Williamson River Delta Restoration Project
Vegetation Technical Report

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1. Introduction

The primary objective of this study was to predict the response of vegetation at the Williamson River Delta Preserve under various restoration options. Specific objectives were to: 1) compile a list of potential wetland plant species, 2) group the potential species into plant community types based on their hydrologic requirements, and 3) map potential plant community distributions for each restoration option based on their corresponding hydrologic regime. Restoration options considered were the current management condition and the various scenarios when the site is reconnected to Upper Klamath Lake and the Williamson River. The latter scenarios were considered collectively because reconnection to Upper Klamath Lake and the Williamson River will produce the same hydrologic regime, regardless of placement of the breaches, and therefore will have the same effect on the vegetation.

The scope of this study was limited to the response of broad-scale plant community types across the preserve, rather than the response of individual species. Wetland plant community types were the primary focus of this study, although areas that are currently and will continue to be composed of upland vegetation following restoration activities were identified. Under the current management condition, the following former agricultural fields on the Tulana portion of the preserve were considered: Campfields, Riverbend, Fields 2-7, North Pump, Searchlight, Strip, E-1, and South Pasture (Figure 1). Under the options to reconnect the site to Upper Klamath Lake and the Williamson River, the response of vegetation was predicted across the entire preserve. Data constraints of this study included incomplete species lists for Upper Klamath Basin wetlands, limited information regarding the hydrologic requirements for many of the potential wetland species, and the effects of soil type, turbidity, and water chemistry on species establishment.

2. Background

Several projects have focused on monitoring and mapping historic and current wetland plant communities in the Upper Klamath Basin. Included are descriptions of the historic vegetation at the Williamson River Delta Preserve, data collected from current vegetation monitoring plots at the preserve, and data from other restoration and mapping projects in Upper Klamath Basin wetlands. Each of these projects is summarized below.

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2.1 Historic vegetation at the Williamson River Delta Preserve

Prior to drainage and conversion to agriculture, vegetation at the Williamson River Delta Preserve was composed of a mosaic of upland and wetland plant communities that typified much of the Upper Klamath Basin in the 19th century. Historic accounts of vegetation mapped by Christy (1996) using General Land Office survey notes from 1871-1898 and soil and forest reserve surveys show four plant communities on the preserve: greasewood/ bunchgrass prairie, wet prairie, tule swamp, and willow swamp. Tule swamp, mapped as the dominant vegetation type, consisted of hardstem bulrush (*Scirpus acutus*), common reed (*Phragmites australis*), and duckweed (*Lemna* sp.) with wocus (*Nuphar polysepalum*) in deeper water zones. Within the tule swamp were scattered stands of willow (*Salix* sp.) and wet prairie vegetation consisting of cattail (*Typha* sp.), mannagrass (*Glyceria* sp.), Nebraska sedge (*Carex nebrascensis*), meadow barley (*Hordeum brachyantherum*), and tufted hairgrass (*Deschampsia caespitosa*) in shallower zones. Greasewood/ bunchgrass prairies consisting of greasewood (*Sarcobatus vermiculatus*) and Great Basin wildrye (*Elymus cinereus*) were mapped in the uplands.

2.2 Restoration and monitoring at the Williamson River Delta Preserve

The Nature Conservancy's efforts to restore wetland vegetation at the Williamson River Delta Preserve began in 1997 with the seasonal flooding of former agricultural fields. Water pumped off remaining agricultural parcels is transferred to former fields with the objective of promoting wetland plant establishment. Early action projects at Campfields and Riverbend in 2000 and South Pasture in 2003 resulted in the hydrologic reconnection to Upper Klamath Lake, and are thus subject to lake level fluctuations. The response of wetland vegetation to changes in the hydrologic regime has been monitored on 396 permanent plots established in 2000 across Tulana and 2002 at South Pasture. The location of vegetation monitoring plots is shown in Figure 1. Larger-scale changes in plant communities across the preserve have been detected using satellite images obtained in 1998 and 2000.

