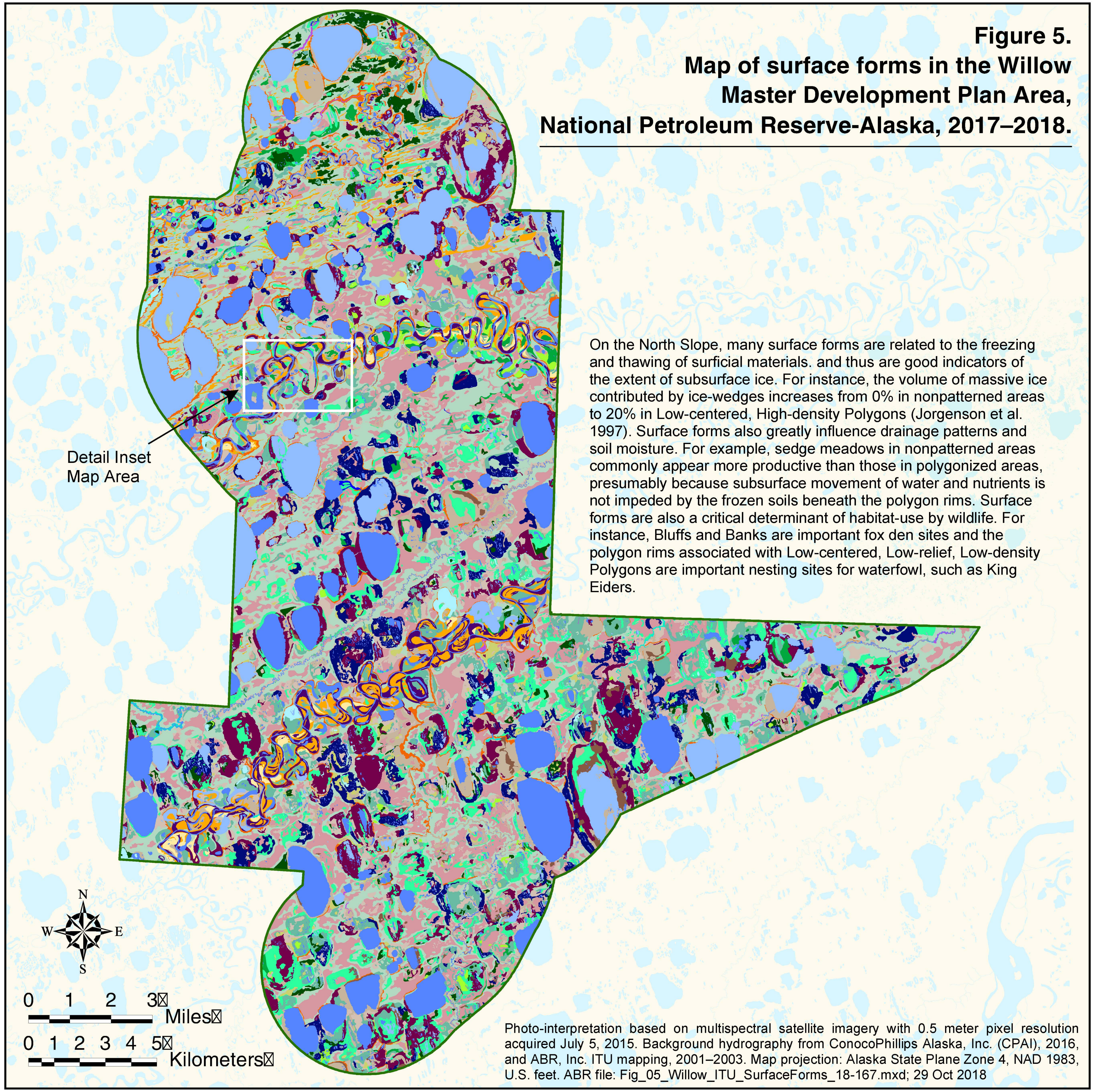
Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_04_Willow_ITU_WaterBodies_18-167.mxd; 29 Oct 2018



Waterbody Class (Aquatic Geomorphic Unit)

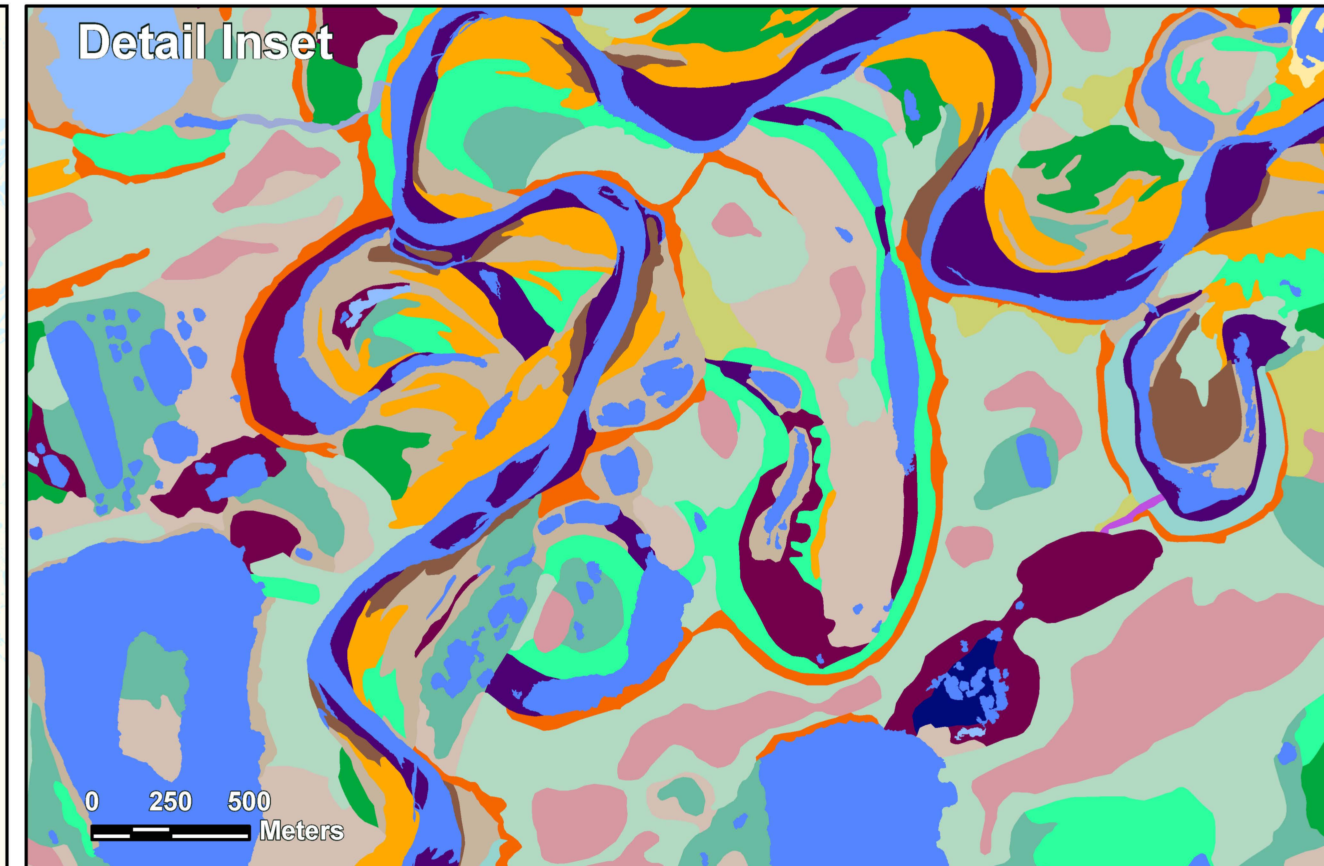
- Thermokarst River
- Lower Perennial River
- Shallow Isolated Dune Lake
- Shallow Isolated Riverine Lake
- Shallow Isolated Lake
- Shallow Connected Riverine Lake
- Shallow Tapped Riverine Lake, High-water Connection
- Deep Isolated Riverine Lake
- Deep Isolated Lake
- Deep Connected Riverine Lake
- Deep Connected Lake
- Deep Tapped Riverine Lake, High-water Connection

Figure 5.
Map of surface forms in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



On the North Slope, many surface forms are related to the freezing and thawing of surficial materials. and thus are good indicators of the extent of subsurface ice. For instance, the volume of massive ice contributed by ice-wedges increases from 0% in nonpatterned areas to 20% in Low-centered, High-density Polygons (Jorgenson et al. 1997). Surface forms also greatly influence drainage patterns and soil moisture. For example, sedge meadows in nonpatterned areas commonly appear more productive than those in polygonized areas, presumably because subsurface movement of water and nutrients is not impeded by the frozen soils beneath the polygon rims. Surface forms are also a critical determinant of habitat-use by wildlife. For instance, Bluffs and Banks are important fox den sites and the polygon rims associated with Low-centered, Low-relief, Low-density Polygons are important nesting sites for waterfowl, such as King Eiders.

Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_05_Willow_ITU_SurfaceForms_18-167.mxd; 29 Oct 2018



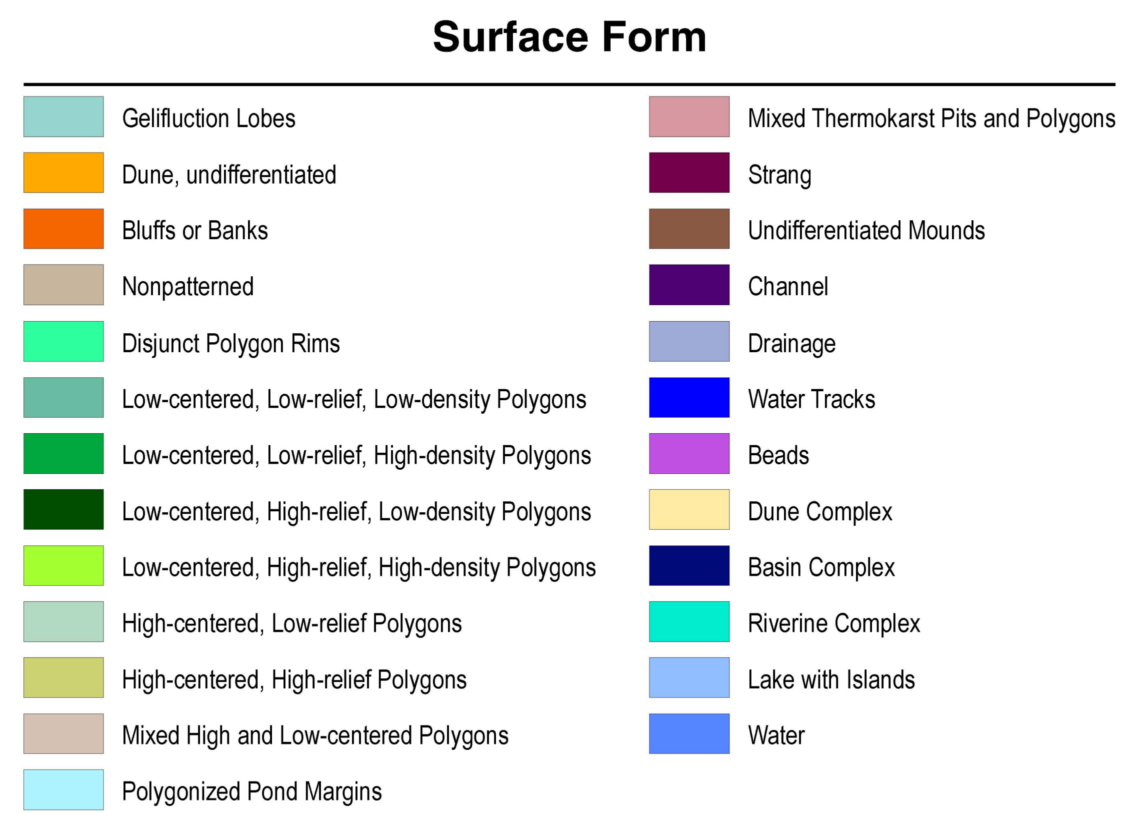


Table 4. Areal extent of surface forms units in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Surface Form	Area*		
	Acres	Hectares	Percent
Basin Complex	6,635	2,685	4.5
Beads	143	58	0.1
Bluffs or Banks	3,455	1,398	2.3
Channel	2,185	884	1.0
Disjunct Polygon Rims	9,775	3,956	6.6
Drainage	151	61	0.1
Dune Complex	612	248	0.4
Dune, undifferentiated	4,208	1,703	2.8
Gelifluction Lobes	77	31	0.1
High-centered, High-relief Polygons	2,071	838	1.4
High-centered, Low-relief Polygons	27,199	11,007	18.2
Lake with Islands	12,317	4,985	8.3
Low-centered, High-relief, High-density Polygons	684	277	0.5
Low-centered, High-relief, Low-density Polygons	2,471	1,000	1.7
Low-centered, Low-relief, High-density Polygons	1,463	592	1.0
Low-centered, Low-relief, Low-density Polygons	8,776	3,552	5.9
Mixed High and Low-centered Polygons	9,303	3,765	6.2
Mixed Thermokarst Pits and Polygons	18,018	7,292	12.1
Nonpatterned	10,210	4,132	6.9
Polygonized Pond Margins	727	294	0.5
Riverine Complex	267	108	0.2
Strang	9,386	3,798	6.3
Undifferentiated Mounds	1,043	422	0.7
Water	17,882	7,236	12.0
Water Tracks	53	21	<0.1
Total	149,111	60,343	100.0

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

because they are important for mapping waterbird habitat: Water (12.0%) and Lakes with Islands (8.3%). See Wells et al. (2018) for a detailed discussion regarding the surface form classification and mapping with respect to ecological processes and wildlife habitat.

4.3.1.c Vegetation

Twenty-three Level IV vegetation classes (Viereck et al. 1992), including Fresh Water, were mapped in the Willow project area (Appendix I). Common vegetation classes included Tussock Tundra (30.8%), Wet Sedge Meadow Tundra (14.2%), Moist Sedge-Shrub Tundra (9.8%), and Wet Sedge-Willow Tundra (5.8%) (Figure 6, Table 5). Four vegetation complexes were mapped in areas where individual patches of vegetation were too small to map separately: Old Basin Wetland Complex (4.4%), Dune Complex (0.4%), Riverine Complex (0.3%), and Young Basin Wetland Complex (0.2%). Old and Young Basin Wetland Complexes share similar vegetation classes including Fresh Water, Moist Sedge-Shrub Tundra, Wet Sedge Meadow Tundra, and Wet Sedge-Willow Tundra, but in differing proportions. Unique to Old Basin Complex is the presence of Tussock Tundra on ice-rich centers with high-centered polygon surface forms, on pingos, and along well-defined polygon rims in patterned ground. Areas mapped as Young Basin Complex may have greater proportions of Fresh Sedge Marsh and Open Low Willow-Sedge Shrub Tundra. Fresh Water and Barrens accounted for 19.7% and 0.8% of the mapped area, respectively.

4.3.1.d Disturbance

Six disturbance classes, including both natural and human-caused disturbance types as well as Absent, were mapped in the Willow study area (Appendix J). Over 99% of the study area was mapped as disturbance class Absent, while less than 1% was identified as having experienced either a human-caused or natural disturbance (Table 6, Figure 7). Only two disturbance classes were mapped with >0.1% cover: Eolian (Wind) (0.2%) and Fluvial (Undifferentiated) (0.2%).

4.3.2 MAP ECOTYPES

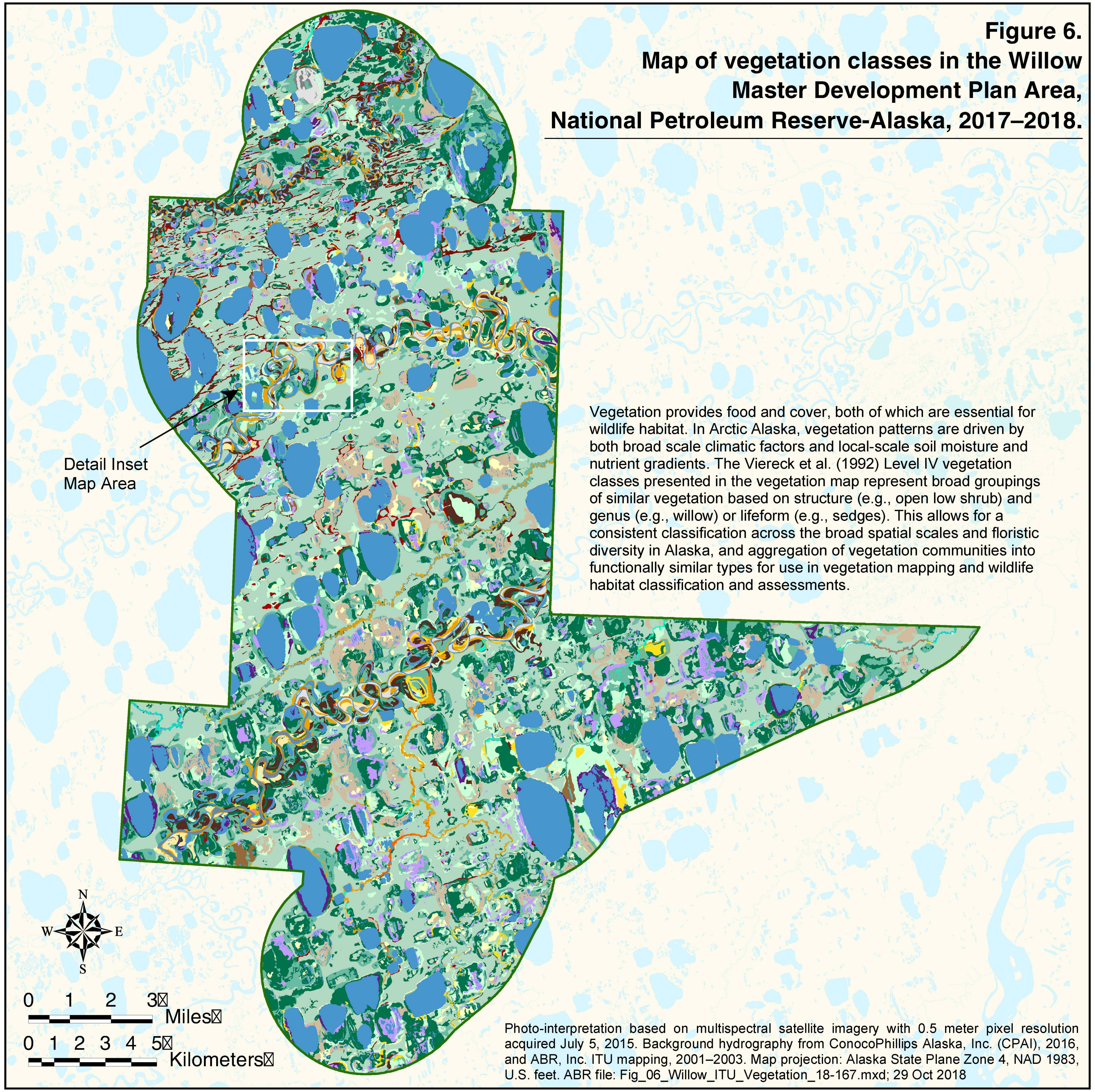
Forty-three ecotypes were mapped in the Willow study area (Appendix K). Combined, the three most common classes accounted for 60.2% of the study area: Upland Moist Tussock Meadow (30.8%), Lowland Lake (17.4%), and Lowland Wet Sedge Meadow (12.0%) (Table 7, Figure 8). Thirty-one map ecotypes had very limited distributions with <1% coverage. In most cases there was a 1:1 relationship between the plot ecotypes and the map ecotypes, with the following exceptions: (1) the plot ecotypes Upland Moist Shrub-Tussock Meadow and Upland Moist Tussock Meadow were combined into the map ecotype Upland Moist Tussock Meadow, and (2) the plot ecotypes Upland Dry Grass Meadow and Riverine Moist Sedge-Shrub Meadow were combined into the map ecotype Riverine Moist Sedge-Shrub Meadow. Four map ecotype classes represent areas of complex vegetation: Lowland Basin Complex, Riverine Complex, Riverine Dune Complex, and Lacustrine Basin Complex. Lowland Basin Complex (4.4%) represents ice-rich drained lake basins where the development of ground ice over time has caused the ecological processes that drive soil development and vegetation cover to transition from Lacustrine to Lowland physiography. Riverine Complex (0.3%) represents the dynamic, frequently disturbed regions adjacent to rivers or streams, and Riverine Dune Complex (0.4%) indicates locations where these alluvial floodplain processes interact with eolian dune processes. Lacustrine Basin Complex (0.2%) indicates ice-poor drained lake basins, which are recently drained (<50–100 years ago), and are mainly affected by ecological processes associated with wetlands in shallow or deep water lake habitats.

4.3.3 BROAD-SCALE WETLAND MAPPING

This broad scale map of wetlands and waters in the Willow project area was created by crosswalking the ITU classification to established NWI types using field data collected in 2017 and 2018.

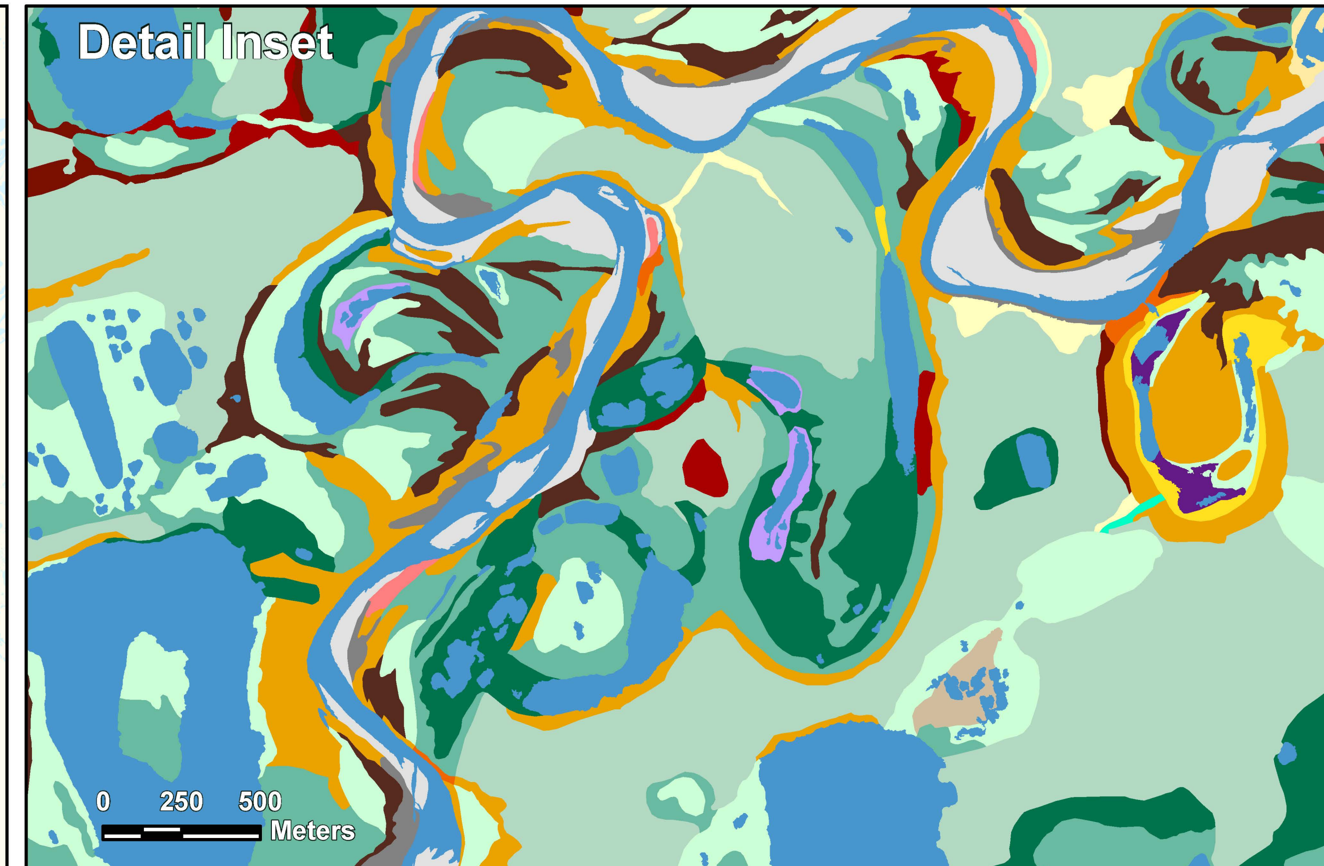
Nineteen NWI wetland types (FGDC 2013) were mapped in the Willow study area: 6 waters, 12 wetlands, and 1 non-wetland upland type (Figure 9, Table 8, Appendix L). Like much of the Arctic Coastal Plain, the Willow study area is predominantly wetland (75.8% of the study area). The most common wetland types were PEM1/SS1D, PEM1/SS1B, and PEM1F, collectively accounting for over 60% of the Willow

Figure 6.
Map of vegetation classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



Vegetation provides food and cover, both of which are essential for wildlife habitat. In Arctic Alaska, vegetation patterns are driven by both broad scale climatic factors and local-scale soil moisture and nutrient gradients. The Viereck et al. (1992) Level IV vegetation classes presented in the vegetation map represent broad groupings of similar vegetation based on structure (e.g., open low shrub) and genus (e.g., willow) or lifeform (e.g., sedges). This allows for a consistent classification across the broad spatial scales and floristic diversity in Alaska, and aggregation of vegetation communities into functionally similar types for use in vegetation mapping and wildlife habitat classification and assessments.

Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_06_Willow_ITU_Vegetation_18-167.mxd; 29 Oct 2018



Vegetation Class

- Barren
- Partially Vegetated
- Open Tall Willow
- Closed Low Willow
- Open Low Willow
- Open Low Willow-Sedge Shrub Tundra
- Open Low Birch-Willow-Ericaceous Shrub
- Dryas Dwarf Shrub Tundra
- Cassiope Dwarf Shrub Tundra
- Ericaceous Dwarf Shrub Tundra
- Seral Herbs
- Moist Sedge-Shrub Tundra
- Tussock Tundra
- Wet Sedge-Willow Tundra
- Wet Sedge Meadow Tundra
- Fresh Grass Marsh
- Fresh Sedge Marsh
- Aquatic Algae
- Dune Complex
- Ice-poor Basin Wetland Complex
- Ice-rich Basin Wetland Complex
- Riverine Complex
- Fresh Water

Table 5. Areal extent of vegetation classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

	Area*		
Vegetation Type	Acres	Hectares	Percent
Aquatic Algae	160	65	0.1
Barren	1,129	457	0.8
Cassiope Dwarf Shrub Tundra	1,398	566	0.9
Closed Low Willow	274	111	0.2
Dryas Dwarf Shrub Tundra	3,936	1,593	2.6
Dune Complex	641	259	0.4
Ericaceous Dwarf Shrub Tundra	1,077	436	0.7
Fresh Grass Marsh	1,179	477	0.8
Fresh Sedge Marsh	4,455	1,803	3.0
Fresh Water	29,337	11,872	19.7
Mesic Shrub Birch-Willow-Ericaceous	3,006	1,217	2.0
Moist Sedge-Shrub Tundra	14,669	5,936	9.8
Old Basin Wetland Complex	6,624	2,681	4.4
Open Low Willow	3,118	1,262	2.1
Open Low Willow-Sedge Shrub Tundra	1,138	461	0.8
Open Tall Willow	44	18	0.0
Partially Vegetated	536	217	0.4
Riverine Complex	427	173	0.3
Seral Herbs	6	2	<0.1
Tussock Tundra	45,894	18,573	30.8
Wet Sedge Meadow Tundra	21,118	8,546	14.2
Wet Sedge-Willow Tundra	8,602	3,481	5.8
Young Basin Wetland Complex	342	139	0.2
Total	149,111	60,343	100.0

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

Table 6. Areal extent of disturbance classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

	Area*		
Disturbance	Acres	Hectares	Percent
Absent	148,460	60,079	99.6
Eolian (Wind)	365	148	0.2
Fluvial erosion/Channel migration	4	1	0.0
Fluvial (undifferentiated)	229	93	0.2
Gravel Pad	3	1	<0.1
Trail (undifferentiated)	51	21	<0.1
Total	149,111	60,343	100.0

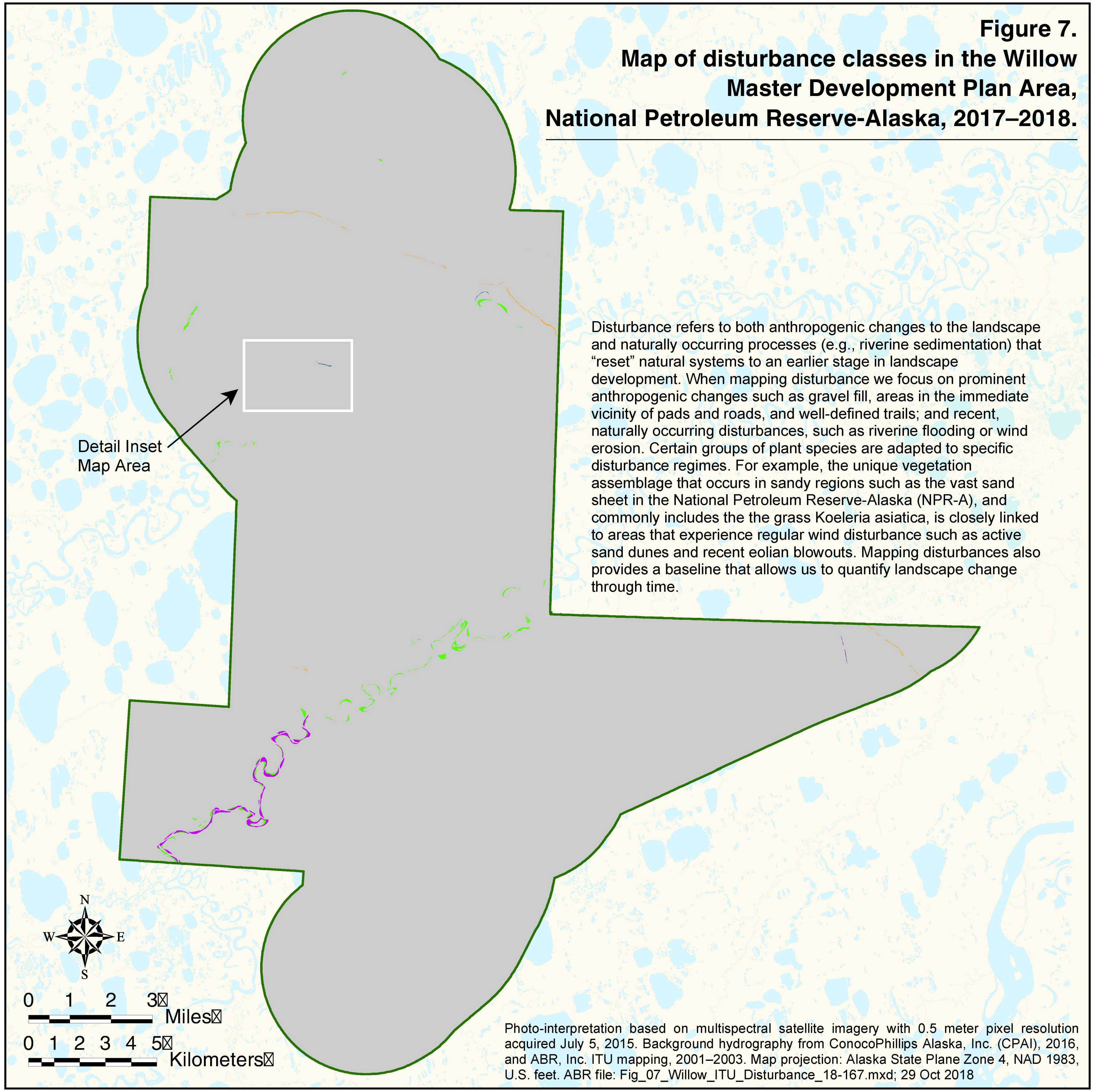
* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

Table 7. Areal extent of ecotypes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

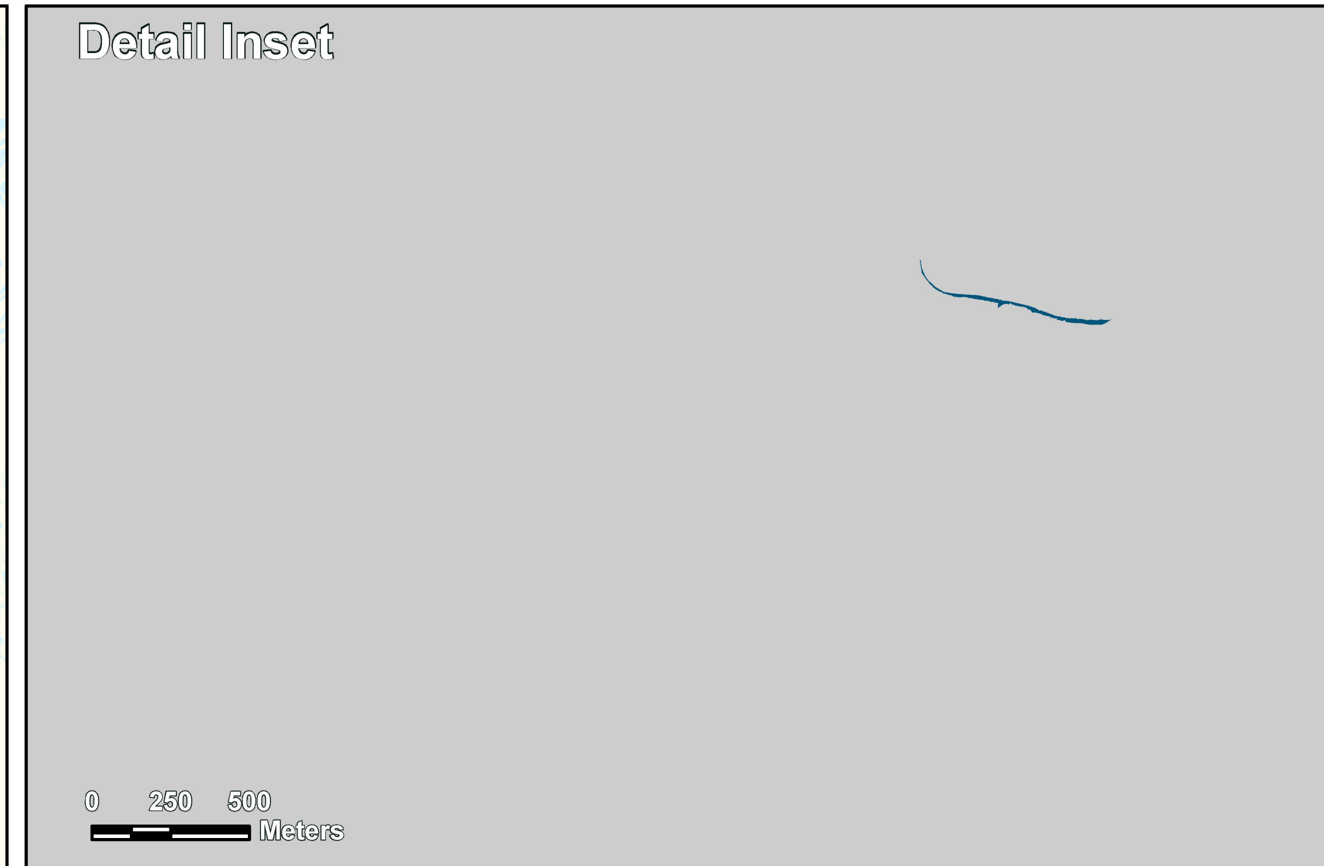
	Area*		
Ecotype	Acres	Hectares	Percent
Beaded Stream	226	91	0.2
Human Modified Dwarf Scrub	1	0	<0.1
Human Modified Moist Meadow	51	21	<0.1
Human Modified Wet Meadow	3	1	<0.1
Lacustrine Aquatic Barrens	157	64	0.1
Lacustrine Basin Complex	342	139	0.2
Lacustrine Grass Marsh	1,004	407	0.7
Lacustrine Moist Barrens	244	99	0.2
Lacustrine Moist Low Willow Shrub	256	104	0.2
Lacustrine Moist Sedge-Shrub Meadow	1,319	534	0.9
Lacustrine Sedge Marsh	891	361	0.6
Lacustrine Wet Sedge Meadow	4,005	1,621	2.7
Lower Perennial River	1,204	487	0.8
Lowland Basin Complex	6,624	2,681	4.4
Lowland Lake	25,924	10,491	17.4
Lowland Moist Birch-Willow-Ericaceous Low Shrub	181	73	0.1
Lowland Moist Low Willow Shrub	902	365	0.6
Lowland Moist Sedge-Shrub Meadow	12,584	5,092	8.4
Lowland Sedge Marsh	3,445	1,394	2.3
Lowland Wet Sedge Meadow	17,847	7,223	12.0
Lowland Wet Sedge-Willow Meadow	6,268	2,536	4.2
Riverine Complex	427	173	0.3
Riverine Dry Dryas Dwarf Shrub	279	113	0.2
Riverine Dune Complex	641	259	0.4
Riverine Grass Marsh	174	71	0.1
Riverine Lake	1,986	804	1.3
Riverine Moist Barrens	1,125	455	0.8
Riverine Moist Herb Meadow	6	2	<0.1
Riverine Moist Low Willow-Sedge Meadow	437	177	0.3
Riverine Moist Low Willow Shrub	1,553	628	1.0
Riverine Moist Sedge-Shrub Meadow	1,009	409	0.7
Riverine Moist Tall Willow Shrub	44	18	<0.1
Riverine Sedge Marsh	119	48	0.1
Riverine Wet Sedge Meadow	1,112	450	0.8
Riverine Wet Sedge-Willow Meadow	486	196	0.3
Upland Dry Barrens	296	120	0.2
Upland Dry Dryas Dwarf Shrub	3,462	1,401	2.3
Upland Dry Tall Willow Shrub	374	151	0.3
Upland Moist Birch-Willow-Ericaceous Dwarf Shrub	2,825	1,143	1.9
Upland Moist Cassiope Dwarf Shrub	1,397	565	0.9
Upland Moist Ericaceous Dwarf Shrub	1,027	416	0.7
Upland Moist Low Willow Shrub	1,009	408	0.7
Upland Moist Tussock Meadow	45,844	18,553	30.8
	149,111	60,343	100.0

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

Figure 7.
Map of disturbance classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



Disturbance refers to both anthropogenic changes to the landscape and naturally occurring processes (e.g., riverine sedimentation) that "reset" natural systems to an earlier stage in landscape development. When mapping disturbance we focus on prominent anthropogenic changes such as gravel fill, areas in the immediate vicinity of pads and roads, and well-defined trails; and recent, naturally occurring disturbances, such as riverine flooding or wind erosion. Certain groups of plant species are adapted to specific disturbance regimes. For example, the unique vegetation assemblage that occurs in sandy regions such as the vast sand sheet in the National Petroleum Reserve-Alaska (NPR-A), and commonly includes the the grass Koeleria asiatica, is closely linked to areas that experience regular wind disturbance such as active sand dunes and recent eolian blowouts. Mapping disturbances also provides a baseline that allows us to quantify landscape change through time.

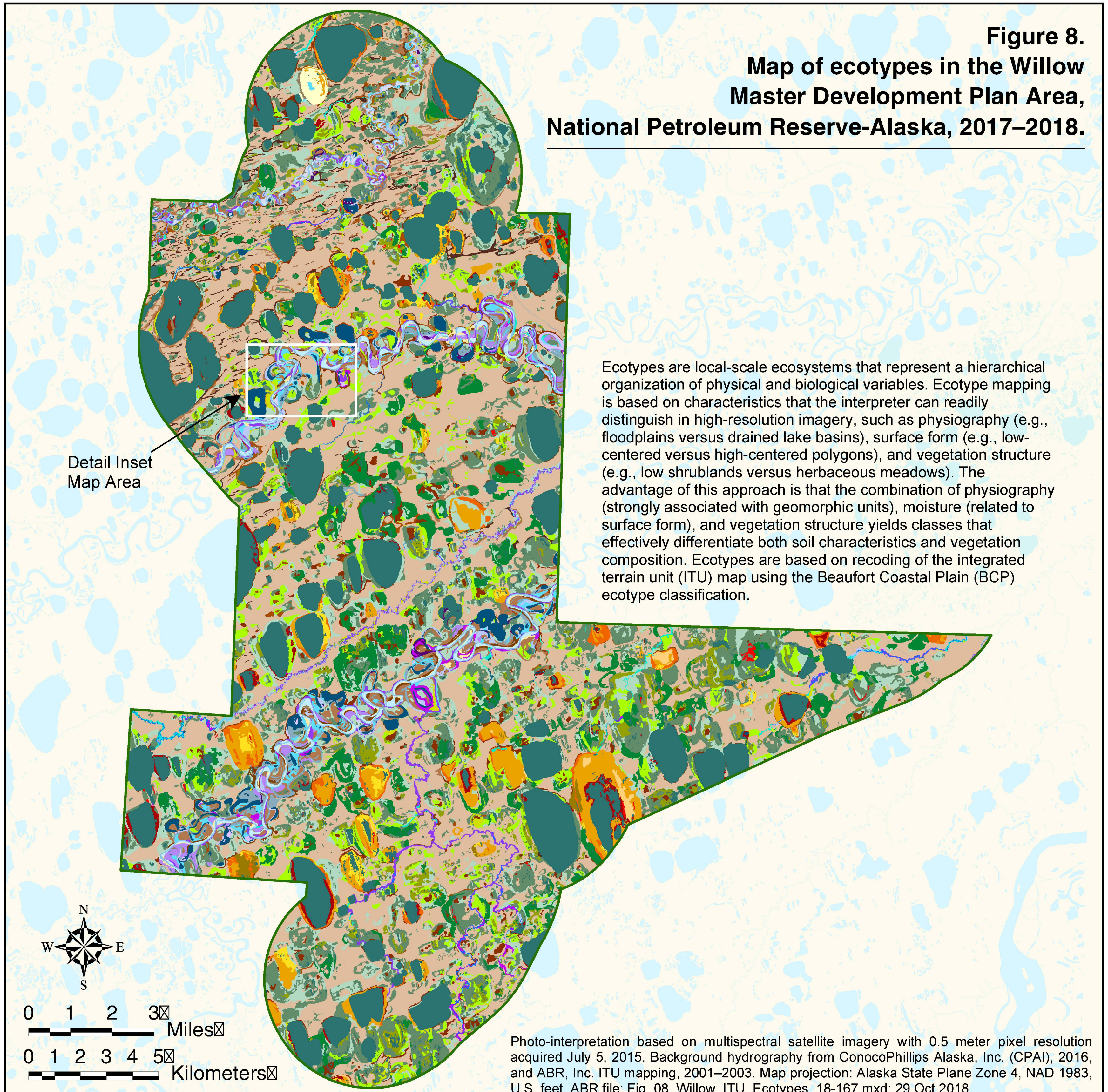


Disturbance Class

- Absent
- Eolian (Wind)
- Fluvial erosion/Channel migration
- Fluvial (undifferentiated)
- Trail (undifferentiated)
- Gravel Pad

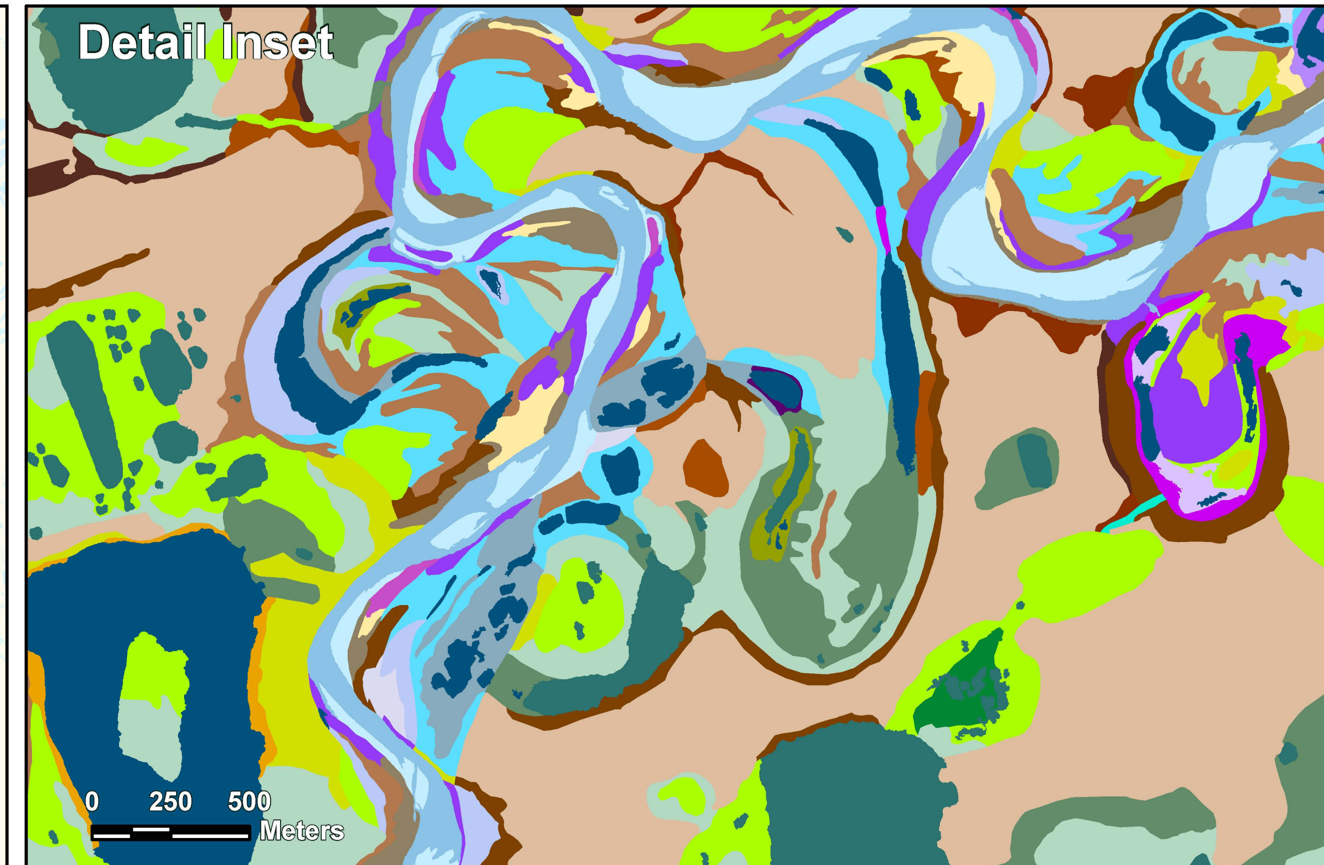
Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_07_Willow_ITU_Disturbance_18-167.mxd; 29 Oct 2018

Figure 8. Map of ecotypes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



Ecotypes are local-scale ecosystems that represent a hierarchical organization of physical and biological variables. Ecotype mapping is based on characteristics that the interpreter can readily distinguish in high-resolution imagery, such as physiography (e.g., floodplains versus drained lake basins), surface form (e.g., low-centered versus high-centered polygons), and vegetation structure (e.g., low shrublands versus herbaceous meadows). The advantage of this approach is that the combination of physiography (strongly associated with geomorphic units), moisture (related to surface form), and vegetation structure yields classes that effectively differentiate both soil characteristics and vegetation composition. Ecotypes are based on recoding of the integrated terrain unit (ITU) map using the Beaufort Coastal Plain (BCP) ecotype classification.

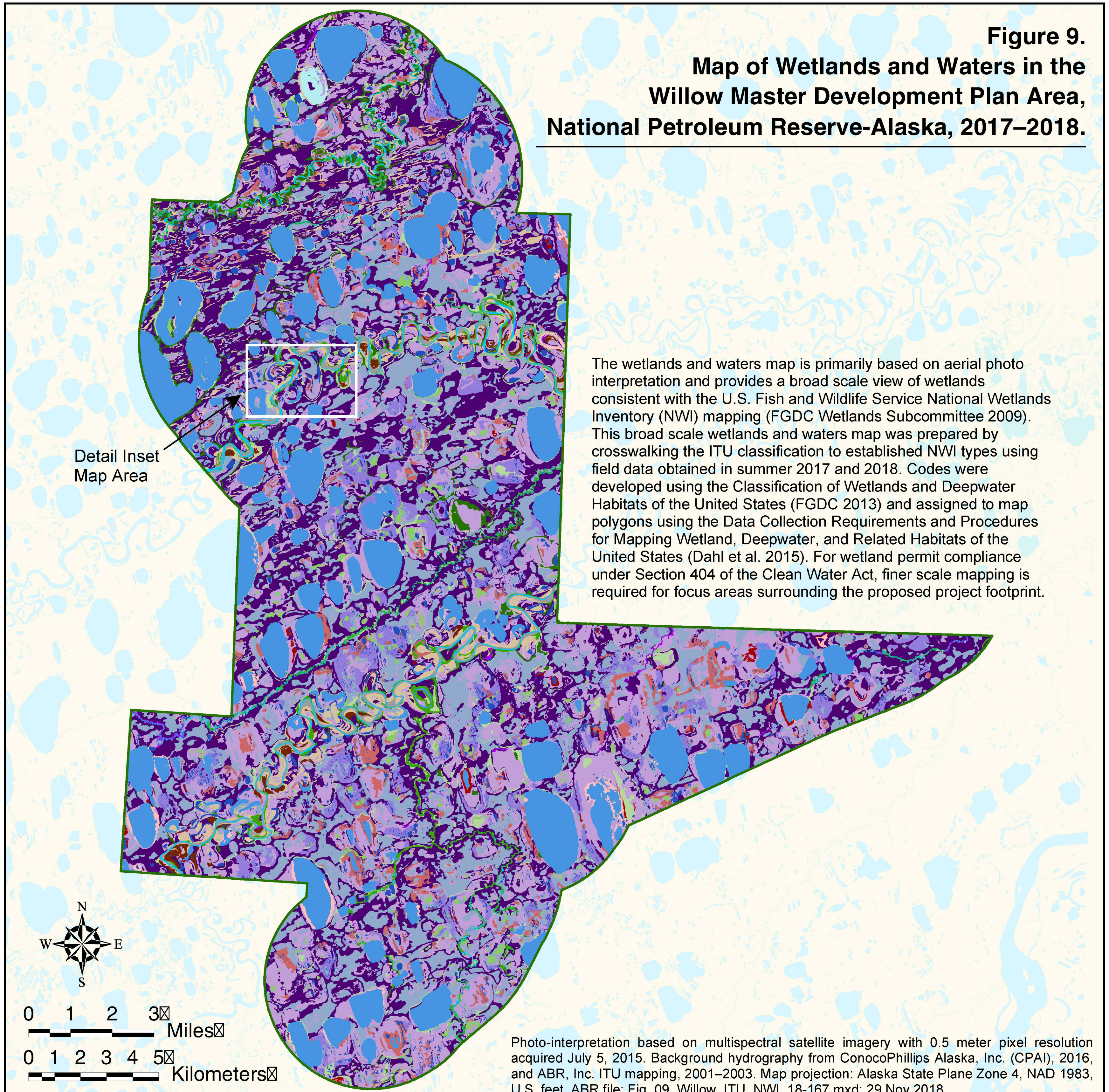
Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_08_Willow_ITU_Ecotypes_18-167.mxd; 29 Oct 2018



Map Ecotype Class

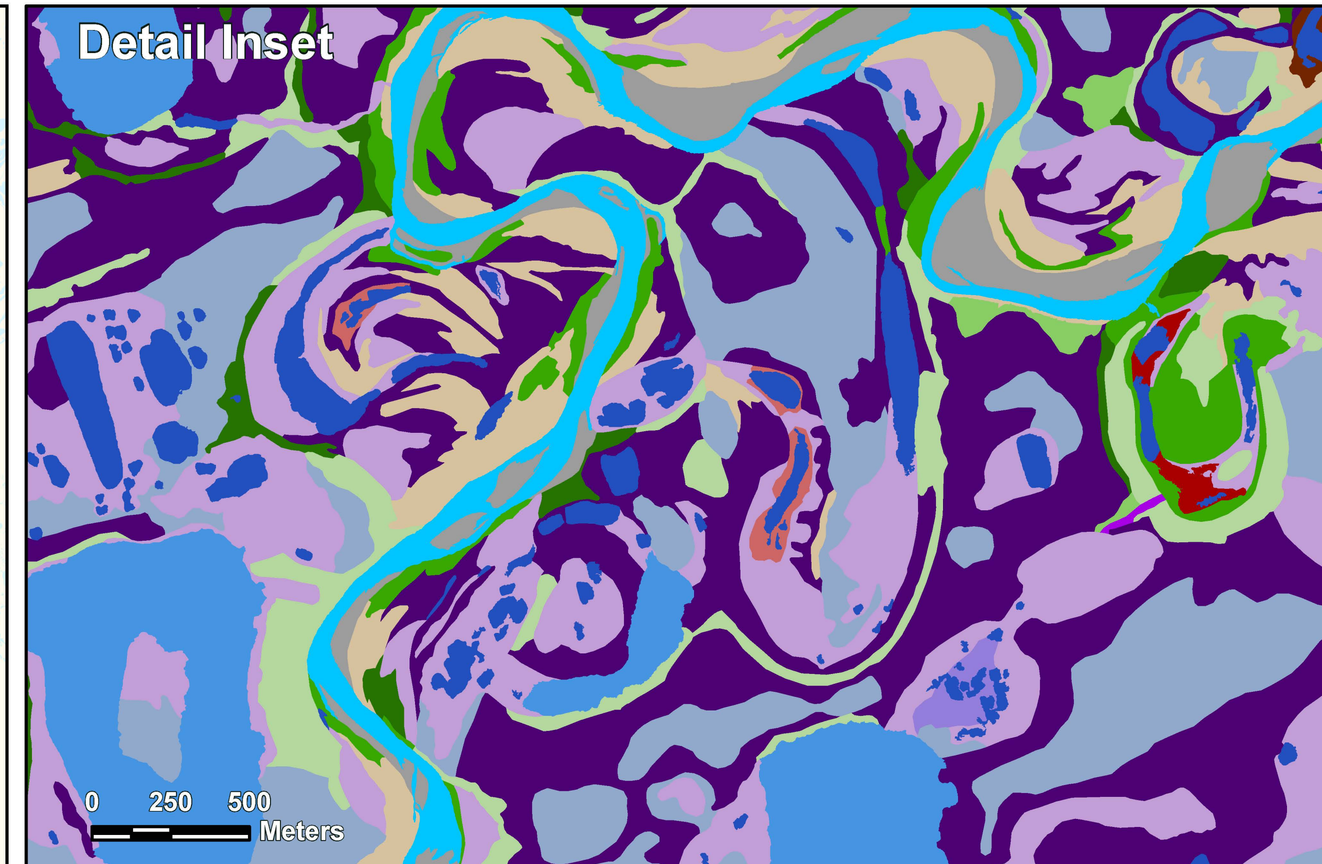
- Riverine Moist Barrens
- Riverine Moist Tall Willow Shrub
- Riverine Moist Low Willow Shrub
- Riverine Dry Dryas Dwarf Shrub
- Riverine Moist Herb Meadow
- Riverine Moist Low Willow-Sedge Meadow
- Riverine Moist Sedge-Shrub Meadow
- Riverine Wet Sedge-Willow Meadow
- Riverine Wet Sedge Meadow
- Riverine Grass Marsh
- Riverine Sedge Marsh
- Riverine Dune Complex
- Riverine Complex
- Riverine Lake
- Lacustrine Moist Barrens
- Lacustrine Aquatic Barrens
- Lacustrine Moist Low Willow Shrub
- Lacustrine Moist Sedge-Shrub Meadow
- Lacustrine Wet Sedge Meadow
- Lacustrine Grass Marsh
- Lacustrine Sedge Marsh
- Lacustrine Basin Complex
- Lowland Moist Low Willow Shrub
- Lowland Moist Sedge-Shrub Meadow
- Lowland Wet Sedge-Willow Meadow
- Lowland Wet Sedge Meadow
- Lowland Sedge Marsh
- Lowland Basin Complex
- Lowland Lake
- Lowland Moist Birch-Willow-Ericaceous Low Shrub
- Upland Dry Barrens
- Upland Dry Tall Willow Shrub
- Upland Moist Low Willow Shrub
- Upland Dry Dryas Dwarf Shrub
- Upland Moist Birch-Willow-Ericaceous Dwarf Shrub
- Upland Moist Ericaceous Dwarf Shrub
- Upland Moist Cassiope Dwarf Shrub
- Upland Moist Tussock Meadow
- Beaded Stream
- Lower Perennial River
- Human Modified Dwarf Scrub
- Human Modified Moist Meadow
- Human Modified Wet Meadow

Figure 9. Map of Wetlands and Waters in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



The wetlands and waters map is primarily based on aerial photo interpretation and provides a broad scale view of wetlands consistent with the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) mapping (FGDC Wetlands Subcommittee 2009). This broad scale wetlands and waters map was prepared by crosswalking the ITU classification to established NWI types using field data obtained in summer 2017 and 2018. Codes were developed using the Classification of Wetlands and Deepwater Habitats of the United States (FGDC 2013) and assigned to map polygons using the Data Collection Requirements and Procedures for Mapping Wetland, Deepwater, and Related Habitats of the United States (Dahl et al. 2015). For wetland permit compliance under Section 404 of the Clean Water Act, finer scale mapping is required for focus areas surrounding the proposed project footprint.

Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_09_Willow_ITU_NWI_18-167.mxd; 29 Nov 2018



Wetlands and Waters[1]

Waters

- L1UBH: Lacustrine Permanently Flooded Limnetic Unconsolidated Bottom Lake
- L2EM2H: Lacustrine Permanently Flooded Nonpersistent Emergent Marsh
- PUBH: Palustrine Permanently Flooded Unconsolidated Bottom Pond
- PUSC: Palustrine Seasonally Flooded Unconsolidated Shore
- R2UBH: Riverine Permanently Flooded Lower Perennial Stream
- R2USC: Riverine Seasonally Flooded Unsosolidated Bottom Bar

Wetlands

- PEM2H: Palustrine Permanently Flooded Nonpersistent Emergent Marsh
- PEM1H: Palustrine Permanently Flooded Persistent Emergent Marsh
- PEM1F: Palustrine Semipermanently Flooded Persistent Emergent Meadow
- PEM1/SS1F: Palustrine Semipermanently Flooded Persistent Emergent/Broad-leaved Deciduous Shrub Meadow
- PEM1/SS1D: Palustrine Continuously Saturated Persistent Emergent/Broad-leaved Deciduous Shrub Meadow
- PEM1/SS1E: Palustrine Seasonally Flooded/Saturated Persistent Emergent/Broad-leaved Deciduous Shrub Meadow
- PEM1/SS1B: Palustrine Saturated Persistent Emergent/Broad-leaved Deciduous Shrub Meadow
- PSS1D: Palustrine Continuously Saturated Broad-leaved Deciduous Shrub Scrub
- PSS1B: Palustrine Seasonally Saturated Broad-leaved Deciduous Shrub Scrub
- PSS3B: Palustrine Seasonally Saturated Broad-leaved Evergreen Scrub
- PSS1C: Palustrine Seasonally Flooded Broad-leaved Deciduous Shrub Scrub
- PSS1/USB: Palustrine Seasonally Saturated Broad-leaved Deciduous Shrub/Unconsolidated Shore

Uplands

- U: Upland

[1] Follows National Wetlands Inventory (NWI) map conventions and FGDC (2013) classification system.