2.3 Other wetland restoration projects in the Upper Klamath Basin

Wetland restoration projects also have been initiated on several other properties in the Upper Klamath Basin. The Wood River Wetland Restoration Project, managed by the Bureau of Land Management, was initiated in 1995 with the objective of restoring approximately 3,000 acres of wetland habitat. Data was collected in 1997, 1999, and 2002 on vegetation monitoring plots. Between 1995 and 1997 several native wetland plant species increased in frequency and two additional obligate wetland species were found, broadleaf cattail (*Typha latifolia*) and giant bur-reed (*Sparganium eurycarpum*) (Bureau of Land Management 2002). Increased water depths between 1999 and 2002 were associated with declines in the frequency of exotic species including reedcanary grass (*Phalaris arundinaceae*) and quackgrass (*Elytrigia repens*) and changes in the distribution and frequency of native wetland species. At the Running Y Ranch Resort, a 94-acre former agricultural parcel was restored to wetlands in 1997. Vegetation monitoring was conducted yearly from 1998-2000. In 2000, several native wetland species new to the site were found. Higher managed water levels during the 2000 growing season were associated with increases in the cover of submerged and floating aquatic vegetation and a corresponding decrease in the cover of some emergent species such as creeping spikerush (*Eleocharis palustris*). Other emergent species that tolerate deeper water such as hardstem bulrush (*Scirpus acutus*) and broadleaf cattail (*Typha latifolia*) increased in cover and stem density (MacLaren and Geiger 2001).

2.4 Wetland plant community mapping in the Upper Klamath Basin

Other wetland inventory projects in the Upper Klamath Basin have focused on mapping plant communities. The Bureau of Reclamation used aerial photographs to map the plant communities within Hanks Marsh in 1994 (Salas 1996) and fringe wetlands on the outer edges of Upper Klamath and Agency Lakes in 1998 (Werth and Peck 2001). Dunsmoor et al. (2000) mapped the linear extent of vegetation types along the shoreline of the Williamson River Delta and assessed how lake pool elevation and shoreline morphology influence vegetation distribution. Werth and Peck's (2001) work does not describe species associated with each plant community or environmental variables influencing the distribution of communities, limiting its utility for the purpose of this report. Although Salas' (1996) report also does not relate plant community distributions to the hydrologic regime or other environmental variables, a species list is provided, which was used to develop a list of desired species for the Williamson River Delta Preserve, as described in section 4.1 of this report. Dunsmoor et al.(2000) found that shoreline aspect and wave action may influence the composition of emergent plant communities. Implications of this finding are discussed in section 4.2 of this report.

2.5 Evaluation of prior wetland plant community projects

The above mentioned projects provide useful information regarding the distribution and composition of current and historic wetland plant communities in the Upper Klamath Basin. However, there is a lack of information regarding the hydrologic regimes associated with each plant community. Understanding the relationship between plant community distribution and hydrology is essential for predicting the response of vegetation at the Williamson River Delta Preserve to the various restoration options, and is thus the focus of this study.

3. Existing Conditions

Vegetation at the Williamson River Delta Preserve currently is dominated by plant communities that naturally have colonized the former agricultural fields, drainage canals, and levees. In addition, there are cultivated crops on the remaining agricultural parcels. As of 2003, a total of 121 species have been identified on the preserve, of which 80 are native, 38 are introduced, and 3 are of unknown origin. The distribution of vegetation (excluding agricultural parcels) appears to be driven primarily by the hydrologic regime and reflects the transitions that occur from upland to wetland with increasing water depth and duration of flooding. Vegetation can be categorized into the following broad plant community types based on water management: upland, transitional, and emergent wetland. The distribution of current vegetation is shown in Figure 1. A description of each type and list of dominant species is provided below.

Upland: Upland plant communities are dominated by annual and biennial exotic species that include prickly lettuce (*Lactuca serriola*), thistles (*Cirsium arvense* and *C. vulgare*), tumblemustard (*Sisymbrium altissimum*), and cheatgrass (*Bromus tectorum*). Perennial species include stinging nettle (*Urtica dioica*) and quackgrass (*Elytrigia repens*). Upland plant communities comprise 39% (1,482 acres) of the current non-agricultural vegetation and occur in areas that are not regularly flooded and along levees in flooded fields.

Transitional: Transitional plant communities are dominated by annual and biennial native species that include golden dock (*Rumex maritimus*) and nodding beggarticks (*Bidens cernua*), as well as the exotic species spotted ladysthumb (*Polygonum persicaria*). Less common is the exotic species reedcanary grass (*Phalaris arundinaceae*) which occurs mainly along levees. Willows (*Salix lucida ssp. lasiandra* and *S. geyeriana*) occur mainly along levees but also have colonized transitional areas in Campfields and Riverbend. Transitional plant communities comprise 16% (598 acres) of the current non-agricultural vegetation and occur in areas that experience some flooding with late spring and early summer drawdowns.