Table 8. Areal extent of National Wetland Inventory classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

NWI Class	NWI Code	Area*		
		Acres	hectares	Percent
Waters				
Lacustrine Permanently Flooded Limnetic Unconsolidated Bottom Lake	L1UBH	23,447	9,489	15.7
Lacustrine Permanently Flooded Nonpersistent Emergent Marsh	L2EM2H	882	357	0.6
Palustrine Permanently Flooded Unconsolidated Bottom Pond	PUBH	4,495	1,819	3.0
Palustrine Seasonally Flooded Unconsolidated Shore	PUSC	244	99	0.2
Riverine Permanently Flooded Lower Perennial Stream	R2UBH	1,430	579	1
Riverine Seasonally Flooded Unconsolidated Shore	R2USC	1,125	455	1
Wetlands				
Palustrine Continuously Saturated Broad-leaved Deciduous Shrub Scrub	PSS1D	1,828	740	1.2
Palustrine Continuously Saturated Persistent Emergent/Broad-leaved Deciduous Shrub	PEM1/SS1D	24,971	10,105	16.8
Palustrine Permanently Flooded Nonpersistent Emergent Marsh	PEM2H	474	192	0.3
Palustrine Permanently Flooded Persistent Emergent Marsh	PEM1H	4,441	1,797	3.0
Palustrine Seasonally Flooded Broad-leaved Deciduous Shrub Scrub	PSS1C	2,034	823	1.4
Palustrine Seasonally Flooded-Saturated Persistent Emergent/Broad-leaved Deciduous	PEM1/SS1E	422	171	0.3
Palustrine Seasonally Saturated Broad-leaved Deciduous Shrub Scrub	PSS1B	3,938	1,594	2.6
Palustrine Seasonally Saturated Broad-leaved Deciduous Shrub/Unconsolidated Shore	PSS1/USB	640	259	0.4
Palustrine Seasonally Saturated Broad-leaved Evergreen Scrub	PSS3B	2,277	922	1.5
Palustrine Seasonally Saturated Persistent Emergent/Broad-leaved Deciduous Shrub	PEM1/SS1B	35,592	14,404	23.9
Palustrine Semipermanently Flooded Persistent Emergent/Broad-leaved Deciduous Shrub	PEM1/SS1F	6,934	2,806	4.7
Palustrine Semipermanently Flooded Persistent Emergent Meadow	PEM1F	29,721	12,028	19.9
Uplands				
Upland	U	4,217	1,707	2.8
Total		149,111	60,343	100.0
Aggregated Subtotals				
Waters	–	31,623	12,798	21.2
Wetlands	–	113,272	45,841	76.0
Uplands	–	4,217	1,707	2.8

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

study area. The PEM1/SS1D (16.8%) and PEM1/SS1B (23.9%) types are low open tussock-shrub tundra wetlands with varying amounts of surface water in thermokarst pits and low-lying troughs while PEM1F (19.9%) is wet sedge meadow found in low-lying areas of drained lake basins. Waters comprise 21.7% of the Willow study area, with L1UBH the most common NWI type (15.7%). These large limnetic systems are frequently deep, and can be connected either to rivers and streams or to isolated lakes. Uplands (non-jurisdictional) comprise 2.8% of the Willow study area. For this broad-scale mapping effort, it was important to limit the identification of non-jurisdictional uplands to areas that could both be reliably interpreted in the aerial imagery at the scale of mapping and consistently documented as uplands in the field data. Uplands were identified on active and inactive dunes in riparian corridors, and on abandoned dunes and bluffs on the eolian sand sheet.

4.4 LAND EVALUATION AND MODELING

4.4.1 WILDLIFE HABITAT

To develop the wildlife habitat classification, we aggregated the original ITUs into a reduced set of habitat classes. The habitat classification emphasized different ecological characteristics than did the ecotype classification, for example, it emphasizes several waterbody characteristics (e.g., presence of islands) that are important for nest-site selection by waterbirds. We also aggregated barrens, shrub types, and wet meadow classes in different ways than in the ecosystem classification. This classification was specifically designed for analyses of waterbird habitats; habitat classifications appropriate for other wildlife species or groups may emphasize other ecological attributes. The habitat classification system we used was originally developed in 1988 (Jorgenson et al. 1989) and has undergone only minor modifications. We maintained the use of the existing system in this study to facilitate comparison with habitat-use results from previous studies at the Colville River Delta (Wells et al. 2018, Johnson et al. 1997) and Prudhoe Bay (Johnson et al. 1990, Anderson et al. 1992, Murphy and Anderson 1993). In contrast to wildlife habitats, the ecotype classification placed greater emphasis on geomorphic and hydrologic linkages and was derived from analyses of the field data collected in 2017.

For the wildlife habitat classification, we reduced the original set of ITUs to 24 wildlife habitat classes (Appendix M): 14 terrestrial habitats, 6 waterbody habitats, and 4 habitat complexes. The most extensive habitats included Moist Tussock Tundra (30.8%), Patterned Wet Meadow (14.6%), Moist Sedge-Shrub Meadow (10.0%), and Deep Open Water without Islands (8.6%) (Table 9, Figure 10). Ten habitats were rare, each comprising <1% of the project area.

4.4.2 SOIL GREAT GROUPS

We classified 16 soil great group mapping classes, which were mapped in combination with water across the Willow study area (Appendix N). Two great group classes comprised over half of the mapping area (Table 10, Figure 11): Aquorthels-Haploturbels-Histoturbels (39.2%) and Historthels-Fibristels-Hemistels (16.2%). Other common great group classes included Aquorthels-Historthels-Fibristels (6.4%) and Aquorthels-Historthels-Fibristels-Water (4.7%). Five great groups were relatively rare, each covering <1% of the Willow project area.

4.4.3 SENSITIVE PLANT HABITAT SUITABILITY

Wells et al. (2018) developed a spatial model of the suitability of map ecotypes as habitat for sensitive plants. The model was based on the occurrences of sensitive plants in each ecotype recorded in the 2017 field data, ancillary datasets, herbarium records, and descriptions of habitat preferences from the scientific literature. Other than adding newly mapped ecotypes, no revisions to the model based on 2018 field data were required. The model indicates that the most suitable ecotypes for sensitive plants (i.e., those ecotypes assigned a suitability ranking of 2 or more), are Upland Dry Barrens, Riverine Moist Barrens, Upland Dry Tall Willow Shrub, and Riverine Dune Complex. These ecotypes occur predominantly along the Kalikpik River, Fish Creek, and Judy Creek and provide habitat for *Koeleria asiatica* and *Poa hartzii* ssp. *alaskana*. Ten ecotypes were assigned a suitability ranking of 1. Of these, Beaded Stream, Lacustrine Grass

Table 9. Areal extent of wildlife habitat classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Habitat Class	Area* Acres	Area* Hectares	Area* Percent
Barrens	1,666	674	1.1
Deep Open Water with Islands or Polygonized Margins	11,353	4,594	7.6
Deep Open Water without Islands	12,890	5,216	8.6
Dry Dwarf Shrub	3,741	1,514	2.5
Dry Tall Shrub	374	151	0.3
Dune Complex	641	259	0.4
Grass Marsh	1,179	477	0.8
Human Modified	54	22	<0.1
Moist Dwarf Shrub	5,249	2,124	3.5
Moist Herb Meadow	6	2	<0.1
Moist Low Shrub	4,338	1,755	2.9
Moist Sedge-Shrub Meadow	14,912	6,035	10.0
Moist Tall Shrub	44	18	<0.1
Moist Tussock Tundra	45,844	18,553	30.8
Nonpatterned Wet Meadow	7,949	3,217	5.3
Old Basin Wetland Complex	6,624	2,681	4.4
Patterned Wet Meadow	21,769	8,810	14.6
Riverine Complex	427	173	0.3
River or Stream	1,430	579	1.0
Sedge Marsh	4,455	1,803	3.0
Shallow Open Water with Islands or Polygonized Margins	1,153	466	0.8
Shallow Open Water without Islands	2,655	1,074	1.8
Tapped Lake with High-water Connection	17	7	<0.1
Young Basin Wetland Complex	342	139	0.2
Total	149,111	60,343	100.0

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

Marsh, and Riverine Grass Marsh provide habitat for *Pleuropogon sabinei*; Lacustrine Moist Barrens, Riverine Complex and Riverine Moist Herb Meadow provide habitat for *Poa hartzii* ssp. *alaskana*; and Lacustrine Moist Barrens, Riverine Moist Low Willow Shrub, Upland Dry Dryas Dwarf Shrub, Upland Moist Cassiope Dwarf Shrub, and Upland Moist Low Willow Shrub provide habitat for *Koeleria asiatica*. The sensitive plant habitat suitability crosswalk in Wells et al. (2018) was used to recode the ecotype map to prepare a map of sensitive plant habitat suitability (Table 11, Figure 12).

The frequency of occurrence and Alaska state rare ranking of sensitive plants are important factors that were not taken into consideration in the sensitive plant habitat suitability model. For instance, *Koeleria asiatica* was the most frequently encountered BLM sensitive plant in and adjacent to the Willow project area and also had the most herbarium records, whereas *Pleuropogon sabinei* had the lowest frequency of occurrence in and

Table 10. Areal extent of aggregated soil great group map classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

	Area*		
soil_great_group	Acres	Hectares	Percent
Aquorthels-Haploturbels-Histoturbels	58,428	23,645	39.2
Aquorthels-Historthels-Fibristels	9,503	3,846	6.4
Aquorthels-Historthels-Fibristels-Water	6,966	2,819	4.7
Aquorthels-Historthels-Histoturbels	1,598	647	1.1
Aquorthels-Psammorthels-Haplorthels	244	99	0.2
Gelaquents-Aquorthels-Haplorthels	1,575	637	1.1
Gelaquents-Aquorthels-Historthels	293	119	0.2
Gelifluvents-Psammorthels-Haplorthels	3,323	1,345	2.2
Gelifluvents-Quartzipsamments	1,131	458	1
Gelifluvents-Quartzipsamments-Historthels-Water	1,068	432	0.7
Historthels-Fibristels-Hemistels	24,115	9,759	16.2
Historthels-Histoturbels-Fibristels	1,083	438	0.7
Human Modified	54	22	<0.1
Psammorthels-Haplorthels-Histoturbels	4,861	1,967	3.3
Psammorthels-Psammoturbels-Haploturbels	4,859	1,966	3.3
Quartzipsamments-Psammorthels	670	271	0.5
Water	29,340	11,873	20.0
Total	149,111	60,343	100.0

* The total areas displayed may differ slightly from the total of the rounded addends due to floating point rounding errors in Microsoft Excel.

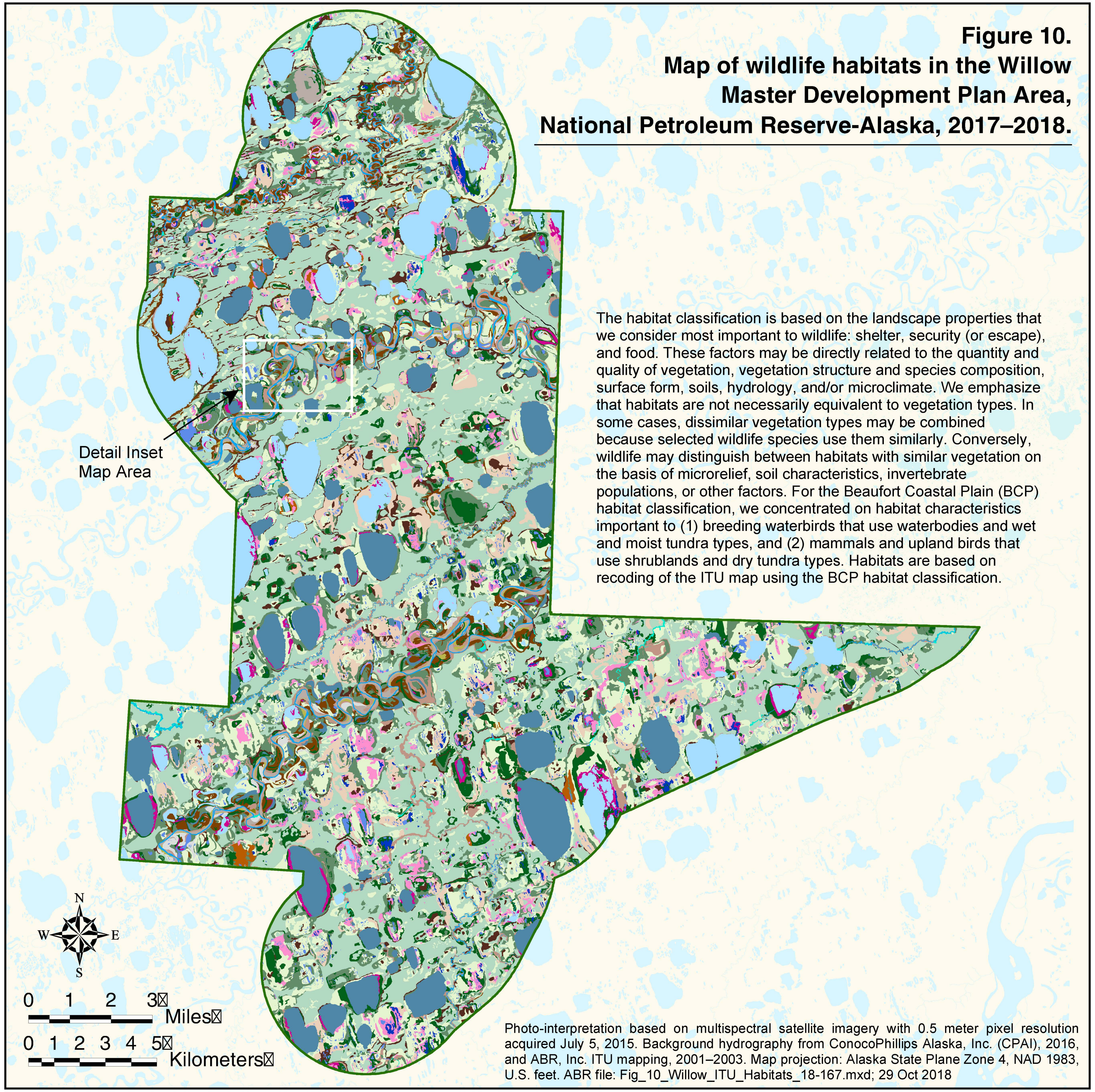
adjacent to the Willow project area, and the nearest records are from the Teshekpuk Lake area. Were the model to incorporate frequency of occurrence, the more commonly encountered sensitive plants could be down-weighted in the model, and the least commonly encountered up-weighted to adjust for the relative abundance of each species in the area of interest. Species weightings could also be related to the Alaska state rare ranking such that species with a higher state rare ranking (e.g., S1) could be weighed more than those with lower state rare ranks (e.g., S4) to better reflect the current conservation status of a species within Alaska.

4.5 MAP ACCURACY ASSESSMENT

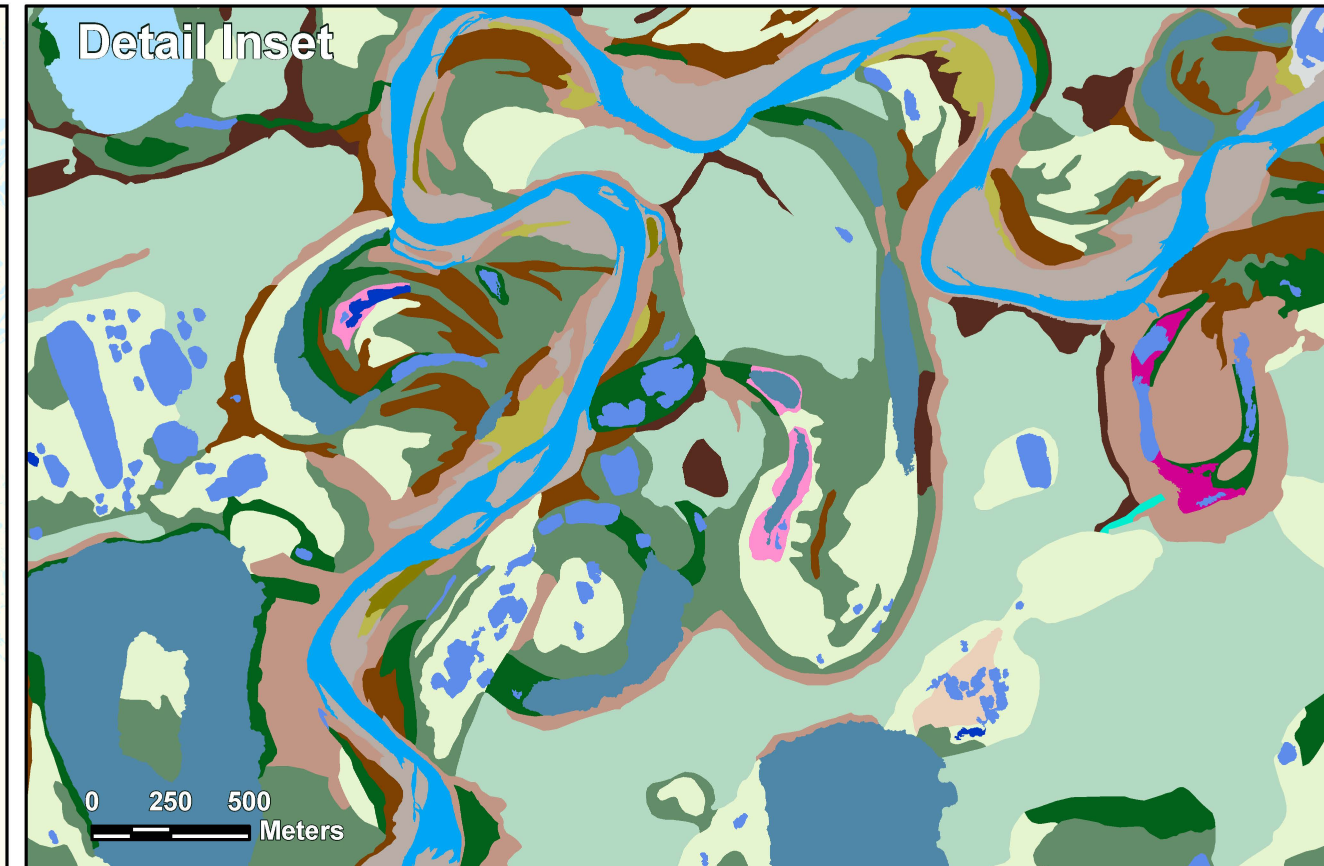
Accuracy assessments provide a metric by which to determine the reliability of a map product for end users (Stehman and Czaplewski 1998). The results of the 2017 wildlife habitat map accuracy assessment are presented in Table 12, which displays a cross tabulation between the wildlife habitat classes from the plot data (rows) and wildlife habitat map classes (columns). The cross-tabulation, termed a "confusion matrix," shows for each wildlife habitat class the number of times the plot data agrees with the mapping (cells along diagonal), and the number of disagreements between the plot data and mapping (off diagonal cells). We considered which of the various types of accuracy metrics to present and discuss here, including commission and omission errors, user's accuracy, and producer's accuracy. We decided to present the user's accuracy as it is both highly intuitive and the most applicable from the standpoint of the end user.

The overall accuracy for the 2017 wildlife habitat map is 66%, calculated as the total of number of agreements divided by the total number

Figure 10.
Map of wildlife habitats in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



The habitat classification is based on the landscape properties that we consider most important to wildlife: shelter, security (or escape), and food. These factors may be directly related to the quantity and quality of vegetation, vegetation structure and species composition, surface form, soils, hydrology, and/or microclimate. We emphasize that habitats are not necessarily equivalent to vegetation types. In some cases, dissimilar vegetation types may be combined because selected wildlife species use them similarly. Conversely, wildlife may distinguish between habitats with similar vegetation on the basis of microrelief, soil characteristics, invertebrate populations, or other factors. For the Beaufort Coastal Plain (BCP) habitat classification, we concentrated on habitat characteristics important to (1) breeding waterbirds that use waterbodies and wet and moist tundra types, and (2) mammals and upland birds that use shrublands and dry tundra types. Habitats are based on recoding of the ITU map using the BCP habitat classification.

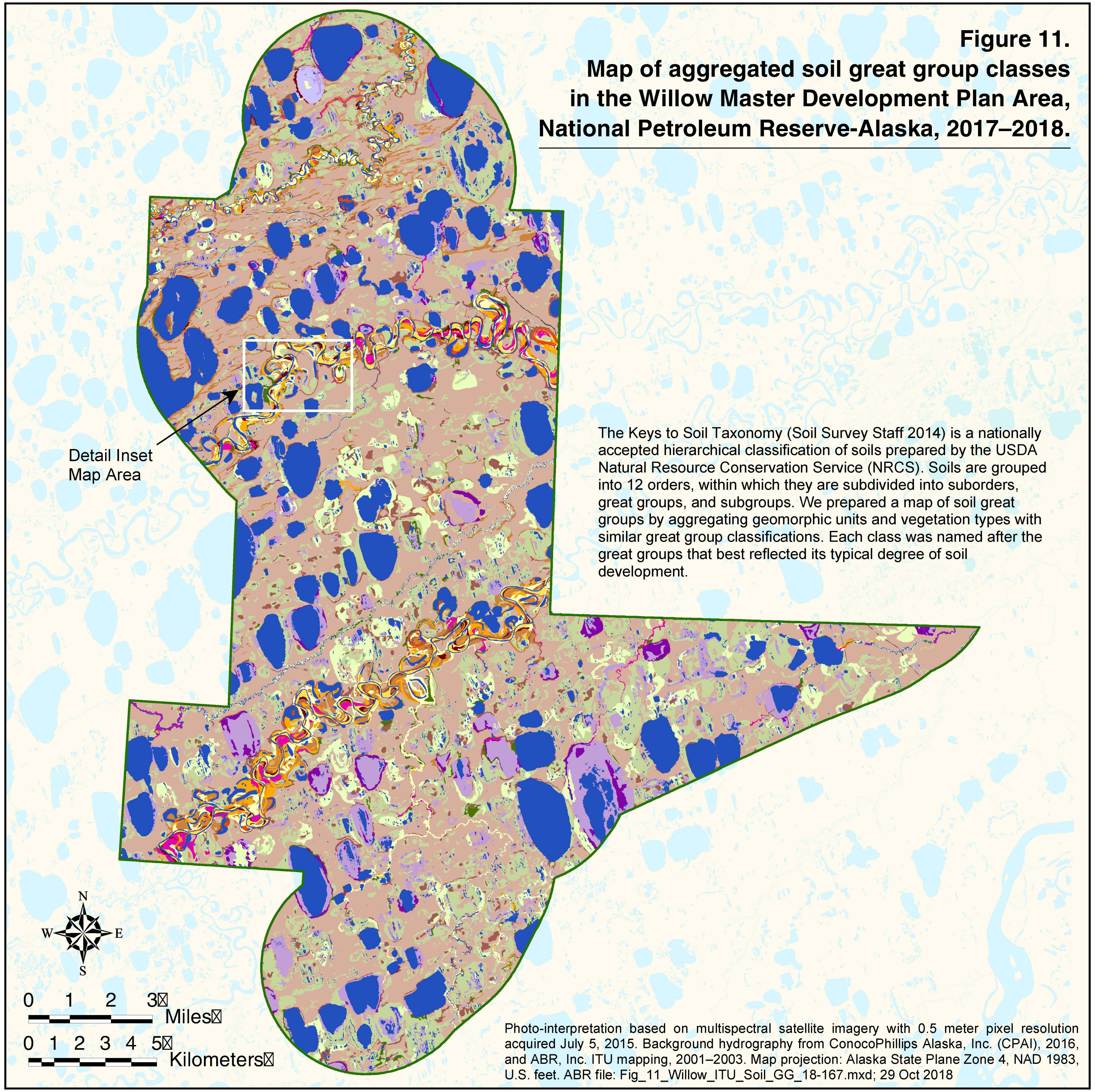


Wildlife Habitat Class

- Barrens
- Dry Tall Shrub
- Moist Tall Shrub
- Moist Low Shrub
- Dry Dwarf Shrub
- Moist Dwarf Shrub
- Moist Herb Meadow
- Moist Sedge-Shrub Meadow
- Moist Tussock Tundra
- Patterned Wet Meadow
- Nonpatterned Wet Meadow
- Grass Marsh
- Sedge Marsh
- Dune Complex
- Young Basin Wetland Complex
- Old Basin Wetland Complex
- Riverine Complex
- River or Stream
- Deep Open Water without Islands
- Deep Open Water with Islands or Polygonized Margins
- Shallow Open Water without Islands
- Shallow Open Water with Islands or Polygonized Margins
- Tapped Lake with High-water Connection
- Human Modified

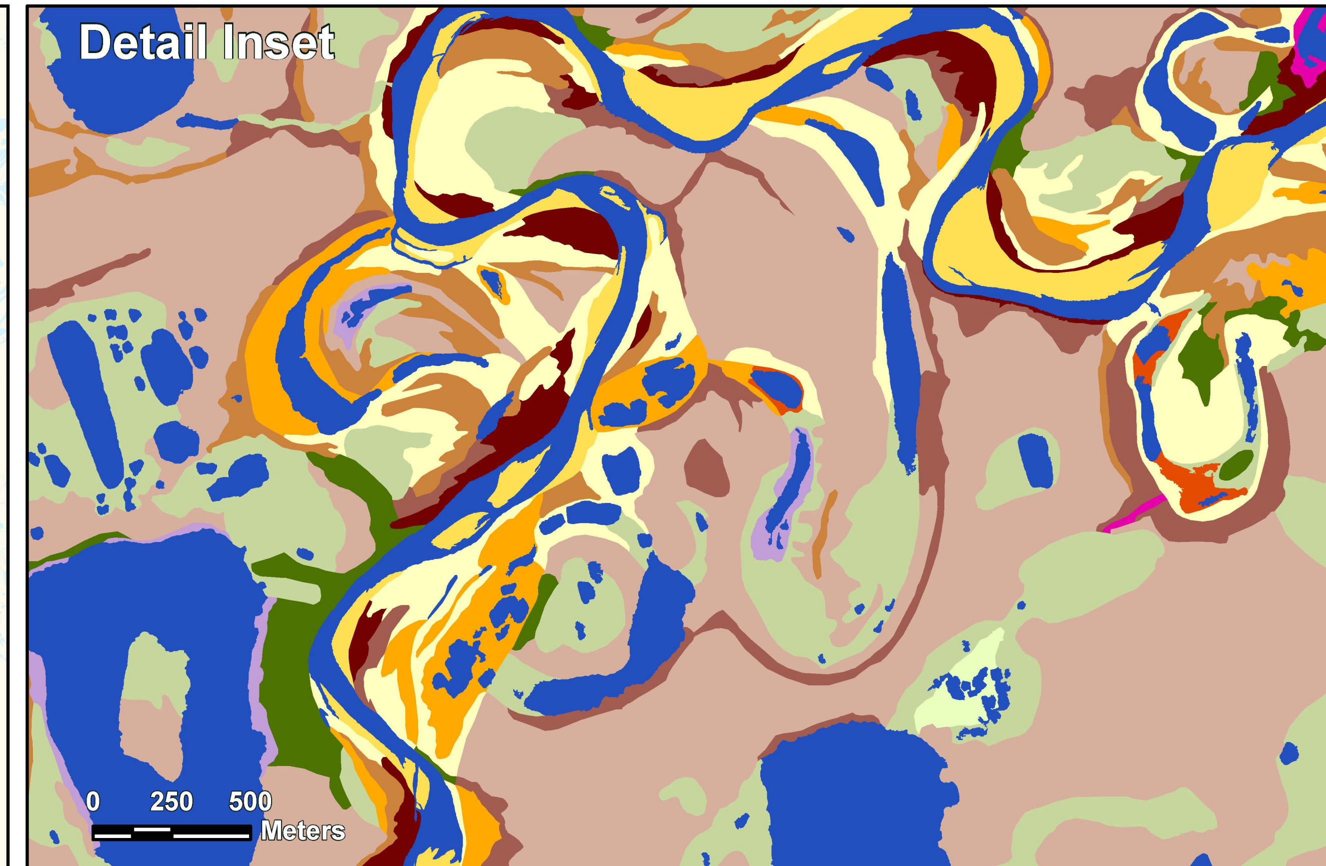
Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_10_Willow_ITU_Habitats_18-167.mxd; 29 Oct 2018

Figure 11.
Map of aggregated soil great group classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



The Keys to Soil Taxonomy (Soil Survey Staff 2014) is a nationally accepted hierarchical classification of soils prepared by the USDA Natural Resource Conservation Service (NRCS). Soils are grouped into 12 orders, within which they are subdivided into suborders, great groups, and subgroups. We prepared a map of soil great groups by aggregating geomorphic units and vegetation types with similar great group classifications. Each class was named after the great groups that best reflected its typical degree of soil development.

Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_11_Willow_ITU_Soil_GG_18-167.mxd; 29 Oct 2018



Soil Great Group

Upland Soils
- Quartzipsamments-Psammorthels
- Psammorthels-Psammoturbels-Haploturbels
- Psammorthels-Haplorthels-Histoturbels
- Aquorthels-Haploturbels-Histoturbels

Lowland Soils
- Historthels-Histoturbels-Fibristels
- Historthels-Fibristels-Hemistels

Lacustrine Soils
- Aquorthels-Psammorthels-Haplorthels
- Gelaquents-Aquorthels-Haplorthels
- Aquorthels-Historthels-Fibristels

Basin Complex Soils
- Aquorthels-Historthels-Fibristels-Water

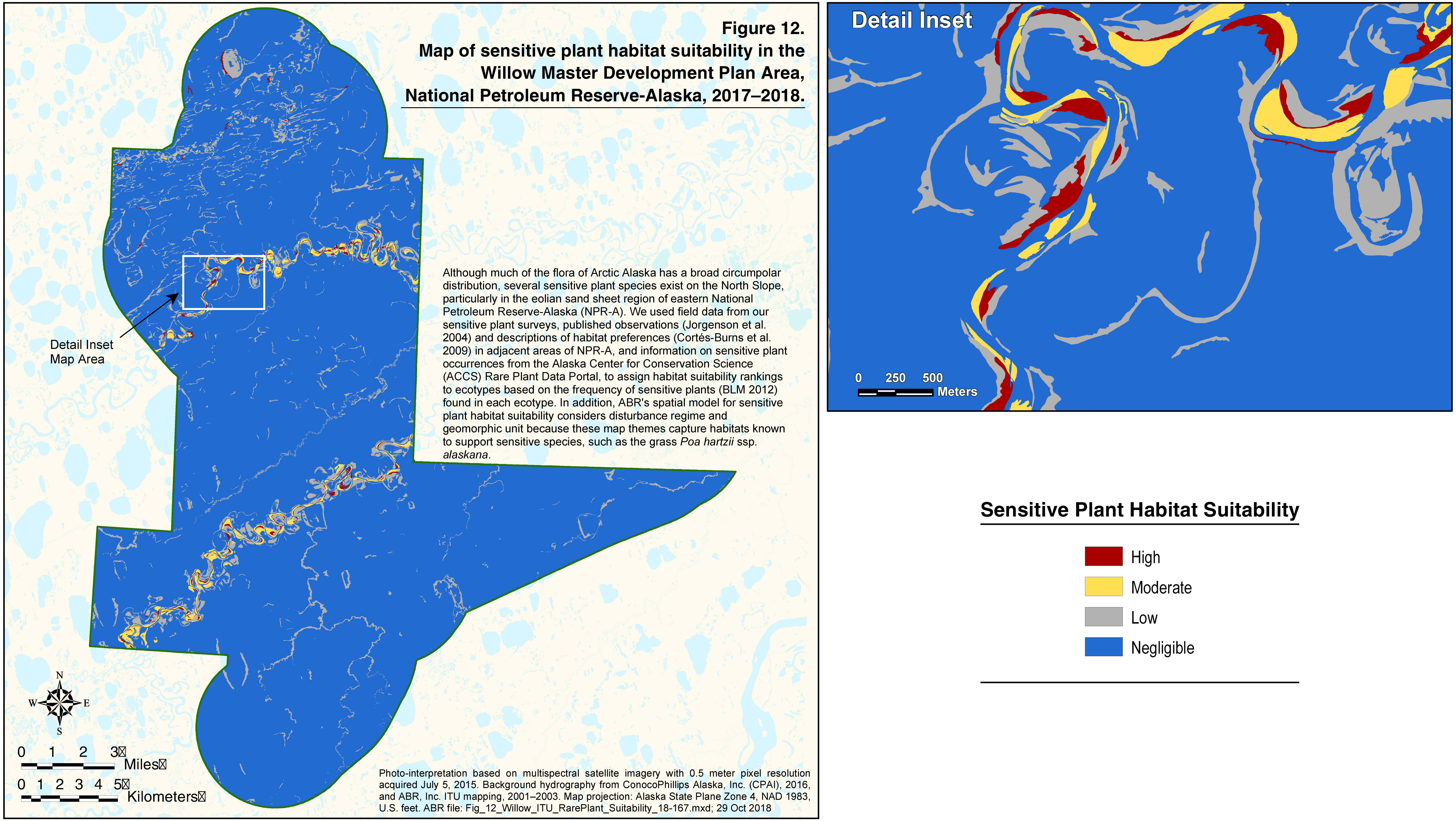
Riverine Soils
- Gelifluvents-Quartzipsamments
- Gelifluvents-Psammorthels-Haplorthels
- Gelaquents-Aquorthels-Historthels
- Aquorthels-Historthels-Histoturbels

Riverine Complex Soils
- Gelifluvents-Quartzipsamments-Historthels-Water

Water
- Water

Human Modified Soils
- Human Modified

Figure 12.
Map of sensitive plant habitat suitability in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.



Although much of the flora of Arctic Alaska has a broad circumpolar distribution, several sensitive plant species exist on the North Slope, particularly in the eolian sand sheet region of eastern National Petroleum Reserve-Alaska (NPR-A). We used field data from our sensitive plant surveys, published observations (Jorgenson et al. 2004) and descriptions of habitat preferences (Cortés-Burns et al. 2009) in adjacent areas of NPR-A, and information on sensitive plant occurrences from the Alaska Center for Conservation Science (ACCS) Rare Plant Data Portal, to assign habitat suitability rankings to ecotypes based on the frequency of sensitive plants (BLM 2012) found in each ecotype. In addition, ABR's spatial model for sensitive plant habitat suitability considers disturbance regime and geomorphic unit because these map themes capture habitats known to support sensitive species, such as the grass *Poa hartzii* ssp. *alaskana*.

Photo-interpretation based on multispectral satellite imagery with 0.5 meter pixel resolution acquired July 5, 2015. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_12_Willow_ITU_RarePlant_Suitability_18-167.mxd; 29 Oct 2018

Table 11. Factors used in characterizing the sensitive plant habitat suitability for each map ecotype in the Willow project area, National Petroleum Reserve-Alaska, 2017–2018.

Map Ecotype	Rare or sensitive plant encountered during 2017–2018 Field Surveys[2]	Sensitive plant encountered in ancillary field datasets[2]	Habitat description from herbarium records	Preferred sensitive plant habitat based on descriptions in literature	Rare Plant Sensitivity Rank[3]
Beaded Stream	1	0	0	1	**1**
Human Modified Dwarf Scrub	0	0	0	0	**0**
Human Modified Moist Meadow	0	0	0	0	**0**
Human Modified Wet Meadow	0	0	0	0	**0**
Lacustrine Aquatic Barrens	0	0	0	0	**0**
Lacustrine Basin Complex[1]	0	0	0	0	**0**
Lacustrine Grass Marsh	1	0	0	1	**1**
Lacustrine Moist Barrens	0	1	0	0	**1**
Lacustrine Moist Low Willow Shrub	0	0	0	0	**0**
Lacustrine Moist Sedge-Shrub Meadow	0	0	0	0	**0**
Lacustrine Sedge Marsh	0	0	0	0	**0**
Lacustrine Wet Sedge Meadow	0	0	0	0	**0**
Lower Perennial River	0	0	0	0	**0**
Lowland Basin Complex[1]	0	0	0	0	**0**
Lowland Lake	0	0	0	0	**0**
Lowland Moist Birch-Willow-Ericaceous Low Shrub	0	0	0	0	**0**
Lowland Moist Low Willow Shrub	0	0	0	0	**0**
Lowland Moist Sedge-Shrub Meadow	0	0	0	0	**0**
Lowland Sedge Marsh	0	0	0	0	**0**
Lowland Wet Sedge Meadow	0	0	0	0	**0**
Lowland Wet Sedge-Willow Meadow	0	0	0	0	**0**
Riverine Complex[1]	0	0	0	0	**1**
Riverine Dry Dryas Dwarf Shrub	0	0	0	0	**0**
Riverine Dune Complex[1]	0	0	0	0	**2**
Riverine Grass Marsh	1	0	0	1	**1**
Riverine Lake	0	0	0	0	**0**
Riverine Moist Barrens	2	1	1	1	**2**
Riverine Moist Herb Meadow	0	0	0	1	**1**

Table 11. Continued.

Map Ecotype	Rare or sensitive plant encountered during 2017–2018 Field Surveys[2]	Sensitive plant encountered in ancillary field datasets[2]	Habitat description from herbarium records	Preferred sensitive plant habitat based on descriptions in literature	Rare Plant Sensitivity Rank[3]
Riverine Moist Low Willow-Sedge Meadow	0	0	0	0	**0**
Riverine Moist Low Willow Shrub	1	0	0	0	**1**
Riverine Moist Sedge-Shrub Meadow	0	0	0	0	**0**
Riverine Moist Tall Willow Shrub	0	0	0	0	**0**
Riverine Sedge Marsh	0	0	0	0	**0**
Riverine Wet Sedge Meadow	0	0	0	0	**0**
Riverine Wet Sedge-Willow Meadow	0	0	0	0	**0**
Upland Dry Barrens	3	2	1	1	**3**
Upland Dry Dryas Dwarf Shrub	1	0	0	0	**1**
Upland Dry Tall Willow Shrub	3	2	1	1	**3**
Upland Moist Birch-Willow-Ericaceous Dwarf Shrub	0	0	0	0	**0**
Upland Moist Cassiope Dwarf Shrub	0	0	0	1	**1**
Upland Moist Ericaceous Dwarf Shrub	0	0	0	0	**0**
Upland Moist Low Willow Shrub	1	0	0	0	**1**
Upland Moist Tussock Meadow	0	0	0	0	**0**

1 Sensitivity ranking for complexes were assigned by taking the highest ranking for the ecotypes that are expect to occur within each and subtracting 1 to account for complexes where the ecotype(s) that provide habitat for the rare and sensitive may not be present.

2 Variable ranking: 0–No rare or sensitive plants encountered during field surveys, 1–One rare or sensitive plant species encountered, 2–Two rare or sensitive plant species encountered, 3–Three or more rare or sensitive plant species encountered.

3 Rare plant sensitivity rank based on the maximum ranking for each ecotype.

Table 12. Results of the Integrated Terrain Unit (ITU) 2017 wildlife habitat map accuracy assessment, Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

	Barrens	**Dry Dwarf Shrub**	**Dry Tall Shrub**	**Grass Marsh**	**Moist Dwarf Shrub**	**Moist Low Shrub**	**Moist Sedge-Shrub Meadow**	**Moist Tussock Tundra**	**Nonpatterned Wet Meadow**	**Patterned Wet Meadow**	**Sedge Marsh**	**Grand Total**	**User's Accuracy**	**Errors of Commission**	**Fuzzy Adjusted Correctly Classifid**	**Fuzzy User's Accuracy**
Barrens	3[a]											**3**	100%	0%	3.00	100%
Dry Dwarf Shrub		5[a]			[b]	[c]	1	1				**9**	56%	44%	5.75	64%
Dry Tall Shrub			4[a]		1							**4**	100%	0%	4.00	100%
Moist Dwarf Shrub		1[b]			[a]	1		1	1			**11**	64%	36%	7.50	68%
Moist Low Shrub	1	1[c]	[c]		[c]	17[a]		2	1			**25**	68%	32%	18.00	72%
Moist Sedge-Shrub Meadow		1 1					9[a]	[c]	[b]	[b]		**15**	60%	40%	11.00	73%
Moist Tussock Tundra		1			2	1	4[c] 2	[a] 1	2			**15**	53%	47%	9.00	60%
Nonpatterned Wet Meadow			2				8		8[a]		2[b]	**10**	80%	20%	9.00	90%
Patterned Wet Meadow		7					2[b]	1	1[b]	12[a]	[b]	**18**	67%	33%	14.50	81%
Sedge Marsh				1[b]			1		2[b]	2	6[a]	**10**	60%	40%	7.50	75%
Grand Total	**4**	**8**	**5**	**1**	**12**	**20**	**17**	**15**	**14**	**14**	**10**	**120**	**66%**	**34%**	**89.3**	**74%**

[a] plot data agrees with mapping
[b] 0.50 fuzzy membership
[c] 0.25 fuzzy membership

of plots. The accuracy of each habitat class is calculated by dividing the number of correctly classified plots by the total number of plots in each habitat class. This type of accuracy is termed the "User's Accuracy" and represents the probability that a given wildlife habitat map class accurately represents the actual habitat on the ground. The wildlife habitats with the highest accuracy include Barrens (100%), Dry Tall Shrub (100%), Nonpatterned Wet Meadow (80%), and Moist Low Shrub (68%). The wildlife habitat classes with the lowest accuracy include Moist Tussock Tundra (53%), Dry Dwarf Shrub (56%), Moist Sedge-Shrub Meadow (60%), and Sedge Marsh (60%). The confusion matrix in Table 12 also provides insights into which wildlife habitat classes were most commonly confused with each other. For instance, Tussock Tundra was most common confused with Moist Sedge-Shrub Meadow in the mapping. These 2 classes have a very similar spectral signature in the imagery and often intergrade with one another on the landscape. Moist Sedge-Shrub Meadow was also commonly confused with Nonpatterned and Patterned Wet Meadow. These three habitat classes are all dominated by sedges and differ mostly in soil moisture which fluctuates both intra- and inter-annually following patterns of precipitation. This can result in disparities if the soil moisture status at the time the plot data was collected differs from the soil moisture status at the time the satellite imagery base map was captured. These disparities may in part explain the frequent confusion between Moist Sedge-Shrub Meadow and Nonpatterned and Patterned Wet Meadow. One approach for addressing the variability in soil moisture, and a potential direction of future study, is a time-series analysis of surface water extent using Landsat imagery following methods described in Macander et al. (2016).

In addition to the traditional accuracy assessment presented above we also performed a fuzzy accuracy assessment (Woodcock and Gopal 2000). In a traditional accuracy assessment a plot is either in the correct map class (1) or not (0), i.e., an all or nothing approach. In a fuzzy accuracy assessment plots are assigned a membership value between 0 and 1, with higher values reflecting a greater similarity in vegetation physiognomy and structure between the plot and map class within which it is located. The assignment of partial credit based on similarities in vegetation between the plot data and mapping provides a more flexible treatment of map accuracy given the continuum of variation in vegetation across the landscape.

In the fuzzy accuracy assessment mis-classified plots that were assigned to the correct physiognomic class (e.g., shrub) were assigned a group membership of 0.25 (see footnotes in Table 12), while those in the correct structure class (e.g., dwarf shrub) were assigned a group membership of 0.50. The results of the fuzzy accuracy assessment are presented in Table 12. The overall fuzzy accuracy of the habitat map is 74%. The wildlife habitats with the highest fuzzy accuracy include Barrens (100%), Dry Tall Shrub (100%), Nonpatterned Wet Meadow (90%), and Patterned Wet Meadow (81%). The wildlife habitat classes with the lowest fuzzy accuracy include Moist Tussock Tundra (60%), Dry Dwarf Shrub (64%), Moist Dwarf Shrub (68%), and Moist Low Shrub (72%). Classes with the largest increases in accuracy using the fuzzy accuracy assessment compared to the traditional accuracy assessment were Moist Sedge-Shrub Meadow, Patterned Wet Meadow, and Sedge Marsh. These 3 classes were commonly confused with one another and differ mostly in soil moisture status. However, all 3 classes are dominated by sedges, as reflected in the higher fuzzy accuracy relative to the traditional accuracy assessment.

Below we frame the results of our accuracy assessment within the broader context of mapping in the Alaskan arctic by providing a short overview of the results of accuracy assessments from other mapping efforts. It should be noted that comparison of map accuracy assessment results between different mapping products is a challenge due to differences in mapping techniques, mapping scale, and classification methods. For instance, a map that differentiates a few generic vegetation classes will inherently have a higher overall accuracy than a map with a greater number of more detailed classes simply because the probability of selecting the correct class by chance is greater in the map with fewer classes. Thus the below discussion should be considered qualitative. Jorgenson et al. (2003), using the same ITU mapping methods and classification as described here, reported a 79% overall accuracy for the ecotype map in NPR-A directly east of the Willow project area. However their sample size was too low for a rigorous analysis of commission and omission errors, and they did not assess the habitat map. They reported confusion, similar to what we observed in this study, between Tussock Tundra and Moist Sedge-Shrub Meadow, and Moist Sedge-Shrub Meadow and Nonpatterned and Patterned Wet Meadow. They also reported that the ecotype class with the lowest accuracy was Lacustrine Grass Marsh, which is equivalent to the Grass Marsh wildlife habitat class. Jorgenson et al. (1994), in the landcover map for the coastal plain of the Arctic National Wildlife Refuge, reported a 50% overall accuracy for their map with 16 landcover classes. The largest source of error was in closely related landcover classes, i.e., those that occur directly adjacent to one another and/or that strongly intergrade across the landscape. When they aggregated similar vegetation types, which collapsed the map legend down to 13 classes, the map accuracy increased to 63%. Jorgenson et al. (2009) in the landcover mapping for the Arctic Network of National Parks assessed the accuracy of their ecotype mapping at between 65–80%. Lastly, several landcover maps for the North Slope do not provide accuracy assessments, including the North Slope Science Initiative landcover map (Ducks Unlimited 2013) and the vegetation mapping in the upper Kuparuk River region by Walker and Maier (2007). We conclude from the above discussion that the accuracy assessment results for the 2017 ITU habitat mapping in the Willow project area are reasonable and on par with other mapping projects in the Alaskan arctic.

Ideally the study design for a map accuracy assessment implements a probability sampling design (e.g., stratified random) so as to provide an adequate sample size, and statistically valid, unbiased assessment of accuracy. However, we were unable to implement a probability study design due to the reconnaissance nature of the field surveys, and the sample size was limited by the remote nature of the study area. Additionally, the sample size of plots available for the accuracy assessment was low relative to the total area mapped and the number of wildlife habitat map classes, and many classes were undersampled or not sampled at all. However, we were able to collect an adequate sample size in some of the most common wildlife habitat classes in the Willow study area (e.g., Moist Tussock Tundra). Despite these shortcomings, the results of the accuracy assessment do provide a measure of the reliability of, and some interesting and valuable insights into, the wildlife habitat map.

5 ERRATA

These corrections pertain to Wells et al. (2018).

- Page 8, 2nd column, line 16: We incorrectly reported that 16 ITU map-validation plots were sampled in 2017. The correct number of ITU map-validation plots sampled in 2017 is 17.
- Page 23, 1st column, lines 20–21: We incorrectly reported that Jorgenson et al. (2004) and Macander et al. (2013) documented 4 occurrences of *Koeleria asiatica* and 6 occurrences of *Poa hartzii* ssp. *alaskana* in and adjacent to the Willow project area. The correct number of occurrences is 6 for *Koeleria asiatica* and 7 for *Poa hartzii* ssp. alaskana.
- Page 60, Table 5: The wrong description appears for several of the geomorphic unit classes. Geomorphic units with incorrect descriptions are: Meander Fine Active Channel Deposit, Meander Fine Inactive Channel Deposit, Meander Inactive Channel Deposit, Meander Inactive Overbank Deposit, Old Alluvial Terrace, and Solifluction Deposit. Please see Appendix F in this report for the correct descriptions for these classes.
- The ITU code combination Wlsi/W/Xbo was incorrectly assigned the NWI class PEM1/SS1F. Subsequent data submittals have corrected the NWI class to PUBH.

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Appendix A. List of vascular and non-vascular plant taxa found in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018, including the frequency of occurrence, Alaska Center for Conservation Science State and global ranking and federal listings for rare and sensitive taxa, and the AKEPIC invasiveness ranking for non-native taxa.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Algae	*Nostoc pruniforme* C. Agardh	nospru	1				
Deciduous Shrubs	*Arctous alpina* (L.) Nied	arcalp1	19				
	Arctous rubra (Rehder & E.H. Wilson) Nakai	arcrub1	79				
	Betula nana L.	betnan	106				
	Salix alaxensis (Andersson) Coville	salala	28				
	Salix arbusculoides Andersson	salarb	1				
	Salix arctica Pall.	salarc	40				
	Salix fuscescens Andersson	salfus	16				
	Salix glauca L.	salgla	55				
	Salix hastata L.	salhas	5				
	Salix niphoclada Rydb.	salnip1	10				
	Salix ovalifolia Trautv.	salova	9				
	Salix phlebophylla Andersson	salphl	43				
	Salix polaris Wahlenb.	salpol1	2				
	Salix pulchra Cham.	salpul1	164				
	Salix reticulata L.	salret	154				
	Salix richardsonii Hook.	salric1	104				
	Salix rotundifolia Trautv.	salrot	12				
	Vaccinium uliginosum L.	vaculi	38				
Evergreen Shrubs	*Andromeda polifolia* L.	andpol	25				
	Cassiope tetragona (L.) D. Don	castet	157				
	Dryas integrifolia M. Vahl	dryint	153				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Evergreen Shrubs, continued	*Empetrum nigrum* L.	empnig	24				
	Ledum decumbens (Aiton) Lodd. ex Steud.	leddec	106				
	Rhododendron lapponicum (L.) Wahlenb.	rholap	2				
	Vaccinium vitis-idaea L.	vacvit	117				
Ferns and allies	*Equisetum arvense* L.	equarv	36				
	Equisetum palustre L.	equpal	1				
	Equisetum scirpoides Michx.	equsci	9				
	Equisetum variegatum Schleich.	equvar	17				
	Equisetum variegatum ssp. *variegatum* Schleich. ex F. Weber & D. Mohr	equvar1	13				
	Lycopodium selago L.	lycsel	11				
Forbs	*Achillea borealis* Bong	achbor	1				
	Androsace chamaejasme Host ssp. *lehmannia* (Spreng.) Hult.	andcha	1				
	Androsace chamaejasme Wulfen ex Host	andcha1	9				
	Androsace septentrionalis L.	andsep	1				
	Anemone drummondii var. *lithophila* (Rydberg) C. L. Hitchcock	anelit	2				
	Anemone narcissiflora L.	anenar	1				
	Anemone parviflora Michx.	anepar	15				
	Anemone richardsonii Hook.	aneric	6				
	Antennaria friesiana (Trautv.) Ekman	antfri	1				
	Antennaria monocephala DC.	antmon	1				
	Arabidopsis lyrata (L.) O'Kane & Al-Shehbaz	aralyr2	2				
	Arabis arenicola (Richards.) Gelert var pubescens	araare	2				
	Armeria maritima (Mill.) Willd.	armmar1	14				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Forbs, continued	*Armeria maritima* (Mill.) Willd. ssp. *arctica* (Cham.) Hult.	armmar	1				
	Arnica frigida C.A. Mey.	arnfri	4				
	Arnica lessingii Greene	arnles	1				
	Artemisia arctica Less.	artarc2	4				
	Artemisia arctica Less. ssp. *arctica*	artarc1	2				
	Artemisia borealis Pall.	artbor	8				
	Artemisia glomerata Ledeb.	artglo1	1				
	Artemisia tilesii Ledeb.	arttil	5				
	Aster sibiricus L.	astsib	14				
	Astragalus aboriginum Richards.	astabo	1				
	Astragalus alpinus L.	astalp1	21				
	Astragalus eucosmus B.L. Rob.	asteuc1	1				
	Astragalus umbellatus Bunge	astumb	24				
	Braya humilis (C.A. Mey.) B.L. Robins. ssp. *richardsonii* (Rydb.) Hultén	braric	1				
	Bupleurum triradiatum Adams ssp. *arcticum* (Regel) Hult.	buptri	2				
	Caltha palustris L.	calpal1	17				
	Cardamine hyperborea O.E. Schulz	carhyp	23				
	Cardamine pratensis L.	carpra3	8				
	Castilleja caudata (Pennell) Rebr.	cascau	9				
	Castilleja elegans Malte	casele	3				
	Castilleja raupii Pennell	casrau	1				
	Cerastium beeringianum Cham. & Schlecht.	cerbee1	3				
	Cerastium jenisejense Hult.	cerjen	1				
	Chrysanthemum bipinnatum L.	chrbip	17				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Forbs, continued	*Chrysanthemum integrifolium* Richards.	chrint	3				
	Draba alpina L.	draalp	1				
	Draba caesia Adams	dracae	1				
	Draba cinerea Adams	dracin	6				
	Draba fladnizensis Wulf	drafla	1				
	Draba hirta L.	drahir	1				
	Draba lactea Adams	dralac	1				
	Draba lonchocarpa Rydb.	dralon2	1				
	Epilobium latifolium L.	epilat	11				
	Erigeron eriocephalus J. Vahl	erieri	2				
	Erigeron humilis Graham	erihum	3				
	Erigeron peregrinus (Pursh) Greene	eriper	1				
	Eritrichium arenosum D.F. Murray	eriare1	1				
	Eritrichium aretioides (Cham.) DC.	eriare	1				
	Eritrichium splendens Kearney	erispl	1				
	Eutrema edwardsii R. Br.	eutedw	15				
	Gentiana propinqua Richardson	genpro	16				
	Gentiana propinqua Richards. ssp. *arctophila* (Griseb.) Hult.	genarc	1				
	Gentiana prostrata Haenke	genpro2	3				
	Hedysarum alpinum L.	hedalp	5				
	Hedysarum hedysaroides (L.) Schinz & Thell.	hedhed	1				
	Hippuris vulgaris L.	hipvul	12				
	Lupinus arcticus S. Wats.	luparc	11				
	Melandrium apetalum (L.) Fenzl.	melape	6				
	Melandrium taimyrense Tolm.	meltai	1				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Forbs, continued	*Menyanthes trifoliata* L.	mentri	2				
	Minuartia arctica (Stev.) Aschers. & Graebn	minarc	4				
	Minuartia obtusiloba (Rydb.) House	minobt	5				
	Minuartia rubella (Wahlenb.) Graebn.	minrub	7				
	Myriophyllum spicatum ssp. *exalbescens* (Fern.) Hult.	myrsib	1				
	*Oxyria digyn*a (L.) Hill	oxydig	4				
	Oxytropis borealis DC.	oxybor	13				
	Oxytropis campestris (L.) DC.	oxycam	1	S3S4Q	GNR	BLM Watch	
	Oxytropis campestris (L.) DC. ssp. *jordalii* (Porsild) Hultén	oxyjor	1				
	Oxytropis deflexa (Pall.) DC.	oxydef	5				
	Oxytropis nigrescens (Pall.) Fisch.	oxynig	6				
	Oxytropis nigrescens ssp. *bryophila* (Greene) Hultén	oxybry1	1				
	Oxytropis viscida Nutt.	oxyvis	4				
	Papaver macounii Greene	papmac	19				
	Parnassia kotzebuei Cham. & Schlecht.	parkot	11				
	Parnassia palustris L.	parpal	5				
	Parrya nudicaulis (L.) Regel	parnud	10				
	Pedicularis capitata Adams.	pedcap	51				
	Pedicularis kanei Durand	pedkan1	3				
	Pedicularis labradorica Wirsing	pedlab	1				
	Pedicularis langsdorffii Fisch.	pedlan3	6				
	Pedicularis lapponica L.	pedlap	10				
	Pedicularis parviflora J.E. Sm. ssp. *pennellii* (Hult.) Hult.	pedpen	1				
	Pedicularis parviflora Sm.	pedpar1	5				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Forbs, continued	*Pedicularis sudetica* Willd.	pedsud	63				
	Pedicularis verticillata L.	pedver	3				
	Petasites frigidus (L.) Franchet	petfri	17				
	Pinguicula vulgaris L.	pinvul1	1				
	Pinguicula vulgaris L. ssp. *vulgaris*	pinvul2	1				
	Polemonium acutiflorum Willd.	polacu	10				
	Polygonum bistorta L. ssp. *plumosum* (Small) Hult.	polbis	92				
	Polygonum viviparum L.	polviv	85				
	Potamogeton filiformis Pers.	potfil	2				
	Potamogeton subsibiricus Hagstr.	potsub	1	S3S4	G3G4	BLM Watch	
	Potentilla hyparctica Malte	pothyp	1				
	Potentilla palustris (L.) Scop.	potpal	20				
	Pyrola asarifolia Michx.	pyrasa	76				
	Pyrola grandiflora Radius	pyrgra	17				
	Pyrola grandiflora var. *canadensis*	pyrgra2	2				
	Pyrola secunda L.	pyrsec1	18				
	Ranunculus confervoides (E. Fries) E. Fries	rancon	1				
	Ranunculus gmelinii DC.	rangme1	5				
	Ranunculus lapponicus L.	ranlap	3				
	Ranunculus pallasii Schlect.	ranpal	10				
	Rubus chamaemorus L.	rubcha	20				
	Sagina intermedia Fenzl	sagint	3				
	Sagina saginoides (L.) Karst.	sagsag	2				
	Saussurea angustifolia (Willd.) DC.	sauang	95				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Forbs, continued	*Saxifraga bronchialis* L.	saxbro	1				
	Saxifraga cernua L.	saxcer	5				
	Saxifraga flagellaris Willd.	saxfla	1				
	Saxifraga foliolosa R. Br.	saxfol	4				
	Saxifraga hieraciifolia Waldst. & Kit.	saxhie	13				
	Saxifraga hirculus L.	saxhir	52				
	Saxifraga nivalis L.	saxniv	2				
	Saxifraga oppositifolia L.	saxopp	3				
	Saxifraga punctata L.	saxpun	7				
	Saxifraga punctata L. ssp. *nelsoniana* (D. Don) Hult.	saxnel	16				
	Senecio atropurpureus (Ledeb.) Fedtsch.	senatr	47				
	Senecio atropurpureus (Ledeb.) Fedtsch. ssp. *frigidus* (Richards.) Hult.	senfri	1				
	Senecio congestus (R. Br.) DC.	sencon1	1				
	Senecio lugens Richardson	senlug	4				
	Senecio resedifolius Less.	senres	4				
	Silene acaulis L.	silaca	23				
	Silene acaulis (L.) ssp. *subacaulescens* (F. N. Williams) Hultén	silsub	1				
	Sparganium angustifolium Michx.	spaang	2				
	Sparganium hyperboreum Laest.	spahyp	2				
	Stellaria crassifolia Ehrh.	stecra	2				
	Stellaria laeta Richards.	stelae	1				
	Stellaria longifolia Muhl. ex Willd.	stelon2	2				
	Stellaria longipes Goldie	stelon1	79				
	Taraxacum alaskanum Rydb.	tarala	1				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Forbs, continued	*Taraxacum phymatocarpum* J. Vahl	tarphy	1				
	Tofieldia coccinea Richards.	tofcoc	10				
	Tofieldia pusilla (Michx.) Pers.	tofpus	40				
	Triglochin maritima L.	trimar	4				
	Utricularia intermedia Hayne	utrint	1				
	Utricularia vulgaris L. ssp. *macrorhiza* (LeConte) Clauson	utrvul	7				
	Valeriana capitata Pall.	valcap	24				
	Valeriana sitchensis Bong.	valsit	1				
	Wilhelmsia physodes (Fisch.) McNeill	wilphy	4				
	Zygadenus elegans Pursh	zygele	2				
Grasses	*Alopecurus magellanicus* Lam.	alomag	4				
	Anthoxanthum arcticum Veldkamp	antarc	5				
	Anthoxanthum hirtum (Schrank) Y. Schouten & Veldkamp	anthir	2				
	Anthoxanthum monticola ssp. *alpinum* (Sw. ex Willd.) Soreng	antalp1	39				
	Arctagrostis latifolia (R. Br.) Griseb.	arclat	76				
	Arctagrostis latifolia (R. Br.) Griseb. ssp. *latifolia*	arclat1	45				
	Arctophila fulva (Trin.) Anderss.	arcful	15				
	Bromus pumpellianus Scribn.	bropum3	17				
	Bromus pumpellianus ssp. *pumpellianus* Scribn.	bropum5	1				
	Calamagrostis purpurascens R. Br.	calpur2	5				
	Calamagrostis purpurascens R. Br. ssp. *purpurascens*	calpur	5				
	Deschampsia cespitosa (L.) P. Beauv.	desces	7				
	Deschampsia cespitosa (L.) P. Beauv. ssp. *cespitosa*	desces1	2				
	Deschampsia sukatschewii (Popl.) Roshev.	dessuk	3				
	Dupontia fisheri R. Br.	dupfis1	10				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Grasses, continued	*Elymus alaskanus* (Scribn. & Merr.) A. Loeve ssp. *alaskanus*	elyala	3				
	Elymus macrourus (Turcz. ex Steud.) Tzvelev	elymac	3				
	Festuca altaica Trin.	fesalt	1				
	Festuca brachyphylla Schult. & Schult. f.	fesbra	15				
	Festuca rubra L.	fesrub	17				
	Festuca rubra ssp. *arctica* (Hack.) Govor.	fesarc	6				
	Koeleria asiatica Domin	koeasi	28	S3	G4	BLM Sensitive	
	Leymus mollis (Trin.) Pilg.	leymol1	1				
	Phleum alpinum L.	phlalp	1				
	Pleuropogon sabinei R. Br.	plesab	1	S1S2	G4G5	BLM Sensitive	
	Poa alpina L.	poaalp1	9				
	Poa arctica R. Br.	poaarc	48				
	Poa arctica ssp. *arctica* R. Br.	poaarc1	27				
	Poa arctica ssp. *lanata* (Scribn. & Merr.) Soreng	poalan1	9				
	Poa glauca M. Vahl.	poagla	3				
	Poa glauca ssp. *glauca* Vahl	poagla1	7				
	Poa hartzii ssp. *alaskana* Soreng	poaala	4	S1S2	G3G4T 1T2	BLM Sensitive	
	Poa pratensis L.	poapra	1				
	Poa pratensis ssp. *alpigena* (Lindm.) Hiitonen	poaalp3	3				
	Poa sublanata Reverd.	poasub	10	S2	GNR		
	Trisetum spicatum (L.) K. Richt.	trispi1	16				
Lichens	*Alectoria nigricans* (Ach.) Nyl.	alenig	4				
	Alectoria ochroleuca (Hoffm.) A. Massal.	aleoch	4				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Lichens, continued	*Bryocaulon divergens* (Ach.) Kärnefelt	brydiv	7				
	Cetraria islandica (L.) Ach.	cetisl	32				
	Cladina mitis (Sandst.) Hustich	clamit	15				
	Cladina rangiferina (L.) Nyl.	claran	2				
	Cladina stygia (Fr.) Ahti	clasty	1				
	Cladonia bellidiflora (Ach.) Schaerer	clabel	1				
	Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel	clachl	7				
	Cladonia digitata (L.) Hoffm.	cladig	1				
	Cladonia gracilis (L.) Willd.	clagra	3				
	Cladonia uncialis (L.) F. H. Wigg.	claunc	12				
	Dactylina arctica (Richardson) Nyl.	dacarc	85				
	*Flavocetraria cucullat*a (Bellardi) Kärnefelt & Thell	flacuc	110				
	Flavocetraria nivalis (L.) Kärnefelt & Thell	flaniv	32				
	Icmadophila ericetorum (L.) Zahlbr.	icmeri	8				
	Lobaria linita (Ach.) Rabenh.	loblin	8				
	Masonhalea richardsonii (Hook.)	masric	38				
	Nephroma arcticum (L.) Torss.	neparc	8				
	Parmelia saxatilis (L.) Ach.	parsax	1				
	Peltigera aphthosa (L.) Willd.	pelaph	43				
	Peltigera canina (L.) Willd.	pelcan	9				
	Peltigera leucophlebia (Nyl.) Gyelnik	pelleu	1				
	Sphaerophorus fragilis (L.) Pers.	sphfra	1				
	Sphaerophorus globosus (Hudson) Vainio	sphglo	18				
	Stereocaulon alpinum Laurer ex Funck	stealp	1				
	Stereocaulon tomentosum Fr.	stetom	5				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Lichens, continued	*Thamnolia vermicularis* (Sw.) Ach. ex Schaerer	thaver	64				
Liverworts	*Aneura pinguis* (L.) Dumort.	anepin	2				
	Blepharostoma trichophyllum (L.) Dum.	bletri	11				
	Pleurocladula albescens (Hook.) Grolle	plealb	7				
	Ptilidium ciliare (L.) Hampe	pticil	42				
	Sauteria alpina (Nees) Nees	saualp	1				
Mosses	*Abietinella abietina* (Hedw.) Fleisch.	abiabi	1				
	Aulacomnium acuminatum (Lindb. & Arnell) Kindb.	aulacu	6				
	Aulacomnium palustre (Hedw.) Schwaegr.	aulpal	48				
	Aulacomnium turgidum (Wahlenb.) Schwaegr.	aultur	105				
	Brachythecium mildeanum (Schimp.) Schimp. ex Milde	bramil	3				
	Brachythecium turgidum (Hartm.) Kindb.	bratur	1				
	Bryum caespiticium Hedw.	brycae	2				
	Bryum pseudotriquetrum (Hedw.) Gaertn. et al.	brypse	5				
	Calliergon cordifolium (Hedw.) Kindb.	calcor	1				
	Calliergon giganteum (Schimp.) Kindb.	calgig	1				
	Calliergon richardsonii (Mitt.) Kindb. in Warnst.	calric	15				
	Calliergon trifarium (F. Weber & D. Mohr) Kindb.	caltri	4				
	Campylium stellatum (Hedw.) C.E.O. Jensen var. *arcticum* (R.S. Williams) Sav.-Ljub.	camarc1	16				
	Campylium stellatum (Hedw.) C.Jens.	camste1	3				
	Catoscopium nigritum (Hedw.) Brid.	catnig	6				
	Ceratodon purpureus (Hedw.) Brid.	cerpur	2				
	Cinclidium arcticum B.S.G.	cinarc	1				
	Cinclidium latifolium Lindb.	cinlat1	5				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Mosses, continued	*Cinclidium stygium* Sw. in Schrad.	cinsty	3				
	Cirriphyllum cirrosum (Schwaegr.) Grout	circir	2				
	Dicranella cerviculata (Hedw.) Schimp.	diccer	1				
	Dicranella subulata (Hedw.) Schimp.	dicsub	2				
	Dicranum acutifolium (Lindb. et H.Arnell) C. Jens.	dicacu	4				
	Dicranum brevifolium (Lindb.) Lindb.	dicbre	1				
	Dicranum elongatum Schleich. ex Schwaegr.	dicelo	41				
	Dicranum fuscescens Turner.	dicfus	2				
	Dicranum groenlandicum Brid.	dicgro	5				
	Dicranum scoparium Hedw.	dicsco	2				
	Distichium capillaceum (Hedw.) B.S.G.	discap	5				
	Ditrichum flexicaule (Schwaegr.) Hampe	ditfle	4				
	Drepanocladus aduncus (Hedw.) Warnst. s.l.	dreadu	4				
	Drepanocladus brevifolius (Lindb.) Warnst.	drebre	6				
	Encalypta rhaptocarpa Schwägr.	encrha	1				
	Eurhynchium pulchellum (Hedw.) Jenn.	eurpul	1				
	Hamatocaulis vernicosus (Mitt.) Hedenaes	hamver	17				
	Hylocomium splendens (Hedw.) B.S.G.	hylspl	99				
	Hypnum bambergeri Schimp.	hypbam	1				
	Hypnum lindbergii Mitt.	hyplin	1				
	Hypnum plicatulum (Lindb.) Jaeg.	hyppli	3				
	Leptobryum pyriforme (Hedw.) Wils.	leppyr1	2				
	Limprichtia revolvens (Sw.) Loeske	limrev	12				
	Loeskypnum badium (Hartm.) Paul	loebad	1				
	Meesia longiseta Hedw.	meelon	1				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Mosses, continued	*Meesia triquetra* (Richter) Aongstr.	meetri	14				
	Meesia uliginosa Hedw.	meeuli	2				
	Oncophorus virens (Hedw.) Brid.	oncvir	1				
	Oncophorus wahlenbergii Brid.	oncwah	26				
	Orthothecium chryseum (Schwägr.) Schimp.	ortchr1	3				
	Paludella squarrosa (Hedw.) Brid.	palsqu	2				
	Philonotis fontana (Hedw.) Brid.	phifon	3				
	*Plagiomnium ellipticum (*Brid.) T.Kop.	plaell	2				
	Pleurozium schreberi (Brid.) Mitt.	plesch	4				
	Pohlia wahlenbergii (Web. & Mohr) Andrews	pohwah	2				
	Polytrichastrum alpinum (Hedw.) G.L.Sm.	polalp	4				
	Polytrichum commune Hedw.	polcom	8				
	Polytrichum commune Hedw. var. *jensenii* (I. Hagen) Mönk.	poljen1	5				
	Polytrichum hyperboreum R.Br.	polhyp	10				
	Polytrichum juniperinum Hedw.	poljun	15				
	Polytrichum strictum Brid.	polstr	17				
	Pseudocalliergon turgescens (T.Jens.) Loeske	psetur	6				
	Ptilium crista-castrensis (Hedw.) De Not.	pticri	1				
	Racomitrium lanuginosum (Hedw.) Brid.	raclan	18				
	Rhytidium rugosum (Hedw.) Kindb.	rhyrug	34				
	Sanionia uncinata (Hedw.) Loeske	sanunc	8				
	Scorpidium scorpioides (Hedw.) Limpr.	scosco	35				
	Sphagnum andersonianum R.E. Andrus	sphand	1				
	Sphagnum arcticum Flatberg & Frisvoll	spharc	2				
	Sphagnum balticum (Russ.) Russ. ex C.Jens.	sphbal	2				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Mosses, continued	*Sphagnum fimbriatum* Wils.	sphfim	10				
	Sphagnum fuscum (Schimp.) Klinggr.	sphfus	7				
	Sphagnum girgensohnii Russ.	sphgir	8				
	Sphagnum nitidum Warnst.	sphnit	4				
	Sphagnum orientale Sav.-Ljub.	sphori	3				
	Sphagnum rubellum Wils.	sphrub	2				
	Sphagnum russowii Warnst.	sphrus	1				
	Sphagnum squarrosum Crome	sphsqu	9				
	Sphagnum steerei R.E. Andrus	sphste	3				
	Sphagnum subsecundum Nees ex Sturm	sphsub	1				
	Sphagnum warnstorfii Russ.	sphwar	26				
	Splachnum sphaericum Hedw	splsph	1				
	Splachnum vasculosum Hedw.	splvas	1				
	Tetraplodon mnioides (Hedw.) Bruch & Schimp. in B.S.G.	tetmni	6				
	Tetraplodon paradoxus (R. Br.) I. Hagen	tetpar	4				
	Timmia austriaca Hedw.	timaus	1				
	Timmia norvegica Zett.	timnor1	1				
	Tomentypnum nitens (Hedw.) Loeske	tomnit	71				
	Tortella tortuosa (Hedw.) Limpr.	tortor	2				
	Tortula ruralis (Hedw.) Gaertn., Meyer, & Scherb.	torrur	1				
Rushes	*Juncus arcticus* Willd.	junarc	14				
	Juncus biglumis L.	junbig	10				
	Juncus castaneus Sm.	juncas1	5				
	Juncus triglumis L.	juntri	7				
	Luzula arctica Blytt.	luzarc1	3				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Rushes, continued	*Luzula arcuata* ssp. *arcuata* (Wahlenb.) Sw.	luzarc3	1				
	Luzula arcuata (Wahlenb.) Sw.	luzarc2	2				
	Luzula confusa Lindeb.	luzcon	31				
	Luzula multiflora (Retz.) Lej.	luzmul	19				
	Luzula parviflora (Ehrh.) Desv.	luzpar	1				
	Luzula tundricola Gorodk.	luztun	17				
	Luzula wahlenbergii Rupr.	luzwah1	4				
	Luzula wahlenbergii Rupr. ssp. *wahlenbergii*	luzwah	1				
Sedges	*Carex amblyorhyncha* Krecz.	caramb	7				
	Carex aquatilis Wahlenb.	caraqu1	180				
	Carex atrofusca Schkuhr	caratr1	24				
	Carex bicolor All.	carbic	4				
	Carex bigelowii Torr.	carbig	144				
	Carex capillaris L.	carcap1	26				
	Carex capitata Soland. In L.	carcap2	2				
	Carex chordorrhiza Ehrh.	carcho	38				
	Carex holostoma Drej.	carhol	3				
	Carex krausei Boeck.	carkra	26				
	Carex maritima Gunn.	carmar	8				
	Carex membranacea Hook.	carmem	15				
	Carex misandra R. Br.	carmis	11				
	Carex nardina E. Fries	carnar	3				
	Carex rariflora (Wahlenb.) Smith	carrar	16				
	Carex rotundata Wahlenb.	carrot	39				
	Carex rupestris All.	carrup	5				

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Number of Occurrences	Alaska Rare Rank	Global Rank	Federal Listing	AKEPIC Invasiveness Rank
Sedges, continued	*Carex saxatilis* L. ssp. *laxa* (Trautv.) Kalela	carsax	44				
	Carex scirpoidea Michx.	carsci	37				
	Carex vaginata Tausch	carvag	23				
	Carex williamsii Britt.	carwil	8				
	Eriophorum angustifolium Honck.	eriang1	156				
	Eriophorum angustifolium Honck. ssp. s*ubarcticum* (V. Vassiljev) Hult.	eriang	4				
	Eriophorum callitrix Cham.	erical	1				
	Eriophorum russeolum E. Fries *var albidum* Nyl.	erialb	1				
	Eriophorum russeolum Fries	erirus	8				
	Eriophorum scheuchzeri Hoppe	erisch	24				
	Eriophorum vaginatum L.	erivag	126				
	Kobresia myosuroides (Vill.) Fiori & Paol.	kobmyo	8				
	Kobresia sibirica Turcz.	kobsib	8				
	Kobresia simpliciuscula (Wahlenb.) Mack.	kobsim	2				

Appendix B. National Plants database synonymy table for ABR taxa that are either not accepted or not recognized for plant species found in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Taxon	Code	USDA Synonym	USDA Code
Achillea borealis Bong	achbor	*Achillea millefolium* var. *borealis* L.	ACMIB
Androsace chamaejasme Host ssp. *lehmannia* (Spreng.) Hult.	andcha	no match	n/a
Anemone drummondii var. *lithophila* (Rydberg) C. L. Hitchcock	anelit	*Anemone lithophila* Rydb.	ANLI4
Anthoxanthum arcticum Veldkamp	antarc	*Hierochloe pauciflora* R. Br.	HIPA3
Anthoxanthum hirtum (Schrank) Y. Schouten & Veldkamp	anthir	*Hierochloe hirta* ssp. *hirta* (Schrank) Borbás	HIHIH2
Arabidopsis lyrata (L.) O'Kane & Al-Shehbaz	aralyr2	*Arabis lyrata* L.	ARLY2
Arabis arenicola (Richards.) *Gelert var pubescens*	araare	*Arabis* media N. Busch	ARME13
Arctous alpina (L.) Nied	arcalp1	*Arctostaphylos alpina* var. *alpina* (L.) Spreng.	ARALA7
Arctous rubra (Rehder & E.H. Wilson) Nakai	arcrub1	*Arctostaphylos rubra* (Rehder & Wilson) Fernald	ARRU
Armeria maritima (Mill.) Willd. ssp. *arctica* (Cham.) Hult.	armmar	*Armeria maritima* ssp. *sibirica* (Mill.) Willd.	ARMAS
Artemisia borealis Pall.	artbor	*Artemisia campestris* ssp. *borealis* var. *borealis* L.	ARCAB4
Aster sibiricus L.	astsib	*Eurybia sibirica* (L.) G.L. Nesom	EUSI13
Astragalus aboriginum Richards.	astabo	no match	n/a
Braya humilis (C.A. Mey.) B.L. Robins. ssp. *richardsonii* (Rydb.) Hultén	braric	*Neotorularia humilis* (C.A. Mey.) Hedge & J. Léonard	NEHU2
Bromus pumpellianus Scribn.	bropum3	*Bromus inermis* ssp. *pumpellianus* var. *pumpellianus* Leyss.	BRINP5
Bromus pumpellianus ssp. *pumpellianus* Scribn.	bropum5	no match	n/a
Bupleurum triradiatum Adams ssp. *arcticum* (Regel) Hult.	buptri	*Bupleurum americanum* J.M. Coult. & Rose	BUAM2
Calamagrostis purpurascens R. Br. ssp. *purpurascens*	calpur	no match	n/a
Cardamine hyperborea O.E. Schulz	carhyp	*Cardamine microphylla* ssp. *blaisdellii* M.F. Adams	CAMIB
Carex amblyorhyncha Krecz.	caramb	*Carex marina* ssp. *marina* Dewey	CAMAM16
Carex saxatilis L. ssp. *laxa* (Trautv.) Kalela	carsax	*Carex saxatilis* L.	CASA10
Cerastium jenisejense Hult.	cerjen	*Cerastium gorodkovianum* Schischkin	CEGO
Chrysanthemum bipinnatum L.	chrbip	*Tanacetum bipinnatum* ssp. *bipinnatum* (L.) Sch. Bip.	TABIB

Appendix B. Continued.

Taxon	Code	USDA Synonym	USDA Code
Chrysanthemum integrifolium Richards.	chrint	*Hulteniella integrifolia* (Richardson) Tzvelev	HUIN3
Deschampsia cespitosa (L.) P. Beauv. ssp. *cespitosa*	desces1	*Deschampsia cespitosa* (L.) P. Beauv.	DECE
Deschampsia sukatschewii (Popl.) Roshev.	dessuk	*Deschampsia cespitosa* (L.) P. Beauv.	DECE
Draba caesia Adams	dracae	*Draba palanderiana* Kjellm.	DRPA7
Draba hirta L.	drahir	*Draba glabella* var. *glabella* Pursh	DRGLG2
Epilobium latifolium L.	epilat	*Chamerion latifolium* (L.) Holub	CHLA13
Equisetum variegatum ssp. *variegatum* Schleich. ex F. Weber & D. Mohr	equvar1	no match	n/a
Erigeron eriocephalus J. Vahl	erieri	*Erigeron uniflorus* ssp. *eriocephalus* L.	ERUNE
Eriophorum angustifolium Honck. ssp. *subarcticum* (V. Vassiljev) Hult.	eriang	*Eriophorum angustifolium* ssp. *angustifolium* Honck.	ERANA3
Eriophorum russeolum E. Fries var *albidum* Nyl.	erialb	no match	n/a
Eritrichium arenosum D.F. Murray	eriare1	no match	n/a
Eritrichium aretioides (Cham.) DC.	eriare	*Eritrichium nanum* var. *aretioides* (Vill.) Schrad. ex Gaudin	ERNAA
Gentiana propinqua Richardson	genpro	*Gentianella propinqua* ssp. *propinqua* (Richardson) J.M. Gillett	GEPRP
Gentiana propinqua Richards. ssp. *arctophila* (Griseb.) Hult.	genarc	*Gentianella propinqua* ssp. *propinqua* (Richardson) J.M. Gillett	GEPRP
Hedysarum hedysaroides (L.) Schinz & Thell.	hedhed	*Hedysarum alpinum* L.	HEAL
Ledum decumbens (Aiton) Lodd. ex Steud.	leddec	*Ledum palustre* ssp. *decumbens* L.	LEPAD
Luzula tundricola Gorodk.	luztun	*Luzula arctica* ssp. *latifolia* Blytt	LUARL4
Luzula wahlenbergii Rupr. ssp. *wahlenbergii*	luzwah	no match	n/a
Lycopodium selago L.	lycsel	*Huperzia selago* var. *selago* (L.) Bernh. ex Schrank & Mart.	HUSES
Melandrium apetalum (L.) Fenzl.	melape	*Silene uralensis* ssp. *uralensis* (Rupr.) Bocquet	SIURU
Melandrium taimyrense Tolm.	meltai	*Silene taimyrensis* (Tolm.) Bocquet	SITA
Myriophyllum spicatum ssp. *exalbescens* (Fern.) Hult.	myrsib	*Myriophyllum sibiricum* Kom.	MYSI
Nostoc pruniforme C. Agardh	nospru	no match	n/a
Oxytropis campestris (L.) DC. ssp. *jordalii* (Porsild) Hultén	oxyjor	*Oxytropis campestris* var. *jordalii* (L.) DC.	OXCAJ3

Appendix B. Continued.

Taxon	Code	USDA Synonym	USDA Code
Oxytropis nigrescens ssp. *bryophila* (Greene) Hultén	oxybry1	*Oxytropis nigrescens* var. *nigrescens* (Pall.) Fisch. ex DC.	OXNIN2
Oxytropis viscida Nutt.	oxyvis	*Oxytropis borealis* var. *viscida* DC.	OXBOV
Pedicularis kanei Durand	pedkan1	*Pedicularis lanata* Cham. & Schltdl.	PELA14
Pinguicula vulgaris L. ssp. *vulgaris*	pinvul2	no match	n/a
Poa sublanata Reverd.	poasub	no match	n/a
Polygonum bistorta L. ssp. *plumosum* (Small) Hult.	polbis	*Polygonum bistorta* var. *plumosum* L.	POBIP
Potamogeton filiformis Pers.	potfil	*Stuckenia filiformis* ssp. filiformis (Pers.) Börner	STFIF
Potentilla hyparctica Malte	pothyp	*Potentilla nana* Willd. ex Schltdl.	PONA6
Potentilla palustris (L.) Scop.	potpal	*Comarum palustre* L.	COPA28
Pyrola grandiflora var. *canadensis*	pyrgra2	*Pyrola grandiflora* Radius	PYGR
Pyrola secunda L.	pyrsec1	*Orthilia secunda* (L.) House	ORSE
Ranunculus confervoides (E. Fries) E. Fries	rancon	*Ranunculus trichophyllus* var. *eradicatus* Chaix	RATRE
Sagina intermedia Fenzl	sagint	*Sagina nivalis* (Lindbl.) Fr.	SANI7
Saxifraga punctata L.	saxpun	*Saxifraga nelsoniana* ssp. *nelsoniana* D. Don	SANEN
Saxifraga punctata L. ssp. *nelsoniana* (D. Don) Hult.	saxnel	*Saxifraga nelsoniana* ssp. *nelsoniana* D. Don	SANEN
Senecio atropurpureus (Ledeb.) Fedtsch.	senatr	*Tephroseris atropurpurea* ssp. *atropurpurea* (Ledeb.) Holub	TEATA
Senecio atropurpureus (Ledeb.) Fedtsch. ssp. *frigidus* (Richards.) Hult.	senfri	*Tephroseris atropurpurea* ssp. *frigida* (Ledeb.) Holub	TEATF2
Senecio resedifolius Less.	senres	*Packera cymbalaria* (Pursh) W.A. Weber & Á. Löve	PACY8
Silene acaulis (L.) ssp. *subacaulescens* (F. N. Williams) Hultén	silsub	*Silene acaulis* var. *subacaulescens* (L.) Jacq.	SIACS2
Stellaria laeta Richards.	stelae	*Stellaria longipes* ssp. *longipes* Goldie	STLOL7
Taraxacum alaskanum Rydb.	tarala	*Taraxacum phymatocarpum* J. Vahl	TAPH
Utricularia vulgaris L. ssp. *macrorhiza* (LeConte) Clauson	utrvul	*Utricularia macrorhiza* Leconte	UTMA
Zygadenus elegans Pursh	zygele	no match	n/a

Appendix C. List of specimens donated to and on record at the Alaska Museum of the North Herbarium from the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

plot_id	veg_spec_field_call	authority	veg_loan_to_institution
willow_aardvark_03_2017	utrmin	*Myriophyllum spicatum* ssp. *exalbescens* (Fern.) Hult.	ala
willow_aardvark_plesab_2017	plesab	*Pleuropogon sabinei* R. Br.	ala
willow_alligator_02_2017	antarc	*Anthoxanthum arcticum* Veldkamp	ala
willow_boa_01_2017	poaalp1	*Poa arctica* ssp. *lanata* (Scribn. & Merr.) Soreng	ala
willow_buzzard_02_2017	poasub	*Poa sublanata* Reverd.	ala
willow_buzzard_03_2017	koeasi	*Koeleria asiatica* Domin	ala
willow_cheetah_03_2017	poaala	*Poa hartzii* ssp. *alaskana* Soreng	ala
willow_cheetah_03_2017	poasub	*Poa arctica* ssp. *lanata* (Scribn. & Merr.) Soreng	ala
willow_cheetah_04_2017	kobre	*Kobresia sibirica* Turcz.	ala
willow_fcb-ubbg_2017	arabi	*Arabis arenicola* (Richards.) Gelert var *pubescens*	ala
willow_fcb-ubbg_2017	arttil	*Artemisia tilesii* Ledeb.	ala
willow_fcb-ubbg_2017	poaalp3	*Poa sublanata* Reverd.	ala
willow_fcb-ubbg_2017	poasub	*Poa sublanata* Reverd.	ala
willow_jcx-bbg_2017	poa1	*Poa hartzii* ssp. *alaskana* Soreng	ala
willow_jcx-bpv_2017	desces	*Poa hartzii* ssp. *alaskana* Soreng	ala
willow_jcx-bpv_2017	poa2	*Poa sublanata* Reverd.	ala
willow_kr-ubbg_2017	melape	*Melandrium taimyrense* Tolm.	ala
willow_lion_04_2017	carhol	*Carex holostoma* Drej.	ala

Appendix D. Observations of *Poa sublanata* and *Potamogeton subsibiricus* in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

project_id	ID	Scientific Name	Latitude (WGS84)	Longitude (WGS84)
17-107	1183	*Potamogeton subsibiricus*	70.138355	-152.375924
17-107	1640	*Poa sublanata*	70.257099	-152.133679
17-107	1669	*Poa sublanata*	70.257694	-152.134694
17-107	2912	*Poa sublanata*	70.212328	-152.35723
17-107	3499	*Poa sublanata*	70.148094	-152.090452
17-107	4995	*Poa sublanata*	70.264911	-152.112734
18-167	5274	*Poa sublanata*	70.331808	-152.317989
18-167	5804	*Poa sublanata*	70.080557	-152.337919
18-167	5846	*Poa sublanata*	70.079856	-152.332393
18-167	5881	*Poa sublanata*	70.246713	-152.292719
18-167	6447	*Poa sublanata*	70.142971	-152.16719

Appendix E. Crosswalk of ecotypes, plant communities, and AVC level IV vegetation classes, and number of field plots, Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Plot Ecotype	Plant Association	Vegetation Class (Level 4)	Number of Plots
Beaded Stream	Fresh Water	Fresh Water	2
	Hippuris vulgaris-Potentilla palustris	Common Marestail	1
		Fresh Herb Marsh	1
Lacustrine Aquatic Barrens	*Eriophorum angustifolium/Scorpidium scorpioides*	Fresh Water	1
Lacustrine Grass Marsh	*Arctophila fulva*	Fresh Grass Marsh	4
Lacustrine Moist Barrens	Barrens	Barren	1
Lacustrine Moist Low Willow Shrub	*Carex aquatilis-Salix richardsonii-Equisetum variegatum*	Open Low Willow-Sedge Shrub Tundra	1
	Salix richardsonii/Carex aquatilis	Open Low Willow-Sedge Shrub Tundra	1
Lacustrine Moist Sedge-Shrub Meadow	*Carex aquatilis-Eriophorum angustifolium-Saxifraga hirculus/Salix arctica/Drepanocladus brevifolius*	Moist Sedge-Shrub Tundra	1
	Dryas integrifolia-Carex bigelowii-Salix richardsonii	Dryas-Sedge Dwarf Shrub Tundra	1
		Willow Dwarf Shrub Tundra	1
	Dryas integrifolia-Salix reticulata/Carex Bigelowii-Saxifraga hirculus	Dryas-Sedge Dwarf Shrub Tundra	1
Lacustrine Wet Sedge Meadow	*Carex aquatilis-Eriophorum angustifolium-Carex chordorrhiza*	Wet Sedge Meadow Tundra	2
	Carex aquatilis-Eriophorum angustifolium-Saxifraga hirculus/Salix arctica/Drepanocladus brevifolius	Wet Sedge Meadow Tundra	1
	Carex aquatilis-Salix richardsonii-Equisetum variegatum	Wet Sedge-Willow Tundra	2
	Eriophorum Scheuchzeri-Carex aquatilus-Juncus arcticus	Wet Sedge-Willow Tundra	1
	Eriophorum angustifolium/Scorpidium scorpioides	Wet Sedge Meadow Tundra	1
Lower Perennial River	Fresh Water	Fresh Water	3
Lowland Lake	Fresh Water	Fresh Water	6
Lowland Moist Birch-Willow-Ericaceous Low Shrub	*Betula nana–Vaccinium vitis-idaea/Saussurea angustifolia/Hylocomium splendens*	Open Low Shrub Birch-Willow	1

Appendix E. Continued.

Plot Ecotype	Plant Association	Vegetation Class (Level 4)	Number of Plots
Lowland Moist Low Willow Shrub	*Betula nana-Salix pulchra/Rubus chamaemorus/Sphagnum*	Open Low Willow-Sedge Shrub Tundra	1
	Salix glauca-Betula nana/Arctagrostis latifolia/Rhytidium rugosum	Open Low Willow	1
	Salix pulchra-Cassiope tetragona	Open Low Willow	1
	Salix pulchra-Salix fuscescens/Carex aquatilis-Eriophorum angustifolium/Sphagnum	Open Low Willow-Sedge Shrub Tundra	1
	Salix richardsonii/Carex aquatilis	Open Low Willow-Sedge Shrub Tundra	2
Lowland Moist Sedge-Shrub Meadow	*Carex aquatilis-Eriophorum angustifolium-Carex chordorrhiza*	Moist Sedge-Shrub Tundra	1
	Carex aquatilis-Eriophorum angustifolium-Saxifraga hirculus/Salix arctica/Drepanocladus brevifolius	Moist Sedge-Shrub Tundra	1
	Dryas integrifolia-Carex bigelowii-Salix richardsonii	Dryas-Sedge Dwarf Shrub Tundra	3
		Moist Sedge-Shrub Tundra	2
		Moist Sedge-Willow Tundra	1
Lowland Sedge Marsh	*Carex aquatilis*	Fresh Sedge Marsh	4
	Carex aquatilis-Eriophorum angustifolium-Carex chordorrhiza	Fresh Sedge Marsh	4
	Eriophorum angustifolium/Scorpidium scorpioides	Fresh Sedge Marsh	1
Lowland Wet Sedge Meadow	*Carex aquatilis*	Wet Sedge Meadow Tundra	6
	Carex aquatilis-Eriophorum angustifolium-Carex chordorrhiza	Wet Sedge Meadow Tundra	17
	Carex aquatilis-Eriophorum angustifolium-Carex saxatilis	Wet Sedge Meadow Tundra	5
	Carex aquatilis-Eriophorum angustifolium-Saxifraga hirculus/Salix arctica/Drepanocladus brevifolius	Wet Sedge Meadow Tundra	6
	Eriophorum angustifolium/Scorpidium scorpioides	Wet Sedge Meadow Tundra	3
Lowland Wet Sedge-Willow Meadow	*Carex aquatilis-Salix richardsonii-Equisetum variegatum*	Wet Sedge-Willow Tundra	4
	Salix richardsonii/Carex aquatilis	Wet Sedge-Willow Tundra	1
Riverine Dry Dryas Dwarf Shrub	*Dryas integrifolia-Carex bigelowii-Salix richardsonii*	Dryas Dwarf Shrub Tundra	1

Appendix E. Continued.

Plot Ecotype	Plant Association	Vegetation Class (Level 4)	Number of Plots
	Dryas integrifolia-Cassiope tetragona/Silene acaulis	Dryas Dwarf Shrub Tundra	1
Riverine Grass Marsh	*Arctophila fulva*	Fresh Grass Marsh	1
Riverine Lake	Fresh Water	Fresh Water	2
Riverine Moist Barrens	Barrens	Barren	5
Riverine Moist Low Willow-Sedge Meadow	*Salix richardsonii/Carex aquatilis*	Open Low Willow-Sedge Shrub Tundra	7
Riverine Moist Low Willow Shrub	*Salix alaxensis/Aster sibiricus-Artemisia Tilesii-Astragalus alpinus*	Open Low Willow	2
	Salix glauca-Arctous rubra	Open Low Willow	1
	Salix pulchra-Carex aquatilis	Closed Low Willow	1
		Open Low Willow	1
	Salix pulchra-Salix fuscescens/Carex aquatilis-Eriophorum angustifolium/Sphagnum	Closed Low Willow	1
	Salix richardsonii/Carex aquatilis	Open Low Willow	1
	Salix richardsonii-Salix glauca/Equisetum arvense-Hedysarum alpinum/Tomenthypnum nitens	Open Low Willow	1
Riverine Moist Sedge-Shrub Meadow	*Dryas integrifolia-Carex bigelowii-Salix richardsonii*	Moist Sedge-Shrub Tundra	1
Riverine Moist Tall Willow Shrub	*Salix alaxensis/Aster sibiricus-Artemisia Tilesii-Astragalus alpinus*	Open Tall Willow	1
	Salix pulchra-Carex aquatilis	Open Tall Willow	1
Riverine Sedge Marsh	*Carex aquatilis*	Fresh Sedge Marsh	3
	Carex aquatilis-Eriophorum angustifolium-Carex saxatilis	Fresh Sedge Marsh	1
Riverine Wet Sedge Meadow	*Carex aquatilis*	Wet Sedge Meadow Tundra	3
	Carex aquatilis-Eriophorum angustifolium-Carex chordorrhiza	Wet Sedge Meadow Tundra	1
	Carex aquatilis-Eriophorum angustifolium-Carex saxatilis	Wet Sedge Meadow Tundra	3
	Carex aquatilis-Eriophorum angustifolium-Saxifraga hirculus/Salix arctica/Drepanocladus brevifolius	Wet Sedge Meadow Tundra	1
	Carex aquatilis-Salix richardsonii-Equisetum variegatum	Wet Sedge Meadow Tundra	1
Riverine Wet Sedge-Willow Meadow	*Carex aquatilis-Salix richardsonii-Equisetum variegatum*	Wet Sedge-Willow Tundra	4

Appendix E. Continued.

Plot Ecotype	Plant Association	Vegetation Class (Level 4)	Number of Plots
Upland Dry Barrens	*Artemisia borealis-Bromus Pumpellianus-Festuca rubra*	Partially Vegetated	1
Upland Dry Dryas Dwarf Shrub	*Dryas integrifolia–Arctous rubra/Oxytropis borealis*	Dryas Dwarf Shrub Tundra	3
	Dryas integrifolia-Carex bigelowii-Salix richardsonii	Dryas Dwarf Shrub Tundra	1
	Dryas integrifolia-Cassiope tetragona/Silene acaulis	Dryas Dwarf Shrub Tundra	3
	Dryas integrifolia–Oxytropis deflexa	Dryas Dwarf Shrub Tundra	1
Upland Dry Grass Meadow	*Arctagrostis latifolia-Artemisia Tilesii-Equisetum arvense*	Moist Grass-Herb Meadow Tundra	1
Upland Dry Tall Willow Shrub	*Salix alaxensis/Artemisia borealis-Armeria maritima*	Open Low Willow	1
	Salix alaxensis-Chrysanthemum bipinnatum	Open Low Willow	4
		Open Tall Willow	2
Upland Moist Birch-Willow-Ericaceous Dwarf Shrub	*Betula nana-Arctous alpina/Anthoxanthum monticola ssp. alpinum*	Open Low Mesic Shrub Birch-Ericaceous Shrub	4
		Open Low Shrub Birch-Willow	1
	Betula nana-Salix pulchra/Rubus chamaemorus/Sphagnum	Open Low Mesic Shrub Birch-Ericaceous Shrub	2
	Betula nana–Vaccinium vitis-idaea/Saussurea angustifolia/Hylocomium splendens	Open Low Mesic Shrub Birch-Ericaceous Shrub	1
	Salix glauca-Betula nana/Arctagrostis latifolia/Rhytidium rugosum	Open Low Shrub Birch-Willow	2
	Salix pulchra-Cassiope tetragona	Open Low Shrub Birch-Willow	1
Upland Moist Cassiope Dwarf Shrub	*Dryas integrifolia-Cassiope tetragona/Silene acaulis*	Cassiope Dwarf Shrub Tundra	15
	Salix pulchra-Cassiope tetragona	Cassiope Dwarf Shrub Tundra	1
Upland Moist Ericaceous Dwarf Shrub	*Betula nana–Vaccinium vitis-idaea/Saussurea angustifolia/Hylocomium splendens*	Ericaceous Dwarf Shrub Tundra	1
	Dryas integrifolia–Arctous rubra/Oxytropis borealis	Bearberry Dwarf Shrub Tundra	1
	Dryas integrifolia-Cassiope tetragona/Silene acaulis	Ericaceous Dwarf Shrub Tundra	1
	Dryas integrifolia-Salix reticulata-Vaccinium uligonosum/Carex Bigelowii-Equisetum arvense	Ericaceous Dwarf Shrub Tundra	1
	Salix pulchra-Cassiope tetragona	Ericaceous Dwarf Shrub Tundra	1

Appendix E. Continued.

Plot Ecotype	Plant Association	Vegetation Class (Level 4)	Number of Plots
Upland Moist Low Willow Shrub	*Salix glauca/Koeleria asiatica*	Open Low Willow	2
Upland Moist Shrub-Tussock Meadow	*Betula nana-Salix pulchra/Eriophorum vaginatum*	Open Mixed Low Shrub-Sedge Tussock Tundra	38
	Eriophorum vaginatum-Dryas integrifolia	Open Mixed Low Shrub-Sedge Tussock Tundra	3
	Eriophorum vaginatum-Ledum decumbens	Open Mixed Low Shrub-Sedge Tussock Tundra	13
	Eriophorum vaginatum/Ledum decumbens-Vaccinium vitis-idaea/Sphagnum	Open Mixed Low Shrub-Sedge Tussock Tundra	1
Upland Moist Tussock Meadow	*Betula nana-Salix pulchra/Eriophorum vaginatum*	Tussock Tundra	1
	Eriophorum vaginatum-Ledum decumbens	Tussock Tundra-Ericaceous	1
	Eriophorum vaginatum/Ledum decumbens-Vaccinium vitis-idaea/Sphagnum	Tussock Tundra	3
		Tussock Tundra-Ericaceous	3
	Eriophorum vaginatum-Valeriana capitata/Dryas integrifolia-Salix reticulata/Tomenthypnum nitens	Tussock Tundra	4
		Tussock Tundra-Dryas	1
		Tussock Tundra-Ericaceous	1

Appendix F. Classification and description of geomorphic units in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Geomorphic Unit	Description
Alluvial-Marine Deposit	A highly variable sequence of alluvial and marine deposits with minor inclusions of eolian sediments corresponding to a series of late Cenozoic marine transgressions and regressions on the Arctic Coastal Plain. Pebbly eolian sand is usually present, but its thickness is highly variable. Underlying fluvial deposits include gravelly sand, silty sand, and organic silt and occasionally contain buried peat beds. Stratified layers of marine gravelly sand, silty sand, silt and minor inclusions of clay occur beneath the fluvial deposits at some locations and commonly are fossiliferous. Recent surficial organic deposits are typically present, ranging from thin (5–14 cm) on convex and gently sloping uplands to thick (≥40 cm in depressions.
Drained Basin, ice-rich center	A lacustrine deposit exposed following natural lake drainage in one of the naturally occurring depressions characteristic of undulating, sandy alluvial-marine and eolian deposits. Ice-rich centers develop over centuries after lake drainage and usually correspond to a former talik or "thaw bulb" that occupied the deepest portion of the former lakebed. Sediments are highly modified by downward freezing of fine-grained, saturated material that is susceptible to ground-ice aggradation. Sediments are characterized by moderate to high ground-ice content, and are dominated by massive fines with organics, cryoturbated fines with organics, and limnic fines (algae-rich) overlain by moderately thick (15–40 cm) surface organic deposits. Ice-rich centers often are raised above the surrounding basin by ice aggradation and tend to have mesic soil moisture conditions. Surface morphologies range from low-centered polygons at early stages of development to high-centered polygons.
Drained Lake Basin, ice-poor center	A lacustrine deposit exposed following natural lake drainage in one of the naturally occurring depressions characteristic of undulating, sandy alluvial-marine and eolian deposits. Ice-wedge polygons are poorly developed or absent, indicating that ground ice content is low and that lake drainage has occurred recently. The sediments in the centers of ice-poor, drained basins are typically finer in texture and have relatively higher ice content compared to ice-poor basin margins. A thin (5–14 cm) surface organic layer is typically present. Ice-poor centers often are raised above the surrounding basin by ice aggradation and tend to have mesic soil moisture conditions.
Drained Lake Basin, ice-poor margin	A lacustrine deposit exposed following natural lake drainage in one of the naturally occurring depressions characteristic of undulating, sandy alluvial-marine and eolian deposits. Ice-wedge polygons are poorly developed or absent, indicating that ground ice content is low and that lake drainage has occurred recently. The sediments on the margins of ice-poor, drained basins are typically sandier and have relatively lower ice content than sediments in ice-poor basin centers. A thin (5–14 cm) or, occasionally, moderately thick (15–40 cm) surface organic layer is typically present. Ice-poor margins are flat to slightly concave, and soil moisture conditions range from aquatic in concavities, to wet in flat areas, and mesic on disjunct polygon rims, strang, and ice-cored mounds.

Appendix F. Continued.

Geomorphic Unit	Description
Drained Lake Basin, ice-poor undifferentiated	A lacustrine deposit exposed following natural lake drainage in one of the naturally occurring depressions characteristic of undulating, sandy alluvial-marine and eolian deposits. Sediments and soil moisture conditions are similar to ice-poor margins and centers. The predominance of nonpatterned ground or disjunct polygon rims indicates that ground ice content is low and that lake drainage has occurred recently. This type is used when the ice-poor basin centers and margins are poorly differentiated.
Drained Lake Basin, ice-rich margin	A lacustrine deposit exposed following natural lake drainage in one of the naturally occurring depressions characteristic of undulating, sandy alluvial-marine and eolian deposits. Sediments were originally deposited in the shallow, nearshore portion of the former lake basin. Ice-rich margins are characterized by moderate to high ice content, but sediments tend to be coarser than those in basin centers and are thus less susceptible to ground ice aggradation. Soil profiles are typically dominated by massive and layered fines and medium sands overlain by moderately thick (15–40 cm) to thick (≥40 cm surficial organic deposits. Ice-rich margins are flat to slightly concave, and soil moisture conditions range from aquatic in concavities, to wet in low-centered polygons, and mesic on high-centered polygons.
Drained Lake Basin, ice-rich undifferentiated	A lacustrine deposit exposed following natural lake drainage in one of the naturally occurring depressions characteristic of undulating, sandy alluvial-marine and eolian deposits. Sediments and soil moisture conditions are similar to ice-rich margins and centers, but there is generally less ground ice with poorly developed low-centered or high-centered polygons. This class is used when the ice-rich drained lake centers and margins are poorly differentiated.
Drained Lake Basin, pingo	A conspicuous, dome-shaped hill, typically found in ice-rich drained lake basins. Pingos form after lake drainage, typically by freezing of water-saturated taliks (thaw bulbs) that existed beneath the former lake bed. Subsequent aggradation of large volumes of ground ice heaves the surface upward, resulting in the characteristic domed shape. High-centered polygons are often present and soils are well-drained.
Eolian Abandoned Sand Dune	An ancient (relict), low mound, ridge, bank or hill formed of compacted, windblown sand that was deposited during a historic climatic period. The sand is typically fine to very fine and well sorted. The soils may contain thin, buried organic soil horizons in the top meter and buried peat beds at greater depths. Abandoned dunes are well vegetated and feature very thin (0.5–5.0 cm) to thin (5–14 cm) surface organic horizons which stabilize the surface. Wind deflation or "blowouts" can be locally common, but is of limited severity and extent.
Eolian Active Sand Dune	A low mound, ridge, bank, or hill of loose, windblown sand. The sand is typically fine to very fine, well sorted, and often stratified, with large-scale cross-bedding in places. Active dunes are barren or partially vegetated and are subject to ongoing accretion, deflation, and slow migration in the direction of the predominant winds.

Appendix F. Continued.

Geomorphic Unit	Description
Eolian Inactive Sand Dune	A low mound, ridge, bank, or hill of compacted, windblown sand. The sand is typically fine to very fine and well sorted. The soils may contain thin buried organic horizons in the top meter and buried peat beds at greater depths. Inactive dunes are well vegetated and feature very thin (0.5–5 cm) surface organic horizons which help stabilize the surface. Wind deflation is common but limited in extent; occasionally it may lead to "blowouts" that can reactivate portions of inactive dunes by exposing the sandy substrate to wind.
Eolian Sand Sheet Lowland	A flat to concave area comprising moderately thick (15–40 cm) to thick (≥40) organic deposits over ancient eolian sand deposits. The land surface lacks the microtopography and slip faces that are characteristic of dunes. Lowland sand sheets exist where the soil moisture is too high to allow the sand particles to become entrained by wind.
Eolian Sand Sheet Upland	A flat to gently sloping upland area comprising a thin (1 to several meters) mantle of ancient eolian sand deposits, but lacking the discernible microtopographic features and planform that characterize dunes. Eolian sand sheets are typically much more extensive than dunes, and exist where the sand grain size is too large, or wind velocities are too low, for dunes to form.
Lowland Headwater Floodplain	A narrow floodplain along a lower order (i.e., Strahler order 1–2) stream and/or its tributaries in a lowland area. These low-gradient streams carry little sediment and the floodplain generally is restricted to the immediate vicinity of the stream.
Meander Abandoned Channel Deposit	Vertical accretion deposits of meandering floodplains that are no longer associated with the present flood regime or where flooding is sufficiently infrequent that recent fluvial sediments form a negligible proportion of the surficial material (upper 40 cm). Surficial materials are typically organic-rich (>20 cm). On flat or convex surfaces, the mineral soil is typically dominated by coarse-textured alluvium (i.e., rock fragments and loamy fine sand or coarser). In concave areas, such as scour channels and former river channels, finer-grained alluvium (loamy very fine sand or finer) predominates.
Meander Abandoned Overbank Deposit	Vertical accretion deposits of meandering floodplains that are no longer associated with the present flood regime or where flooding is sufficiently infrequent that recent fluvial sediments form a negligible proportion of the surficial material (upper 40 cm). Surficial materials are typically organic-rich (>20 cm), but may include a mixture of finer-textured (i.e., loamy very fine sand or finer) soils from alluvium and/or eolian deposition.
Meander Active Channel Deposit	Sediments deposited by fluvial processes as a lateral accretion deposit in an active channel of a river characterized by a meandering planform. Vegetation, where present, is usually restricted to sparse stands of pioneering species, due to frequent flooding, sedimentation, and scouring.

Appendix F. Continued.

Geomorphic Unit	Description
Meander Active Overbank Deposit	Vertical accretion deposits on low-lying portions of the overbank environment near meandering river channels. Surficial material (upper 40 cm) is typically comprised of fine-textured material (i.e., loamy very fine sand or finer) that has a laminar, interbedded structure formed by changes in velocity and deposition during waxing and waning floods. The surface organic horizon ranges from absent to very thin (0–5 cm).
Meander Fine Active Channel Deposit*	Sand and silt deposited by fluvial processes as a lateral accretion deposit in an active channel of a river characterized by a meandering planform. Occasional subrounded to rounded pebbles may be present. Vegetation, where present, is usually restricted to sparse stands of pioneering species, due to frequent flooding, sedimentation, and scouring.
Meander Fine Inactive Channel Deposit*	Sand and silt deposited by fluvial processes during periods of high flow as a lateral accretion deposit in an inactive channel of a river characterized by a meandering planform. These formerly active channel deposits have been cut off from floodwaters during low-flow conditions by river channel migration.
Meander Inactive Channel Deposit	Sediments deposited by fluvial processes during periods of high flow as a lateral accretion deposit in an inactive channel of a river characterized by a meandering planform. These formerly active channel deposits have been cut off from floodwaters during low-flow conditions by river channel migration.
Meander Inactive Overbank Deposit	Vertical accretion deposits formed on higher portions of the overbank environment near meandering river channels that are subject to infrequent. Surficial material (upper 40 cm) is typically comprised of a thin (5–14 cm) surface organic horizon overlying stratified fine-textured (i.e., loamy very fine sand or finer) alluvium, and buried organic horizons.
Old Alluvial Terrace	A flat-topped geomorphic surface in a river valley that flanks and is parallel to a modern river channel. Old Alluvial Terraces are remnants of an ancient floodplain that formed during the Pleistocene Epoch (ca. >12,000 years ago). They are positioned on the landscape at a higher elevation than the current floodplain, and therefore are never subject to flooding under the modern flow regime. The substrate consists of alluvial sands, silts, and gravels, often overlain by a moderately thick (15–40 cm) to thick (>40 cm) mantle of eolian and/or organic material.
Solifluction Deposit	Unconsolidated colluvial material resulting from the downslope movement of saturated surface soils atop frozen subsurface soils. Solifluction deposits are typically found on moderate to steep slopes and are often associated with snowbeds.
Upland Loess*	A homogenous, typically non-stratified fine-grained deposit of windblown sediments occurring in upland areas and consisting predominantly of silt with secondary grain sizes ranging from clay to fine sand.

* Class described in field but not mapped.

Appendix G. Classification and description of waterbodies in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Waterbody Class	Description
Deep Connected Lake	A deep (≥1.5 m) pond or lake that is connected to a river network by a distinct outlet in which water flows throughout the freeze-free period. These lakes do not freeze to the bottom during winter, potentially providing wintering habitat for fish. The presence of a surface connection to an active channel provides opportunities for fish passage during the thaw season.
Deep Connected Riverine Lake	A deep (≥1.5 m) pond or small lake that occupies an abandoned river channel or oxbow, and has an outlet to an active river channel in which water flows throughout the freeze-free period. Emergent vegetation may or may not be present. These lakes do not freeze to the bottom during winter, potentially providing wintering habitat for fish. The surface connection to an active channel provides opportunities for fish passage throughout the thaw season.
Deep Isolated Lake	A deep (≥1.5 m) pond or lake that lacks a distinct outlet and thus is not connected to a river network. These lakes do not freeze to the bottom during winter, but the absence of a surface connection to an active channel limits opportunities for fish passage.
Deep Isolated Riverine Lake	A deep (≥1.5 m) pond or small lake on a floodplain in an abandoned river channel or oxbow that lacks an outlet to an active river channel. Sediments may include a wide range of particle sizes, from sand to clay. Emergent vegetation may or may not be present. These lakes do not freeze to the bottom during winter, but the absence of a surface connection to an active channel limits opportunities for fish passage. However, the floodplain location provides the opportunity for fish to be carried into these lakes by overbank flooding during high-water events.
Deep Tapped Riverine Lake, High-water Connection	A deep (≥1.5 m) pond or lake that has been partially drained (tapped) through a distinct breach formed by bank erosion of the adjacent river. These lakes are connected to rivers only during high-water events. They do not freeze to the bottom during winter, potentially providing wintering habitat for fish. Shorelines are typically broad and flat with silty clay sediments that represent a portion of the exposed former lake bottom.
Deep Thermokarst Pit*	A small (<0.05 ha , deep (≥1.5 m) pond formed by melting ground ice, often located at the intersection of 2 or more ice wedges in polygonized tundra. These ponds have no distinct outlet and thus are not connected to a river network.
Lower Perennial River, non-glacial	Permanently flooded channels of freshwater rivers and streams in the lower portions of unglaciated watersheds. Gradients and flow velocities are typically low. Discharge and turbidity are affected by surface water run-off and groundwater recharge; peak flows typically occur during spring break-up. Substrates may consist of rock, cobble, gravel, and sand.

Appendix G. Continued.

Waterbody Class	Description
Shallow Connected Riverine Lake	A shallow (<1.5 m) pond or small lake that occupies an abandoned river channel or oxbow, and has an outlet to an active river channel in which water flows throughout the freeze-free period. Emergent vegetation is commonly present. These lakes freeze to the bottom during winter, but thaw by early to mid-June and are warmer in summer than deep lakes. Sediments may include a wide range of particle sizes, from sand to clay. The presence of a surface connection to an active channel provides opportunities for fish passage during the thaw season.
Shallow Isolated Dune Lake	A shallow (<1.5 m) pond or lake in a depression between sand dunes. These lakes lack a distinct outlet and thus are not connected to a river network. These lakes freeze to the bottom during winter, thaw by early to mid-June, and are warmer in summer than deep lakes.
Shallow Isolated Lake	A shallow (<1.5 m) pond or lake that lacks a distinct outlet and thus is not connected to a river network. These lakes freeze to the bottom during winter, thaw by early to mid-June, and are warmer in summer than deep lakes.
Shallow Isolated Riverine Lake	A shallow (<1.5 m) pond or small lake that occupies an abandoned river channel or oxbow and lacks an outlet to an active river channel. Emergent vegetation is commonly present. These lakes freeze to the bottom during winter, but thaw by early to mid-June, and are warmer in summer than deep lakes. Sediments may include a wide range of particle sizes, from sand to clay. The absence of a surface connection to an active channel limits opportunities for fish passage; however, the floodplain location provides the opportunity for fish to be carried into these lakes by overbank flooding during high-water events.
Shallow Tapped Riverine Lake, High-water Connection	A shallow (<1.5 m) pond or lake that has been partially drained (tapped) through a distinct breach formed by bank erosion of the adjacent river. These lakes are connected to rivers only during high-water events. They freeze to the bottom in winter and thus do not provide wintering habitat for fish. Shorelines are typically broad and flat with silty clay sediments that represent a portion of the exposed former lake bottom.
Shallow Thermokarst Pit*	A small (<0.05 ha), shallow (<1.5 m) pond formed by melting ground ice, often located at the intersection of two or more ice wedges in polygonized tundra. These ponds lack a distinct outlet and are not connected to a river network.
Thermokarst River	A type of stream that flows through ice-rich soils in a permafrost environment. The stream channel consists of small linked ponds (“beads”) created by thawing ice lenses or ice-wedges, resembling beads on a string. These rivers flow freely throughout the summer. In winter, shallow (<1.5 m) beads and channels typically freeze completely, while deep (≥1.5 m beads and channels do not freeze to the bottom. Winter flow, if any, may be limited to the hyporheic zone.

* Class described in field but not mapped.

Appendix H. Classification and description of surface forms in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Surface Form Class	Description
Basin Complex	Complex microrelief within large basins formed by the thawing and draining of lakes in permafrost-dominated landscapes. In young, Ice-poor Thaw Basins, the complex generally includes Ponds, Nonpatterned ground, and Disjunct Polygons. In older, Ice-rich Thaw Basins, the complex usually consists of Ponds, Low-centered Polygons, and High-centered Polygons.
Beads	A characteristic pattern of small streams in areas underlain by ice wedges. The course of the stream channel is controlled by the pattern of the wedges, with pools ("beads") occurring at the junctions of the wedges.
Bluffs or Banks	Moderately steep (10–15°) to very steep (>30°) slopes of unconsolidated material that often border a stream, river, lake, drained lake basin, or ocean. Slopes in this class are at least 1.5 m in height from the slope break (<10°) at the base to the slope crest.
Channel	The bed where a natural body of surface water flows or may flow; a natural passageway or depression of perceptible extent containing continuously or periodically flowing water, or forming a connecting link between two bodies of water.
Disjunct Polygon Rims	Disjunct polygon rims are found where ice-wedge development is not sufficiently advanced to create closed polygons. This surface form is common in recently-drained thaw basins and isolated depressions in older basins where ice wedges are actively developing.
Drainage	A term restricted to relatively small, roughly linear or arcuate depressions that move concentrated water at some time, and either lack a defined channel (e.g., head slope, swale) or have a small, defined channel (e.g., low order streams).
Dune Complex	Complex microrelief that includes three and/or more unique vegetation communities or dune geomorphic classes. This class most often applies to dunes that have formed along a river corridor where the active, inactive and abandoned dunes are either too small to delineate at the scale of mapping, or where moist and wet inter-dune areas must be mapped in the same delineation.
Dune, undifferentiated	A low mound, ridge, bank or hill of loose, windblown, subaerially deposited granular material (generally sand), either barren and capable of movement from place to place, or covered and stabilized with vegetation, but retaining its characteristic shape.
Eolian Patterns*	A general term for microtopographic features formed by wind-related erosional or depositional processes.
Erosion Pavements*	Surficial layers of gravels, other rock fragments, and/or coarse sand remaining on the soil surface after sheet, rill, or wind erosion has removed the finer soil particles. These coarse layers tend to protect the underlying soil from further erosion.
Gelifluction Lobes	Tongue-shaped features up to 25 m wide and 150 m long, typically with steep fronts (15°–25°) and a relatively smooth upper surfaces. Gelifluction lobes are formed by soil creep over frozen ground on moderately steep to steep sections of permafrost-affected hillslopes.

Appendix H. Continued.

Surface Form Class	Description
High-centered, High-relief Polygons	High-centered polygons are composed of a raised “center” surrounded by a low “trough” separating the center from adjacent polygons. Troughs are underlain by ice wedges. Most high-centered polygons range 5–10 m in diameter. High-centered polygons generally result from the progressive thawing of ice wedges, which initiates subsidence and the development of deep (≥50 cm troughs. This thermokarst process frequently is related to changes in drainage and is often found near lake outlets and streambanks, or following surface disturbance.
High-centered, Low-relief Polygons	High-centered polygons are composed of a raised “center” surrounded by a low “trough” separating the center from adjacent polygons. Troughs are underlain by ice wedges. Most high-centered polygons range 5–10 m in diameter. High-centered, low-relief polygon centers are only slightly raised (<50 cm) with respect to the troughs. This class also includes “flat-centered” polygons where the relief between centers and troughs is barely noticeable. This surface form is common on old surfaces such as abandoned floodplains deposits, alluvial–marine terraces, or older ice-rich drained basins.
Hummocks*	Small (<0.5 m wide), low (<0.5 m high) knobs; typically dome-shaped, but sometimes elongated on gentle slopes. Hummocks often occur in groups, with spacing generally less than the diameter of the individual hummocks. They are formed by freeze-thaw processes and, in many cases, by the development of vegetation and surface peat.
Ice-cored Mounds*	Small (1–5 m wide), low (<1 m high) ice-cored mounds that form during the freezing of supra-permafrost water at the base of the active layer in permafrost landscapes.
Lake with Islands	Lakes and ponds with one or more island(s), which are at least 1 m wide and 3 m from the shore.
Low-centered, High-relief, High-density Polygons	Low-centered polygons are composed of a low-lying, often wet or flooded “center” surrounded by a “rim” that separates the center from adjacent polygons. Rims are underlain by ice wedges. Low-centered polygons in this class have rims that exceed 50 cm in height with respect to centers. High-relief polygons are more likely to have well-developed troughs between polygon rims. Relief can be accentuated by thaw settlement of the polygon center. High-density polygons are relatively small (~8–15 m across), resulting in high microtopographic variability.
Low-centered, High-relief, Low-density Polygons	Low-centered polygons are composed of a low-lying, often wet or flooded “center” surrounded by a “rim” that separates the center from adjacent polygons. Rims are underlain by ice wedges. Low-centered polygons in this class have rims that exceed 50 cm in height with respect to centers. High-relief polygons are more likely to have well-developed troughs between polygon rims. Relief can be accentuated by thaw settlement of the polygon center. Low-density polygons have rims greater than 50 cm tall, but the individual polygons are larger (~15–30 m across).

Appendix H. Continued.

Surface Form Class	Description
Low-centered, Low-relief, High-density Polygons	Low-centered polygons are composed of a low-lying, often wet or flooded “center” surrounded by a “rim” that separates the center from adjacent polygons. Rims are underlain by ice wedges. Low-centered polygons in this class have rims less than 50 cm in height with respect to centers. High-relief polygons are more likely to have well-developed troughs between polygon rims. Relief can be accentuated by thaw settlement of the polygon center. Low-density polygons have rims greater than 50 cm tall, but the individual polygons are relatively small (~8–15 m across).
Low-centered, Low-relief, Low-density Polygons	Low-centered polygons are composed of a low-lying, often wet or flooded "center" surrounded by a “rim” that separates the center from adjacent polygons. Rims are underlain by ice wedges. Low-centered polygons in this class have rims less than 50 cm in height with respect to centers. High-relief polygons are more likely to have well-developed troughs between polygon rims. Relief can be accentuated by thaw settlement of the polygon center. Low-density polygons have rims greater than 50 cm tall, but the individual polygons are large (~15–30 m across). Larger polygons often are partially bisected by indistinct rims, which overlie newly-developing ice wedges.
Mixed High and Low-centered Polygons	This class contains elements of both high- and low- centered polygons and is characterized by flooded, often deep (2 m) thermokarst pits at the intersections of polygon troughs. The pits form due to thaw of the uppermost parts of ice wedges, resulting in surface subsidence.
Mixed Thermokarst Pits and Polygons	This class contains elements of both high- and low- centered polygons and is characterized by flooded, often deep (2 m) thermokarst pits at the intersections of polygon troughs. The pits form due to thaw of the uppermost parts of ice wedges, resulting in surface subsidence.
Nonpatterned	Flat areas that lack microtopographic features. Microtopographic features may be present, but these occur irregularly and compose less than 5% of the surface area.
Polygonized Pond Margins	A distinctive feature of pond shorelines formed when polygon centers merge with the adjacent pond leaving the elevated rims as peninsulas extending into the waterbody. This class is appropriate when at least 10% of the shore is polygonized, islands also may be present.
Polygon Rims*	Low (<1 m high), narrow (<0.5 m wide) ridges formed by ice wedges and bounding low-centered polygons.
Polygon Troughs*	Shallow (<1 m deep), linear (<50 cm wide) depressions developing above ice wedges and separating raised rims at the edges of adjacent polygons.
Ripples*	A variety of small (<30 cm wide), low (<10 cm high), roughly triangular-shaped bed forms. Ripples develop in geomorphically active environments due to the interaction of wind or flowing water with a mobile substrate (most commonly sand-sized sediment).

Appendix H. Continued.

Surface Form Class	Description
Riverine Complex	Mosaic of 3 or more surface forms occurring in floodplains where no form is dominant and patches are too small to map individually based on the minimum map unit size.
Small Dunes*	Elongated mounds or low ridges composed of wind-blown sand. Individual dunes are typically less than 1 m high and 2 m long.
Strang	Roughly parallel, narrow ridges of peat characteristic of string bogs. The ridges are dominated by peat vegetation and interspersed with slight depressions, many of which contain shallow pools. The ridges are at right angles to low (<2°) slopes. They are typically 1–3 m wide, up to 1 m high and may be over 1 km long. The ridges are slightly elevated and are better drained allowing shrubs to grow.
Thermokarst Troughs*	Relatively short (<15 m long), linear (<50 cm wide) depressions associated with degrading ice-wedge polygons. Thawing of the underlying ice wedges results in surface subsidence and flooding of the troughs.
Undifferentiated Mounds	Isolated, but repeating low mounds that are not clearly attributable to specific geomorphic or periglacial processes.
Water	Permanent waterbodies.
Water Tracks	Linear to curvilinear non-incised channels that are expressed as saturated stripes across hillslopes in permafrost environments. Water flows subsurface and is confined to the active layer (<1 m due to the presence of impermeable continuous permafrost.
Wind Scour Depressions*	Barren or partially vegetated areas in which the soils have been eroded by wind scour, resulting in small (<3 m long and wide, <1 m deep) concavities in the soil surface. These areas lack a resistant soil layer (e.g., gravels) in the upper meter of the soil profile, and thus are prone to ongoing erosion over time. As vegetation develops, these surfaces may eventually become stable, if enough time passes between catastrophic wind events that can trigger erosion.

* Class described in field but not mapped.

Appendix I. Classification and description of vegetation classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Vegetation Class	Description
Aquatic Algae	This class includes ponds and small lakes in which the surface water has drained or evaporated leaving the bottom of the former pond or lake exposed. The lacustrine sediments are covered with a layer of benthic algae that is typically reddish-orange in color. Widely scattered sedges may be present but total live vascular cover is <5%. Surface water is absent or patchy, and water, when present is typically <0.15 m deep.
Barren	This class includes non-vegetated surfaces that are either too recently deposited, too frequently disturbed, or too exposed to support more than a few pioneering plants (<5% live cover).
Bearberry Dwarf Shrub Tundra*	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. *Arctous rubra* or *A. alpina* are the dominant shrubs. Ericaceous shrubs and dwarf willows may also be abundant or even codominant. This class occurs in arctic and alpine tundra where it occupies moderately exposed sites.
Cassiope Dwarf Shrub Tundra	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. *Cassiope* is the dominant shrub. This class occurs in arctic and alpine tundra and is commonly associated with snowbed microsites.
Closed Low Willow	This class has ≥75% cover of low shrubs (0.2–1.5 m), trees are absent, and shrubs ≥1.5 m in height provide <25% cover. Willows (*Salix*) are the dominant shrub. The understory may include a variety of herbs and mosses, but the abundance and diversity of understory plants tends to be lower than in Open Low Willow. This is because the closed canopy reduces the amount of sunlight reaching the understory making for less optimal growing conditions. This class occurs in a wide range of environments and landscape positions.
Common Marestail*	This class is dominated by Hippuris vulgaris. It occurs in permanently flooded depressions, shallow ponds, lake margins, and at the edges of slow moving streams. Water depth is ≥0.15 m. Patch sizes are typically small (<0.10 ha).
Dryas Dwarf Shrub Tundra	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. *Dryas* is the dominant shrub and the combined cover by lifeform for sedges, forbs, and lichens are all <15%. This class occurs on exposed sites in arctic and alpine tundra, and on river bars in the boreal zone.
Dryas-Forb Dwarf Shrub Tundra*	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. *Dryas* is the dominant shrub and forbs are abundant (≥15%) and conspicuous lending to high species diversity. This class occurs on exposed sites in arctic and alpine tundra.
Dryas-Lichen Dwarf Shrub Tundra*	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. *Dryas* is the dominant shrub and fruticose lichens are abundant (>15%) and form a conspicuous ground cover between the dwarf shrubs. The vegetation cover is usually discontinuous, but species diversity is high. This class occurs on exposed sites in arctic and alpine tundra.

Appendix I. Continued.

Vegetation Class	Description
Dryas-Sedge Dwarf Shrub Tundra*	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. Dryas is the dominant shrub and sedges (*Carex*, *Kobresia*) are abundant (≥15% cover). Species diversity is typically high and includes a variety of herbs, mosses, and lichens occurring at relatively low cover. This class occurs on sheltered sites in mesic tundra.
Dune Complex	This complex class was not described in the field, but was used for mapping a mosaic of several vegetation types associated with active and inactive dunes on meandering river floodplains, where narrow ridges and swales are smaller than the minimum map unit size. Vegetation is patchily distributed on dune surfaces of varying age and activity; recent dune blowouts are common. A variety of herbaceous and shrub communities occur in moist to wet swales, while moist to dry, sandy dunes are typically Barren or Partially Vegetated.
Ericaceous Dwarf Shrub Tundra	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. Ericaceous shrubs are the most abundant, but no single species is dominant. Total cover of fruticose and crustose lichens is <15%. This class occurs in arctic and alpine tundra where it occupies moderately exposed sites.
Fresh Grass Marsh	This class is dominated by the aquatic emergent grass *Arctophila fulva*. It occurs in shallow ponds, lake margins, and at the edges of slow moving streams. Water depth is ≥0.15 m. Patch sizes are typically small (<0.10 ha).
Fresh Herb Marsh*	This class is dominated by a variety of aquatic and semi-aquatic forbs, sedges, and grasses, and no single genus or species is dominant. Aquatic mosses are common. This class occurs in permanently flooded sites such as shallow ponds, lake margins, and slow-moving streams. Water depth is ≥0.15 m. Patch size is typically small (<0.10 ha).
Fresh Sedge Marsh	This class is dominated by a variety of sedges (e.g., *Carex*, *Eriophorum*). Aquatic herbs are commonly present but rarely contribute much biomass. Aquatic mosses are common. This class occurs in permanently flooded sites such as shallow ponds, lake margins, and slow-moving streams. Water depth is ≥0.15 m.
Fresh Water	This class consists of permanently flooded, non-vegetated freshwater (electrical conductivity <800 µS) waterbodies, including shallow and deep lakes, ponds, rivers, and low-order streams. Areas mapped as Fresh Water may include some partially vegetated waterbodies where aquatic vegetation is submerged and therefore not discernable in high-resolution imagery.
Mesic Shrub Birch-Willow-Ericaceous	This class was not described in the field, but was used for mapping the combined distribution of Open Low Mesic Shrub Birch–Ericaceous Shrub and Open Low Shrub Birch–Willow; two classes that were described in the field. The 2 classes have a similar color signature making it difficult to distinguish between them in the high-resolution imagery. For additional details please refer to the descriptions for the individual classes.

Appendix I. Continued.

Vegetation Class	Description
Moist Grass-Herb Meadow Tundra*	This class is codominated by grasses (e.g., *Arctagrostis*, *Festuca*, *Bromus*), and forbs (e.g., *Artemisia*) and/or horsetails (*Equisetum*). Sedges may be present but are not codominant with grasses. Trees are absent and combined shrub cover is <10%. This class occurs on mesic sites in arctic and alpine tundra.
Moist Sedge-Dryas Tundra*	This class is dominated by sedges (e.g., *Carex*, *Eriophorum*, *Kobresia* and ≥50% of the shrub cover is contributed by *Dryas*. Willows and ericaceous shrubs may be minor components of the vegetation. Trees are absent, combined cover of low shrubs is 10–24%, and combined cover of low and dwarf shrubs is 10–34%. Feather mosses are common and may form a nearly continuous mat. This class occurs on mesic sites in arctic and alpine tundra.
Moist Sedge Meadow Tundra*	This class is dominated by sedges (e.g., *Carex*, *Eriophorum*), trees are absent, and shrub cover is <10%. This class occurs on mesic sites in arctic and alpine tundra.
Moist Sedge-Shrub Tundra	This class is dominated by sedges (e.g., *Carex*, *Eriophorum*, *Kobresia* and no single shrub genus or species contributes ≥50% of the total shrub cover. Trees are absent, combined cover of low shrubs is 10–24%, and combined cover of low and dwarf shrubs is 10–34%. Feather mosses are common and may form a nearly continuous mat. This class occurs on mesic sites in arctic and alpine tundra. This class is most commonly applied in the office for mapping vegetation, but may also be applied in the field when the dominant shrub is not definitive.
Moist Sedge-Willow Tundra*	This class is dominated by sedges (e.g., *Carex*, *Eriophorum*) and greater than 50% of the shrub cover is contributed by *Salix*. Other shrubs may be present but are usually minor components of the vegetation. Trees are absent, combined cover of low shrubs is 10–24%, and combined cover of low and dwarf shrubs is 10–34%. Feather mosses are common and may form a nearly continuous mat. This class occurs on mesic sites in arctic and alpine tundra.
Old Basin Wetland Complex	This complex class was not described in the field, but was used for mapping a mosaic of several vegetation types occurring in older drained thaw lake basins with low-centered polygons. No one class is dominant and patches of individual types are smaller than the minimum map unit size. These complexes typically include a combination of Wet Sedge Meadow Tundra, Moist Sedge-Shrub Tundra, and Fresh Water. Fresh Grass Marsh and Fresh Sedge Marsh occur less commonly.
Open Low Mesic Shrub Birch-Ericaceous Shrub*	This class has 25–74% cover of low shrubs (0.2–1.5 m), trees are absent, and shrubs ≥1.5 m in height provide <25% cover. Birch (*Betula*) shrubs are dominant. Ericaceous shrubs such as *Ledum decumbens*, *Vaccinium uliginosum*, *V. vitis-idaea*, and *Cassiope* are common and may be codominant with the shrub birches. The understory typically includes a variety of graminoids and feather mosses. This class occurs in a wide range of environments and landscape positions.
Open Low Shrub Birch-Willow*	This class has 25–74% cover of low shrubs (0.2–1.5 m), trees are absent, and shrubs ≥1.5 m in height provide <25% cover. Birch (*Betula*) shrubs are co-dominant with willows (*Salix*). Ericaceous

Vegetation Class	Description
	shrubs such as *Ledum decumbens*, *Vaccinium uliginosum*, *V. vitis-idaea*, and *Cassiope* are common. A continuous moss mat composed primarily of feather mosses is characteristic of this class. This class occurs in a wide range of environments and landscape positions.
Open Low Willow	This class has 25–74% cover of low shrubs (0.2–1.5 m), trees are absent, and shrubs ≥1.5 m in height provide <25% cover. Willows (*Salix*) are the dominant shrub. The understory often includes a variety of herbs and species richness and diversity is typically high. This class occurs in a wide range of environments and landscape positions.
Open Low Willow-Sedge Shrub Tundra	This class has 25–74% cover of low shrubs (0.2–1.5 m), trees are absent, and shrubs ≥1.5 m in height provide <25% cover. Willows (*Salix*) are the dominant shrub and cover of hydrophytic sedges is ≥15%. This class occurs in a wide range of environments and landscape positions.
Open Mixed Low Shrub-Sedge Tussock Tundra*	The class has ≥25% cover of low shrubs (0.2–1.5 m or ≥35% combined cover of low and dwarf shrubs and total shrub cover is <75%. Trees are absent, and shrubs ≥1.5 m in height provide <25% cover. The herbaceous layer is dominated by the tussock-forming sedges *Eriophorum vaginatum* and *Carex bigelowii. Carex bigelowii* tends to dominate on steeper, better drained, and less acid soils than *Eriophorum vaginatum*. Cover of live tussocks is typically ≥5% and combined foliar cover of sedges is typically ≥15%. This class tends to develop in old landscape positions that have not experienced recent disturbance.
Open Tall Willow	This class has 25–74% cover of tall shrubs ≥1.5 m), and trees are absent. Willows (*Salix*) are the dominant shrub. The understory often includes a variety of herbs and species richness and diversity is typically high. This class occurs in a wide range of environments and landscape positions.
Partially Vegetated	This class includes partially vegetated (5–30% cover) surfaces that are too unstable or exposed to support continuous cover of vegetation.
Riverine Complex	This complex class was not described in the field, but was used for mapping permanently flooded channels and narrow bands or patches of riparian vegetation that are smaller than the minimum map unit size. The distribution of vegetation types within the complex reflects local differences in the degree and frequency of flooding. Common vegetation classes include Barren and Partially Vegetated point bars, and a variety of mesic and wet herbaceous and shrub classes.
Seral Herbs	This class includes early successional plant communities dominated by pioneering grasses and forbs, typically found on recently disturbed sites. Vegetation is typically discontinuous, but with total live cover >30%. Though biomass and cover are relatively low, diversity often is high. This vegetation class is seral and does not persist at any one site for more than a few years unless disturbance is renewed.

Appendix I. Continued.

Vegetation Class	Description
Tussock Tundra	This class is dominated by the tussock-forming sedges *Eriophorum vaginatum* and *Carex bigelowii*. *Carex bigelowii* tends to dominate on steeper, better drained, and less acid soils. Cover of live tussocks is typically >5% and combined foliar cover of sedges is typically >15%. Trees are absent, and shrubs are common, but the total live cover of low shrubs is <25%, and the combined live cover of dwarf and low shrubs is <35%. The species composition of plants growing among the tussocks varies depending on soil pH, and often overlaps with Moist Sedge–Shrub Tundra. Tussock Tundra tends to develop in old landscape positions that have not experienced recent disturbance.
Tussock Tundra-Dryas*	This class is a specific type of Tussock Tundra in which the shrub component is dominated by Dryas and soil chemistry is circumneutral.
Tussock Tundra-Ericaceous*	This class is a specific type of Tussock Tundra in which the shrub component is dominated by ericaceous shrubs and soil chemistry is acidic.
Wet Sedge-Birch Tundra*	This class is co-dominated by hydrophytic sedges (e.g., *Carex*, *Eriophorum*) and birch (*Betula*) shrubs. Trees are absent, combined cover of low shrubs is 10–24%, and combined cover of low and dwarf shrubs is 10–34%. This class is found in low-lying, poorly drained areas. Shrubs are usually concentrated on mesic microsites in areas that are otherwise wet.
Wet Sedge Meadow Tundra	This herbaceous class is dominated by hydrophytic sedges (e.g., *Carex*, *Eriophorum*), trees are absent, and shrub cover is <10%. Associated species include a variety of forbs, shrubs, and mosses tolerant of saturated soils. This class is found in low-lying, poorly drained areas.
Wet Sedge-Willow Tundra	This class is co-dominated by hydrophytic sedges (e.g., *Carex*, *Eriophorum*) and *Salix*. Trees are absent, and combined cover of low shrubs is 10–24% and combined cover of low and dwarf shrubs is 10–34%. This class is found in low-lying, poorly drained areas. Shrubs are usually concentrated on mesic microsites in areas that are otherwise wet.
Willow Dwarf Shrub Tundra*	This class has ≥25% cover of dwarf shrubs <0.2 m height , trees are absent, and shrubs ≥0.2 m in height provide <25% cover. Dwarf willows (*Salix*) are the dominant shrub. Ericaceous and other dwarf shrubs are often present and may be codominant. Species diversity tends to be high and a variety of forbs are often present. This class occurs in arctic and alpine tundra on a variety of sites from sheltered to exposed.
Young Basin Wetland Complex	This complex class was not described in the field, but was used for mapping a mosaic of several vegetation types occurring in recently drained lake basins. No one class is dominant and patches of individual types are smaller than the minimum map unit size. These complexes typically include a mosaic of Fresh Water, Fresh Sedge and Grass Marshes, Wet Sedge Meadow, and a variety of mesic classes.

* Class described in field but not mapped.

Appendix J. Classification and description of disturbance classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Disturbance Class	Description
Absent	No evidence of recent (within ~5–10 years) disturbance. Sites that are in perpetually disturbed areas (e.g., active river bars, active dune, etc.) are not described as disturbed unless the disturbance is outside of the inherent disturbance regime.
Animals, Wildlife*	A generalized class that encompasses alterations to natural vegetation and/or soils that results from animal activities (e.g., browsing).
Eolian (Wind)	This category refers to disturbance of vegetation and soils by the forces of wind (e.g., erosion pavements).
Fluvial Deposition*	Fluvial disturbance processes along active river channels and overbanks that result in the deposition of sediment at the soil surface. Active channel surface deposits are primarily made of bed-material transport (sand to cobble-sized particles) and overbank deposits tend to be fine sediment deposits (sand, silt, and clay).
Fluvial erosion/Channel migration	Fluvial disturbance processes along active river channels and overbanks that result in the removal and downstream transport of sediment at the soil surface. Fluvial erosion may occur vertically (i.e., downcutting) or laterally (i.e., bank erosion).
Fluvial (undifferentiated)	A generalized class that encompasses all natural disturbances related to flowing waters in and along streams and rivers, including sedimentation, erosion, and channel migration. Disturbances can be annual (e.g., flooding of active channels during peak flow in spring), but episodic events (e.g., large floods with low return periods) can affect much larger areas.
Geomorphic Process*	A generalized class that encompasses all natural disturbances related to geomorphic processes (e.g., fluvial erosion).
Gravel Pad	Human disturbance resulting from the deposition of gravel or other fill material for the purpose of constructing gravel pads.
Mammal excavations*	Disturbance to vegetation and soils resulting from digging or burrowing by animals. This type of disturbance may be evident from above (e.g, grizzly bear excavations) or below (e.g., bioturbation) the soil surface.
Natural*	A generalized class that encompasses one, or a combination of, biotic (e.g., pests and pathogens, exotic species invasion, etc.) or abiotic (e.g., weather, wildfire, etc.) agents that result in pronounced changes to ecosystems.
Thermokarst*	Ground surface subsidence following thaw of ice-rich permafrost.
Trail (undifferentiated)	A generalized class that encompasses trails of any origin, or for any intended use. Recreational trails may be paved or bare soil. Vehicular trails are typically produced by seismic exploration activities. Vegetation recovery varies widely by vegetation type, management objective, and the season in which the trail is primarily used.

*Class described in field but not mapped.

Appendix K. Classification and description of ecotypes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Ecotype	Description
Beaded Stream	Beaded Streams are low-gradient freshwater streams with a distinctive morphology that consists of deep pools connected by short, shallow runs, resembling beads on a string. The streams are formed by thermal erosion of subsurface ice wedges in polygonal ground. The pools may be several meters deep and can remain unfrozen throughout the winter. The water chemistry is circumneutral with low electrical conductivity.
Human Modified Dwarf Scrub	Human Modified Dwarf Scrub includes dwarf shrub-dominated plant communities that are temporarily or permanently affected by human activities (e.g., seismic trails).
Human Modified Moist Meadow	Human Modified Moist Meadow includes moist meadow plant communities that are temporarily or permanently affected by human activities (e.g., seismic trails).
Human Modified Wet Meadow	Human Modified Wet Meadow includes wet meadow plant communities that are temporarily or permanently affected by human activities (e.g., seismic trails).
Lacustrine Aquatic Barrens	Lacustrine Aquatic Barrens are typically found within recently drained lake basins, or along the margins of shallow waterbodies that become gradually exposed as surface water evaporates over the summer. Water depth is typically <0.15 m and the light, flocculent sediments are covered with a layer of benthic algae. Soils are very poorly drained and remain wet throughout summer. Scattered sedges such as *Carex aquatilis* may be present.
Lacustrine Basin Complex	Lacustrine Basin Complexes occur in young drained lake basins in which ice-wedge development has not been sufficient to produce extensive polygonal ground. This class is characterized by a mosaic of ecotypes in which at least three ecotypes occur together and no single class is dominant. Basins often have distinct rims marking the location of old shorelines, but these boundaries may be indistinct due to the coalescence of multiple basins. Lacustrine Basin Complexes typically are flooded during early spring and water remains close to the soil surface throughout the growing season. Soils generally are circumneutral with thin to intermediate (5–20 cm) surface organic horizons. Ecotype classes commonly found in this complex include Lacustrine Grass Marsh, Lacustrine Sedge Marsh, Lacustrine Wet Sedge Meadow, Lacustrine Moist Sedge-Shrub Meadow, Lacustrine Moist Low Willow Shrub, and Lowland Lake.
Lacustrine Grass Marsh	Lacustrine Grass Marshes are characterized by the emergent grass *Arctophila fulva* growing in shallow ponds and along lake margins. *Hippuris vulgaris* and *Carex aquatilis* may also be present. This distinctive ecotype is particularly common in remnant waterbodies within young drained lake basins. Water depth is usually <1 m. Water chemistry is circumneutral to alkaline. The underlying lake sediments have a surface organic horizon of variable thickness (10–40 cm).
Lacustrine Moist Barrens	Lacustrine Moist Barrens (<30% live cover) occur on ice-poor drained basin deposits. The surface tends to be non-patterned, but can be shaped by eolian processes into small active dunes over time. The dominant texture is associated with the parent material, and ranges from sandy on the sandsheet, to sandy or loamy in Marine-Alluvial deposits. The moderately well-drained soils are moist, circumneutral to brackish, and sandy, with little to no organic accumulation. The depth to permafrost is typically >50 cm below the soil surface.

Appendix K. Continued.

Ecotype	Description
Lacustrine Moist Low Willow Shrub	Lacustrine Moist Low Willow Shrub occurs on mesic microsites within recently drained lake basins. The vegetation is characterized by low (0.2–1.5 m) willows such as *Salix pulchra* or *S. richardsonii*. Typical understory plants include *Eriophorum angustifolium*, *Carex aquatilis*, and the mosses *Tomentypnum nitens* and *Aulacomnium turgidum*. Soils are circumneutral, sandy, and somewhat poorly drained, with thin to moderately thick surface organic horizons (5–15 cm) and intermediate to deep active layers (40–80 cm).
Lacustrine Moist Sedge-Shrub Meadow	Lacustrine Moist Sedge-Shrub Meadow occurs in young drained lake basins, typically in association with nonpatterned ground or ice-cored mounds. Dwarf shrubs (e.g., *Dryas integrifolia* and *Salix reticulata*) and sedges (e.g., *Carex aquatilis* and *C. bigelowii*) are codominant. Common associates include *S. pulchra*, *S. rotundifolia*, *Eriophorum angustifolium*, and the mosses *Tomentypnum nitens* and *Hylocomium splendens*. Soils are somewhat poorly drained and circumneutral pH, with thin to moderately thick (10–20 cm) surface organic horizons and intermediate active layers (40–60 cm). Surface water is lacking but groundwater is present below 15 cm.
Upland Dry Grass Meadow	Upland Dry Grass Meadow occurs on eolian active sand dunes and on ice-poor centers in drained lake basins. Soils range from dry to moist and are typically well drained with a depth to permafrost >75 cm below the soil surface. The sandy soils in this ecotype range from circumneutral to alkaline, with very thin (0.5–5 cm) to no surface organic matter accumulation at the surface. Common plants include *Arctagrostis latifolia*, *Elymus mollis*, *Festuca arctica*, *Bromus pumpellianus*, *Artemisia tilesii*, *A. borealis*, *Equisetum arvense*, and *Epilobium latifolium*.

Appendix L. Classification and description of National Wetland Inventory classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

NWI Code	Description
L1UBH	L1UBH includes all waterbodies >20 acres in size regardless of the water depth. The majority of the large waterbodies, however, are deep, limnetic systems. Lakes occur throughout the mapping area as large, connected or isolated basins, and as impounded, abandoned riverine depressions.
L2EM2H	L2EM2H is used to delineate fresh grass marshes occuring in the littoral zone of lakes. L2EM2H is a permanently flooded aquatic type that can be identified with photo interpretation when the dominant plant (*Arctophila fulva*) is at the emergent stage in its growth cycle. Because *A. fulva* is a non-persistent aquatic plant, the detection of this type with photo-interpretation is dependent on the timing of photography; thus, the full extent of L2EM2H wetlands may not be represented in the mapping. Other aquatic plants that may co-occur with *A. fulva* are *Hippuris vulgaris* and *Sparganium angustifolium*.
PUBH	PUBH includes all shallow open waterbodies <20 acres in size. Shallow waters (defined in the ITU mapping protocols as <1.5 m in depth) are identified through photo-interpretation. These waterbodies typically occur within drained lake basins as components of extensive wetland complexes or are waters on inactive or abandoned floodplain geomorphic types that may or may not be connected to the neighboring riverine waters.
PUSC	PUSC are seasonally flooded depressions in the landscape, often recently drained lakes or shallow ponds that have water some years but not others.
R2UBH	R2UBH includes all flowing waters that have permanent flow at least throughout the growing season. This type includes small beaded streams, sinuous headwater streams, and larger perennial rivers including Fish and Judy Creeks.
R2USC	R2USC is an unvegetated type located on mid- and side-channel bars adjacent to perennial streams. This barren type has hydrologic indicators of frequent flood events occurring throughout the growing season. The water table is usually very near the surface.
PEM2H	PEM2H is composed of fresh grass marshes confined to the margins of ponds and depressions in drained lake basins. PEM2H is a permanently flooded aquatic type that can be identified by photo-interpretation when the dominant plant (*Arctophila fulva*) is at the emergent stage in its growth cycle. Because *A. fulva* is a non-persistent aquatic plant, the detection of this type with photo-interpretation is dependent on the timing of photography; thus, the full extent of PEM2H wetlands may not be represented in the mapping. Other aquatic plants that may co-occur with *A. fulva* are *Hippuris vulgaris* and *Sparganium angustifolium*.
PEM1H	PEM1H includes fresh sedge marshes that occur on the margins of open waterbodies, in wet depressions within drained lake basins, and in riparian areas. Sedge marshes are most commonly non-patterned but occasionally have evidence of permafrost including strangmoor, low-centered polygons, or disjunct polygon rims. PEM1H is dominated primarily by sedges and grasses including *Carex aquatilis*, *Arctophila fulva*, *C. chordorrhiza*, and *Eriophorum angustifolium*. Surface water is almost always present and hydric soils are assumed in this flooded type.

Appendix L. Continued.

NWI Code	Description
PEM1F	PEM1F is composed of wet sedge meadows and is typically found in low-lying areas within drained basins or is associated with active riverine corridors. PEM1F typically is flooded with a shallow active layer and surface indicators of permafrost including low-centered polygons and strangmoor, as well as non-patterned ground. The plant community is dominated by sedges including *Carex aquatilis*, *C. chordorrhiza*, and *Eriophorum angustifolium*. Dwarf or low shrubs including *Salix pulchra*, *Betula nana*, and *Andromeda polifolia* may be present in low numbers. The most common hydric soil indicator is a histosol.
PEM1/SS1F	PEM1/SS1F is used to describe drained lake basin complexes that include small open waterbodies, wet sedge meadow and marsh, and moist graminoid tundra. Wetlands and waters within basin depressions are often finely integrated and likely ecologically similar in functional characteristics, which are driven largely by the depressional hydrogeomorphic class. The integrated vegetation communities and complex patterning of surface features is a result of differential permafrost melt and aggradation. A diversity of hydric soil indicators occur in the various types within this complex.
PEM1/SS1D	Floristically, PEM1/SS1D is approximately equivalent to PEM1/SS1B. PEM1/SS1D is distinguished by the presence of small patches of surface water that accumulate in thermokarst pits and low-lying troughs between high-centered polygons. The surface water persists throughout the growing season and the polygon centers remain saturated to the surface. The predominant hydric soil indicator for PEM1/SS1D is a histic epipedon.
PEM1/SS1E	PEM1/SS1E is used to describe riverine complexes that include wet sedge meadows and marshes, riverine barrens, and moist tundra occurring on active and inactive riverine geomorphic features. These complexes are mapped where the riparian communities are finely integrated and likely ecologically similar in functional characteristics, which are driven largely by riverine processes. A diversity of hydric soil indicators occur in the various types within this complex.
PEM1/SS1B	PEM1/SS1B includes moist sedge-shrub tundra, moist tussock tundra, and low open tussock-shrub tundra. The photo signatures for these communities are very similar and almost indistinguishable. These are moist communities typified by the lack of extensive surface water. The seasonally saturated hydrologic regime is characteristic of moist communities that have soils saturated to the surface in the early growing season that tend to dry out by the end of the growing season. The plant communities are dominated by *Eriophorum vaginatum*, *Carex bigelowii*, *E. angustifolium*, and *C. aquatilis*, with codominant dwarf or low shrubs including *Dryas integrifolia*, *Betula nana*, *Salix reticulata*, and *S. pulchra*. Hydric soil indicators include histosols, histic epipedons, and problematic Alaska Redox with 2.5Y Hue.
PSS1D	PSS1D was not sampled during the field survey but was identified based on an assessment of the combination of mapped vegetation types and surface form features. Vegetation types include dwarf ericaceous shrub tundra and low open birch-willow-ericaceous shrub communities. These vegetation types occur on high-centered, high-relief polygons or on high-centered polygons intermixed with thermokarst pits, which account for the numerous low depressions filled with permanent surface water. Based on data from similar field plots, the plant dominants are likely to include *Salix pulchra*, *S. reticulatata*, *S. richardsonii*, *Dryas integrifolia*, and *Cassiope tetragona*. The low-lying troughs most likely support *Carex aquatilis* and *Eriophorum angustifolium*. Well-developed organic layers with persistent saturation are expected in the PSS1D wetland type with the dominant hydric soil indicator being a histosol.

Appendix L. Continued.

NWI Code	Description
PSS1B	PSS1B includes dwarf willow, low willow, and birch-ericaceous shrub communities. PSS1B occurs in various landscape positions on sand sheet, marine deposit, drained lake basins, and riverine geomorphic features. This type is dominated by deciduous shrubs including *Salix richardsonii*, *S. reticulata*, *S. pulchra*, and *Betula nana*. Wetter areas support codominant sedges, including *Carex aquatilis*, *C. bigelowii*, and *Eriophorum angustifolium*. Non-jurisdictional upland areas are common within this wetland type, but for mapping purposes these were classified as wetlands because it was not possible to identify from aerial imagery the wetland/upland transitions occurring within the uniform shrub photo-signatures characteristic of this class. The primary hydric soil indicator in this class is a histic epipedon, and the primary wetland hydrology indicator is saturation (soils typically were saturated within 8 inches of the surface). Surface indicators of permafrost are limited and surface water is generally absent.
PSS3B	PSS3B includes moist dwarf shrub communities occurring on convex shallow ridges bordering drained lake basins or abandoned fluvial terraces. This type typically occurs on non-patterned ground with saturated soils and has very few surface indicators of permafrost. Areas of non-jurisdictional uplands occur regularly within this type but accurate wetland/upland boundaries cannot be determined from aerial imagery in the uniform dwarf shrub photo-signatures characteristic of this class, so all occurrences are assumed to be seasonally saturated wetlands. Dominant dwarf shrubs include *Cassiope tetragona*, *Dryas integrifolia*, *Salix reticulata*, *S. pulchra*, and *Betula nana*. *Carex bigelowii* is the dominant graminoid species and forbs (*Astragalus umbellatus* and *Oxytropis borealis*) can also be present in low numbers. A histic epipedon is the most common hydric soil indicator.
PSS1C	PSS1C is limited to low and tall willow communities on active and inactive fluvial geomorphic deposits. A subset of polygons mapped as PSS1C are non-jurisdictional uplands, but a seasonally flooded hydrologic regime is assumed for all these deciduous shrub communities occurring in geomorphic positions susceptible to flooding. The dominant willow species include *Salix alaxensis*, *S. richardsonii*, and *S. reticulata*. Understory graminoid dominants include *Festuca rubra* and *Juncus arcticus*. Hydric soils generally are problematic but can develop features consistent with the Alaska Redox indicator. Wetland hydrology indicators are commonly secondary indicators related to evidence of frequent flooding.
PSS1/USB	PSS1/USB describes a complex of interrelated types commonly occurring on active dune geomorphic features. Vegetation types include raised convex ridges supporting dwarf shrub or low willow communities, barren or partially vegetated sandy surfaces, and low-lying concave depressions supporting wet meadows or moist tundra communities. Areas of non-jurisdictional uplands may occur on the well-drained convex surfaces commonly found within this complex.
U	U includes all non-jurisdictional uplands. These typically occur on active and inactive dunes in riparian corridors, and on abandoned dunes and bluffs on the sand sheet. These features are reliably photo-interpreted throughout the study area, and field data for these features consistently indicates non-jurisdictional uplands. Active dunes are either partially vegetated or support low willow communities dominated by *Salix alaxensis*, with associated grasses such as *Bromus pumpellianus* and *Koeleria asiatica*. Abandoned dunes support dwarf shrub communities dominated by *Dryas integrifolia* and *Cassiope tetragona*, with associated graminoids such as *Anthoxanthum monticola* ssp. *alpinum*, *Carex scirpoidea*, and *Poa arctica*. Inactive dunes support either low willow and/or dwarf shrub communities as described for active and abandoned dunes. The sandy soils in this type do not meet any hydric soil indicators, and typically no wetland hydrology indicators are observed.

Appendix M. Classification and description of wildlife habitat classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Habitat	Description
Barrens	This habitat class includes barren (<5% plant cover) and partially vegetated (5–30% cover) areas. These habitats lack continuous plant cover due to high levels of exposure, frequent disturbance, or recent deposition of sediments. Barrens can occur in a variety of different landscape settings, particularly floodplains, eolian dunes, and recently drained lake basins. Where present, vegetation is usually dominated by early successional species, particularly grasses, forbs, and shrubs.
Deep Open Water with Islands or Polygonized Margins	Similar to Deep Open Water without Islands; this habitat consists of deep (≥1.5 m bodies of freshwater ranging in size from small ponds (<1 ha) to large open lakes (>100 ha). Emergent vegetation may be present along shorelines, but covers <5% of the surface. They do not freeze to the bottom during winter. To be included in this class, waterbodies must possess either an island that is >0.5 m in size and >2 m from shore, or complex shorelines in which the rims of thermally eroded low-centered polygons form a network of peninsulas and small islands. The presence of islands and/or complex shorelines provides more nesting opportunities for waterbirds than does Shallow Open Water without Islands.
Deep Open Water without Islands	Similar to Deep Open Water with Islands; this habitat consists of deep (≥1.5 m) bodies of freshwater ranging in size from small ponds (<1 ha) to large open lakes (>100 ha). They do not freeze to the bottom during winter. Many deep lakes originated from thawing of ice-rich sediments, while others are associated with abandoned river channels. The lack of islands and the less complex shorelines limit nesting opportunities for many waterbirds, compared to Deep Open Water with Islands.
Dry Dwarf Shrub	This habitat occurs on exposed, well drained landscape positions such as upland ridges, bluffs, river terraces, ice-rich basin centers, and pingos. The vegetation is dominated by dwarf shrubs, particularly Dryas integrifolia, but often including *Salix reticulata*, *S. rotundifolia*, *S. arctica*, and *Cassiope tetragona*. The sedges *Eriophorum vaginatum* and *Carex bigelowii*, the grass *Arctagrostis latifolia*, and lichens, also commonly occur. The soils generally have thin (<5 cm) surface organic horizons and deep (>100 cm) active layers.
Dry Tall Shrub	This habitat is usually found on floodplains; it is uncommon and patch sizes are generally small. The vegetation consists of tall (>1.5 m), open (25–75% live cover) stands of willows, typically dominated by Salix alaxensis and S. glauca. Common understory species include the shrubs *Arctous rubra*, *S. reticulata*, and *Dryas integrifolia* and diverse herbs such as *Lupinus arcticus*, *Astragalus* spp., and *Equisetum* spp. The well developed vertical structure of this plant community provides high-value foraging opportunities and cover for songbirds and mammals. Soils are sandy and well drained with deep (>100 cm) active layers. Surface organic horizons are typically thin (<5 cm) or absent due to frequent sediment deposition by fluvial or eolian processes.

Appendix M. Continued.

Habitat	Description
Dune Complex	This habitat typically occurs on the floodplains of meandering rivers. It is formed by the interaction of river flooding and eolian processes, which create a mosaic of narrow swales and ridges, oriented parallel to river flow. The individual habitat patches are too small to map individually. Soil moisture in swales ranges from moist to wet, while dune ridges are moist to dry. Habitat patches in swales typically consist of Moist Low Shrub, Nonpatterned Wet Meadow, or Sedge Marsh, while Dry Dwarf Shrub or Moist Low Shrub are most common on ridges.
Grass Marsh	Grass Marsh is a distinctive aquatic habitat found in shallow (typically <1 m) water. It usually occurs in narrow bands along lakeshores, but can form extensive patches in young, ice-poor drained lake basins. Vegetation is dominated by the emergent grass *Arctophila fulva*. The water freezes to the bottom in the winter and thaws by early June. Stem densities and annual productivity vary widely among sites, but vegetation is typically more productive than in Sedge Marsh. Grass Marsh tends to have abundant invertebrates and is important to many waterbirds for feeding and brood rearing.
Human Modified	This class includes a wide variety of habitats altered by human activity, ranging from gravel roads and pads to natural lakes and tundra affected by dust, ice roads, drainage impoundment, leachates, and disturbance-induced thermokarst.
Moist Dwarf Shrub	Moist Dwarf Shrub occurs on mesic sites on streambanks, bluffs, pingos, and lake margins. The evergreen dwarf shrub Cassiope tetragona is usually dominant, particularly at sites that with late-lying snowbanks. Vegetation is species-rich and frequently includes other shrubs (e.g., *Dryas integrifolia*, *Salix reticulata*, and *S. arctica*) and sedges such as *Carex bigelowii* and *C. membranacea*. Lichens and mosses also are common. Soils are moist, typically with moderately thick (10–20 cm) surface organic horizons, and thaw deeply (60–100 cm) in summer.
Moist Herb Meadow	Moist Herb Meadow is found on mesic upland sites such as the lower slopes of bluffs, often in association with late-lying snow, and riverine areas including unstable banks and river bars. Vegetation in uplands is dominated by a diverse assemblage of forbs; common species include *Polygonum bistorta*, *P. viviparum*, *Valeriana capitata*, and *Saussurea angustifolia*. In riverine areas, *Chrysanthemum bipinnatum* and *Equisetum arvense* are the dominant species. Other characteristic species include *Artemisia tilesii*, *Astragalus alpinus*, *Deschampsia caespitosa*, *Festuca rubra*, *Pedicularis verticillata*, *Salix alaxensis*, and *Wilhelmsia physodes*. Upland soils are typically loamy with moderately thick (10–20 cm) surface organic horizons, while soils in riverine areas are loamy–sandy with little to no surface organics.

Appendix M. Continued.

Habitat	Description
Moist Low Shrub	Moist Low Shrub is most common in riparian areas, where it often forms long, narrow belts. It can also occur on well drained sites outside floodplains, such as bluffs and high-centered, high-relief polygons within ice-rich drained lake basins. This habitat includes both open (25–75% low shrub cover) and closed (>75% cover) shrublands with canopy heights ranging 0.2–1.5 m in height. In riparian areas, willows such as *Salix richardsonii*, *S. glauca*, or *S. pulchra* usually dominate the shrub canopy, whereas *Betula nana* tends to be more important in polygonal ground. Understory vegetation is highly variable, but typically includes sedges (e.g., *Carex aquatilis*, *Eriophorum angustifolium*, *C. bigelowii)*, dwarf shrubs, and mosses. Soils vary considerably, from interbedded riverine deposits with thin (<5 cm) surface organic horizons and deep active layers, to loamy soils with moderately thick (5–20 cm) surface organic horizons and shallow thaw depths in polygonal ground.
Moist Sedge-Shrub Meadow	This habitat is widespread in a variety of landscape positions, particularly on moderately well drained soils on inactive and abandoned floodplains and in drained lake basins. Moist Sedge-Shrub Meadow can occur on a variety of surface forms, most commonly low-centered polygons and nonpatterned ground. Sedges (e.g., *Carex aquatilis*, *C. bigelowii*, and *Eriophorum angustifolium*) and dwarf shrubs (e.g., *Dryas integrifolia* and *Salix pulchra*) are codominant; however, the total shrub cover is ≤25%. Soils generally have moderately thick (5–20 cm) surface organic layers over silt loam or sands, with moderate active-layer thickness (50–70 cm). Soils may be saturated at intermediate depths (>15 cm) but surface water is generally absent except immediately after snowmelt.
Moist Tall Shrub	Moist Tall Shrub typically occurs on the active floodplains of meandering rivers, and occasionally forms stringers along beaded streams. This habitat consists of open (25–75% shrub cover) stands of tall (>1.5 m) willows; it is similar to Dry Tall Shrub but soils are less well drained and tend to be loamier. The shrub canopy is dominated by willows such as *Salix alaxensis*, S. *glauca*, and *S. pulchra*. Common understory species include a variety of low and dwarf shrubs, graminoids, and forbs. Moist Tall Shrub is limited in extent, but its well developed vertical structure provides high-value foraging opportunities and cover for songbirds and mammals.Soils range from sandy to loamy, with deep (>100 cm) active layers. Surface organic horizons are typically thin (<5 cm) or absent due to frequent sediment deposition.
Moist Tussock Tundra	Moist Tussock Tundra occurs on old, stable landscape positions such as alluvio-marine deposits, eolian sand sheet uplands, and the uplifted centers of older drained lake basins, usually in association with high-centered polygons. Vegetation is dominated by the tussock-forming sedge *Eriophorum vaginatum*. On acidic sites, typical associate species include *Ledum decumbens*, *Betula nana*, and *Vaccinium vitis-idaea*, while *Dryas integrifolia*, *Salix reticulata*, *Carex bigelowii*, and lichens are more common on circumneutral sites. Soils are mesic and loamy to sandy, typically with moderately thick (10–30 cm) surface organic horizons and shallow (<40 cm) active layers.

Appendix M. Continued.

Habitat	Description
Nonpatterned Wet Meadow	Nonpatterned Wet Meadows typically occur within young drained-lake basins, as narrow margins along receding waterbodies, or on inactive and abandoned floodplains that have not yet undergone extensive ice-wedge polygonization. The vegetation is strongly dominated by sedges, particularly *Carex aquatilis* and *Eriophorum angustifolium*. Hydrophytic mosses such as *Calliergon* and *Scorpidium* are also common. Dwarf willows (e.g., *Salix pulchra*) are often present but total shrub cover is <25%. This habitat lacks extensive microrelief and therefore provides fewer potential nest sites for waterbirds than Patterned Wet Meadow. The surface generally is flooded during early summer (depth <0.3 m) and drains as the season progresses, but soils remain saturated within 15 cm of the surface throughout the summer. The lack of microrelief in permits more lateral movement of soil water; therefore vegetation productivity tends to be higher than in Patterned Wet Meadows. Soils generally have moderately thick (10–30 cm) surface organic horizons and intermediate active layer depths (40–60 cm).
Old Basin Wetland Complex	Old Basin Wetland Complex occurs in lake basins that have been drained long enough for extensive ice-wedge polygons to develop. This habitat consists of a mosaic of terrestrial and aquatic habitats, where patch sizes are too small to map individually. Various polygonal surface forms are typically present, as well as inclusions of nonpatterned ground. Low-centered polygons tend to dominate the basin margins, but high-centered polygons often occur in the basin centers, where ice-wedge development proceeds more quickly. Complexes in basin margins generally include Patterned Wet Meadows, Moist Sedge–Shrub Meadows, and small (<0.25 ha) ponds. The waterbodies in Old Basin Wetland Complexes generally have smoother, more rectangular shorelines and are less interconnected than those in Young Basin Wetland Complexes. Habitats in basin centers generally include Moist Sedge–Shrub Meadows and Moist Tussock Tundra on high-centered polygons and Patterned Wet Meadows with low-centered polygons. Soil properties vary by microsite, but generally have moderately thick (10–30 m) surface organic layers and intermediate active-layers depths (40–60 cm).
Patterned Wet Meadow	Patterned Wet Meadows are very common in polygonized areas within drained lake basins and on abandoned floodplains. This habitat is closely associated with low-centered polygons and strang (undulating raised sod ridges). Water depth varies through the season, to a maximum of 0.3 m. The complex microtopography interrupts lateral movement of surface and soil water, so only interconnected polygon troughs receive downslope flow and dissolved nutrients; water input to polygon centers is limited to precipitation. As a result, vegetation growth typically is more robust in polygon troughs than in centers. Vegetation is dominated by sedges, usually *Carex aquatilis* and *Eriophorum angustifolium*. Other common sedges include *C. chordorrhiza*, *C. rotundata*, *C. saxatilis, C. membranacea*, and *E. russeolum*. Willows and other dwarf shrubs can be abundant on the mesic microsites formed by polygon rims. Soil properties vary by microsite; the wet polygon centers generally have intermediate to thick (20–40 cm) surface organic horizons and intermediate active-layer depths (40–60 cm).

Appendix M. Continued.

Habitat	Description
Riverine Complex	Riverine Complex occurs on active or inactive floodplain deposits and are characterized by a complex mosaic of shrub, meadow, marsh, and barren habitats occurring in patches that are too small (<0.5 ha) to map individually. Surface forms include nonpatterned ground, low-centered or mixed high- and low-centered polygons, old channels, and small (<0.25 ha) lakes. Riverine Complexes may be entirely inundated during peak river flows in spring. Soil properties vary considerably by microsite, but surface organic layers are typically thin (<5 cm) or absent and active-layers are often deep (>60 cm).
River or Stream	This habitat includes all permanently flooded river channels. Rivers generally experience peak flooding during spring breakup; the lowest water levels occur during mid-summer.
Sedge Marsh	Sedge Marsh occurs in shallow (≤0.3 m deep), permanently flooded areas, chiefly in ice-rich drained lake basins and along lakeshores. Vegetation is dominated by emergent sedges, chiefly *Carex aquatilis*. Water and bottom sediments freeze completely during winter, but the ice melts in early June. A moderately thick to thick layer of surface peat (0.2–0.5 m thick) is usually present. Sedge Marsh provides important nesting and brood-rearing habitat for many waterbirds.
Shallow Open Water with Islands or Polygonized Margins	Similar to Shallow Open Water without Islands, this habitat consists of shallow (<1.5 m deep) lakes and ponds, with emergent vegetation covering <5% of the surface. They freeze to the bottom during winter, thaw by early to mid-June, and reach maximum temperatures higher than those in deep water habitats. To be included in this class, waterbodies must possess either an island that is >0.5 m in size and >2 m from shore, or complex shorelines in which the rims of thermally eroded low-centered polygons form a network of peninsulas and small islands. The presence of islands and/or complex shorelines provides more nesting opportunities for waterbirds than does Shallow Open Water without Islands.
Shallow Open Water without Islands	Similar to Shallow Open Water with Islands, this habitat consists of shallow (<1.5 m deep) lakes and ponds, with emergent vegetation covering <5% of the surface. They freeze to the bottom during winter, thaw by early to mid-June, and reach maximum temperatures higher than those in deep water habitats. Due to less complex shorelines and lack of islands, Shallow Open Water without Islands provides fewer nesting opportunities for waterbirds than does Shallow Open Water with Islands.
Tapped Lake with High-water Connection	This habitat occurs primarily on river deltas, and consists of waterbodies that have been partially drained by erosion. It is similar to Tapped Lake with Low-water Connection, except that the connecting channels are dry during low water and the lakes are connected to river channels only during flooding events. Deeper lakes (≥1.5 m) in this habitat do not freeze to the bottom during winter. Water is usually fresh, but brackish water can enter tapped lakes during coastal storm events. Small deltaic fans are common near the connecting channels due to sediment deposition during seasonal flooding. These lakes provide important fish habitat.

Appendix M.   Continued.

Habitat	Description
Young Basin Wetland Complex	Young Basin Wetland Complexes occur in recently drained lake basins. This habitat consists of a mosaic of terrestrial and aquatic habitats, where patch sizes are too small to map individually. Nonpatterned ground typically dominates the terrestrial portions; ice-cored mounds may be present in basin centers, but ground-ice development is insufficient to produce extensive ice-wedge polygons. Deeper basins may be entirely inundated during spring breakup. Soils generally are fine-grained, organic-rich, and ice-poor. Vegetation in these young basins appears to be much more productive than in the Old Basin Wetland Complex habitat type.

Appendix N. Classification and description of aggregated soil great group map classes in the Willow Master Development Plan Area, National Petroleum Reserve-Alaska, 2017–2018.

Soil Great Group Map Class	Description
Aquorthels-Haploturbels-Histoturbels	The Aquorthels-Haploturbels-Histoturbels class characterizes soils in two distinct vegetation types, Moist Sedge Shrub Meadow and Tussock Tundra, which often occur in close proximity. This class characterizes both upland and lowland soils that occur on alluvial-marine or sandsheet deposits in areas of nonpatterned ground and high-center polygons. Of lesser extent, this class occurs in ice-rich drained basins and on older alluvial sediments outside of the 100 year floodplain (e.g., abandoned overbank and old alluvial terrace deposits). Aquorthels and Histoturbels occur on concave landscape positions and surface forms and represent the wet end of the soil moisture spectrum in this class. Soil drainage in these great groups ranges from very poorly to moderately well drained (Schoeneberger et al. 2012). Histoturbels are the oldest soils in this class and occur in areas that have not experienced recent disturbance. Haploturbels represent the drier end of the spectrum and occur on convex landscape positions and surface forms. Soil drainage in this great group ranges from moderately well to well drained. This class includes two map ecotypes: Lowland Moist Sedge-Shrub Meadow and Upland Moist Tussock Meadow.
Aquorthels-Historthels-Fibristels	The Aquorthels-Historthels-Fibristels class characterizes early soil development in ice-poor, recently drained lake basins with aquatic or wet soil moisture. Vegetation in this class is dominated by hydrophytic sedges in wet meadows and marshes.Aquorthels are associated with nonpatterned ground along the margins of drained lake basins. Historthelsare primarily associated with nonpatterned ground or low-centered polygons. Fibristels are associated with patterned ground such as disjunct polygon rims, low- and high-centered polygons, and strang bog. This class includes five map ecotypes: Lacustrine Aquatic Barrens, Lacustrine Grass Marsh, Lacustrine Sedge Marsh, Lacustrine Wet Sedge Meadow, and Lowland Sedge Marsh. This class differs from the Gelaquents-Aquorthels-Haplorthels class by having soils with thicker accumulations of organic matter and poorer drainage, and by a paucity of shrubs.
Aquorthels-Historthels-Fibristels-Water	The Aquorthels-Historthels-Fibristels-Water class characterizes portions of drained lake basins with complex surface form and vegetation. No single surface form or vegetation type is dominant and patches of individual types are smaller than the minimum map unit size. Spatial heterogeneity exists for vegetation cover, hydrology, and soil both within a single drained basin, and across adjacent drained lake basins, and as such the relative proportion of soil classes in this map unit varies across the landscape. Aquorthels in this class are associated with wet basin margins in areas of nonpatterned ground and disjunct polygon rims in ice-poor basins. Historthels are primarily associated with nonpatterned ground or low-centered polygons in ice-rich basins, but may also occur on non-patterned ground in ice-poor basins. Fibristels are most often associated with low-centered polygons and strang bog in ice-rich basins. Water occurs in small lakes and ponds. This class includes the Lacustrine Basin Complex and Lowland Basin Complex map ecotypes.

Appendix N. Continued.

Soil Great Group Map Class	Description
Aquorthels-Historthels-Histoturbels	The Aquorthels-Historthels-Histoturbels class characterizes wet, organic-rich soils occurring in riverine physiography on inactive overbank deposits dominated by hydrophytic sedges. Soils in this class are formed from alluvial sediments on infrequently flooded geomorphic surfaces that have had sufficient time for ice aggradation and development of low-center polygons. Aquorthels are the least developed soils in this class and occur in areas with more frequent flooding and sedimentation than Historthels and Histoturbels. This class includes two map ecotype classes: Riverine Wet Sedge Meadow and Riverine Wet Sedge-Willow.
Aquorthels-Psammorthels-Haplorthels	The Aquorthels-Psammorthels-Haplorthels class characterizes primary soil development in ice-poor, contemporary (<50 years ago) drained lake basins with moist to wet soil moisture conditions. This class occurs in barrens, partially vegetated, and moist/wet sedge (Eriophorum) meadow tundra communities. In all three great groups permafrost is present in the upper 2 m of the soil profile, surface organic layers range from absent to thin (5–14 cm), and very thin (0.5–5 cm) buried organic layers are common. Aquorthels are unique from the other 2 great groups in this class in that the water table is <50 cm below the soil surface throughout most or all of the growing season. Psammorthels and Haplorthels are on the drier end of the soil moisture spectrum. A water table may temporarily be present in the upper 50 cm of the soil profile for a short period early in the growing season. Haplorthels and Psammorthels differ primarily in their dominant mineral texture, with the former characterized by fine textures (finer than loamy fine sand) and the later characterized by coarse textures (loamy fine sand or coarser). Psammorthels are restricted to sandy geomorphic units (e.g., Eolian Sand Sheet Upland), while Haplorthels occur on a wide variety of geomorphic units.
Gelaquents-Aquorthels-Haplorthels	The Gelaquents-Aquorthels-Haplorthels class characterizes early soil development in ice-poor, recently drained lake basins with moist or wet soil moisture conditions. Gelaquents form on wet, basin margins in areas of non-patterned ground and ice-cored mounds. Aquorthels form on wet basin margins in areas of nonpatterned ground and disjunct polygon rims.Haplorthels form in moist isolated areas of fine-textured (i.e., very fine sandy loam and finer) lacustrine sediments that aggrade ice faster (e.g., ice-rich centers with high-center polygons) and are the least extensive great group in this class. This class includes Lacustrine Moist Low Willow Shrub and Lacustrine Moist Sedge-Shrub Meadow map ecotypes. This class differs from the Aquorthels-Historthels-Fibristels class by having soils with thinner accumulations of organic matter and better drainage, and by supporting extensive shrub cover.
Gelaquents-Aquorthels-Historthels	The Gelaquents-Aquorthels-Historthels class characterizes poorly developed soils forming in aquatic moisture conditions in riverine physiography. Soils in this class are associated with shallow ponds and margins of deep lakes; inactive channels with ponded water; and low-center, high-relief polygons on inactive overbank deposits. Gelaquents and Aquorthels occur in areas with more frequent flooding and sedimentation than Historthels. This class includes the Riverine Grass Marsh and Riverine Sedge Marsh map ecotypes.

Appendix N. Continued.

Soil Great Group Map Class	Description
Gelifluvents-Psammorthels-Haplorthels	The Gelifluvents-Psammorthels-Haplorthels class characterizes moist, weakly developed soils in mid-seral vegetation on active floodplains. Soils in this class are most often associated with inactive channel, and active and inactive overbank deposits along rivers and streams. When this class is located adjacent to active dunes soil properties reflect a combination of fluvial and eolian (wind) processes. Gelifluvents, the least developed soils in this class, are associated with partially vegetated areas and low and tall willow (Salix) on active and inactive channel deposits. Psammorthels are associated with coarse, frozen, sandy sediments on active and inactive overbank deposits in areas of low willow and Dryas dwarf shrub. Haplorthels are associated with fine-textured (i.e., very fine sandy loam and finer) frozen sediments on active and inactive overbank deposits in areas of low and tall willow. This class includes 5 map ecotypes; Riverine Dry Dryas Dwarf Shrub, Riverine Moist Low Willow Shrub, Riverine Moist Low Willow-Sedge Meadow, Riverine Sedge-Shrub Meadow, and Riverine Moist Tall Willow Shrub.
Gelifluvents-Quartzipsamments	The Gelifluvents-Quartzipsamments class characterizes poorly developed soils on active floodplains. Spatially this class is often located adjacent to active dunes where the soils often reflect a combination of fluvial and eolian (wind) processes. Quartzipsamments are associated with barrens or partially vegetated areas on active channel deposits. Gelifluvents are associated with early seral riverine vegetation on active channel and overbank deposits. This class includes the Riverine Moist Barrens and Riverine Moist Herb Meadow map ecotypes.
Gelifluvents-Quartzipsamments-Historthels-Water	The Gelifluvents-Quartzipsamments-Historthels-Water class characterizes areas along rivers with complex surface form and vegetation. No single surface form or vegetation type is dominant and patches of individual types are smaller than the minimum map unit size. This class encompasses active and inactive channel deposits, as well as active and inactive dunes. Quartzipsamments are associated with barrens or partially vegetated areas on active channel deposits. Quartzipsamments lack buried organic horizons and rarely have any accumulation of organic material at the surface. Gelifluvents in this class are most often associated with inactive or active channel deposits where the vegetation is dominated by willow (Salix). Historthels are most often associated with fine (i.e., very fine sandy loam or finer) inactive channel deposits. Gelifluvents and Quartzipsamments form in nonpatterned, mounded, or dune surface forms. Historthels develop in flat and slightly concave nonpatterned areas including shallow ponds, low-center polygons in former river channels, and interdune swales. Water occurs in small lakes and ponds. This class includes the Riverine Complex and Riverine Dune Complex map ecotypes.
Historthels-Fibristels-Hemistels	The Historthels-Fibristels-Hemistels class characterizes lowland soils that form predominantly in ice-rich basins, alluvial-marine deposits, sandsheet lowlands. and alluvial sediments on terraces and abandoned floodplains. Soils form in wet to aquatic conditions where vegetation is dominated by hydrophytic sedges. Historthels are the youngest, least developed soils in this class and occur in areas of nonpatterned ground and disjunct polygon rims. Fibristels and Hemistels are wet, organic soils that occur in areas of strang bog, low-center polygons, and peat mounds. This class is associated with the Lowland Wet Sedge Meadow and Lowland Wet Sedge-Willow Meadow ecotypes.

Appendix N. Continued.

Soil Great Group Map Class	Description
Historthels-Histoturbels-Fibristels	The Historthels-Histoturbels-Fibristels class characterizes lowland soils that form in ice-rich basins, alluvial-marine deposits, and alluvial sediments on terraces and abandoned floodplains. Soils form in moist to wet conditions with willow (Salix) as the dominant or codominant low shrub. Historthels are the youngest, least developed soils in this class and occur on basin margins and centers in areas of nonpatterned ground, high-center polygons, and on polygons rims. Histoturbels are cryoturbated (frost-churned) soils that develop in fine-textured (i.e., very fine sandy loam and finer) soils on moist basin margins and centers in areas of nonpatterned ground, disjunct polygon rims, and high-center polygons; and on alluvial terraces, abandoned floodplains, and alluvial-marine deposits on nonpatterned ground and low- and high-center polygons. Fibristels are wet, organic soils that occur on basin margins, alluvial-marine deposits, and sandsheet lowlands in areas of low-center polygons. This class includes the Lowland Moist Birch-Willow-Ericaceous Low Shrub and Lowland Moist Low Willow Shrub map ecotypes.
Human Modified	This class is not associated with a specific soil great group since mineral soil material that has undergone a purposeful alteration of soil properties may be classified broadly into different great group classes. Rather, this class is designed to represent any soil class that has been altered by human activity. This great group class includes five map ecotypes; Human Modified Barrens, Human Modified Dwarf Shrub, Human Modified Low Shrub, Human Modified Moist Meadow, and Human Modified Wet Meadow.
Psammorthels-Haplorthels-Histoturbels	The Psammorthels-Haplorthels-Histoturbels class characterizes soils on stable upland landforms. Psammorthels develop in coarse sandy deposits on inactive and abandoned dunes, and on areas of the sandsheet where loess (silt) deposits are <25 cm thick (e.g., bluffs and convex landscape positions). Haplorthels are associated with high-centered polygons in fine textured alluvial marine and ice-rich drained lake basin deposits. Histoturbels commonly occur on polygon rims and in concave landscape positions. Soils in this class occur on similar landforms as the Psammorthels-Psammoturbels-Haploturbels class, however they tend to be relatively wetter, have thicker surface organic horizons, and range from somewhat poorly to well drained (Schoeneberger et al. 2012). This class includes three map ecotypes; Upland Moist Birch-Willow-Ericaceous Shrub, Upland Moist Ericaceous Dwarf Shrub, and Upland Moist Low Willow Shrub.
Psammorthels-Psammoturbels-Haploturbels	The Psammorthels-Psammoturbels-Haploturbels class characterizes soils on stable upland landforms. Psammorthels and Psammoturbels develop in coarse sandy deposits ranging from dry to moist, on inactive and abandoned dunes, and on areas of the sandsheet where loess (wind retransported silt) deposits are <25 cm thick. Haploturbels are associated with moist, fine textured alluvial-marine deposits, old alluvial terraces, and areas of the sandsheet that feature a thick (≥25 cm loess mantle. This class also occurs in ice-rich drained lake basins on high-centered polygons, bluffs, and pingos. Soils in this class occur on similar landforms as the Psammorthels-Haplorthels-Histoturbels class, however they tend to be relatively drier, have thinner surface organic horizons, and range from moderately well to somewhat excessively drained (Schoeneberger et al. 2012). This class includes the Upland Dry Dryas Dwarf Shrub and Upland Moist Cassiope Dwarf Shrub map ecotypes.

Appendix N. Continued.

Soil Great Group Map Class	Description
Quartzipsamments-Psammorthels	The Quartzipsamments-Psammorthels class characterizes coarse sandy soils that have formed in an upland physiography on active and inactive sand dunes. Spatially this class is often located adjacent to active floodplains where soil properties reflect a combination of eolian (wind) and fluvial processes. Quartzipsamments are associated with barrens or partially vegetated areas on active dunes or sandy bluffs and banks. Psammorthels in this class are associated with the establishment of low and tall willow (Salix) vegetation. This class includes the Upland Dry Barrens and Upland Dry Tall Willow Shrub map ecotypes.
Water	The Water class covers areas of the landscape that are permanently flooded with <5% live vegetation cover. This class includes five map ecotype classes; Beaded Stream, Headwater Stream, Lower Perennial River, Lowland Lake and Riverine Lake.