Emergent wetland: Emergent wetland plant communities are dominated by native species that include hardstem bulrush (*Scirpus acutus*), creeping spikerush (*Eleocharis palustris*), and broadleaf cattail (*Typha latifolia*). Less common native species include water smartweed (*Polygonum amphibium*), arumleaf arrowhead (*Sagittaria cuneata*), chairmaker's bulrush *(Scirpus americanus*), cosmopolitan bulrush (*Scirpus maritimus*), American water-plantain (*Alisma plantago-aquatica*), various sedges (*Carex* sp.), and common mare's tail (*Hippuris vulgaris*). Emergent plant communities comprise 46% (1,756 acres) of the current non-agricultural vegetation and occur in areas that experience seasonal flooding and mid-summer to early fall drawdowns.

4. Methods

The primary factors that drive the distribution of wetland vegetation are water depth and duration of flooding (Hammer 1997). Thus, predicting the response of wetland vegetation to various restoration options requires both knowledge of the hydrologic requirements of the potential plant species and the hydrologic regime associated with each restoration option. To predict the distribution of vegetation at the Williamson River Delta Preserve, first a list of potential wetland species that are native to Upper Klamath Lake wetlands was compiled. Second, species were grouped in plant community types based on their hydrologic requirements. Third, the distribution of plant community types was predicted based on the hydrologic regime associated with each restoration option. Specific methodologies used for each step are described below.

4.1 Potential wetland species

Four sources of reference information were used to create a list of potential wetland plant species: 1) historical accounts of the nineteenth century vegetation of the Williamson River Delta (Christy 1996), 2) the species list for Hanks Marsh, a relatively undisturbed adjacent wetland (Salas 1996), 3) the current species list for the Wood River Wetland, a restored wetland managed by the Bureau of Land Management (BLM, unpublished data), and 4) the current species list for the Williamson River Delta (TNC, unpublished data). Christy's (1996) nineteenth century vegetation map of the Williamson River Delta provides a rough glimpse of plant communities that once existed on the site prior to levee construction and drainage for agriculture. Although dramatic changes in both the hydrologic regime and ground surface elevations since the nineteenth century precludes this account from being used to predict the distribution of the plant communities, it is still useful for developing a list of desirable plant communities and associated species. In contrast, contemporary plant communities at Hanks Marsh, one of the few remaining undrained wetlands in Upper Klamath Lake, reflect the current highly altered hydrologic regime and water chemistry of Upper Klamath Lake. These conditions are similar to those that the Williamson River Delta wetlands will experience if the site is hydrologically reconnected to the lake. The Bureau of Reclamation compiled a species list for Hanks Marsh while collecting ground-truthing data for a plant community map in 1994 (Salas 1996). The species list for the WRDP was compiled from vegetation data collected from 2000-2003 on permanent vegetation monitoring plots established along transects designed to capture the environmental gradient with increasing water depth and duration of flooding from upland to wetland. The current species list for the preserve reflects only the early stages of wetland plant community development and does not include the deeper water species that would occur with hydrologic reconnection to Upper Klamath Lake. However, the current species list provides valuable information on which species can be expected to colonize following future restoration efforts. A limitation of all three reference sources is that rare and ephemeral species are probably excluded, although all three sources combined should capture the majority of species that occur in Upper Klamath Lake wetlands.

The list of potential wetland species was created by compiling the native species listed in the above four sources with a wetland status of obligate or facultative wetland for region 9 as defined by US Fish and Wildlife Service (1988). Species nativity follows USDA (2002).

4.2 Plant community types

The list of potential wetland species was divided into the following four generalized plant communities based on their maximum water depth and duration of flooding tolerances: open water, deep water wetland, emergent wetland, and riparian/wet prairie. Upland plant communities are also included although identifying the potential upland species was beyond the scope of this study. Maximum water depths and duration of flooding associated with each plant community are provided in Table 1. An attempt was made to use regional information on the habitat requirements for each species, however little research has been conducted on Upper Klamath Lake wetland plant communities. For a few species, no information on the hydrologic requirements was found; in these cases species were assigned to plant communities based on their association with other species in that community, according to either species descriptions provided in Guard (1995) or from personal experience.

This approach assumes that water depth and duration of flooding are the only factors that drive species distributions. Other factors may influence the ability of a species to colonize and persist within a given hydrologic zone such as turbidity, soil type, water chemistry, and exposure to wave energy. High turbidity is most likely to limit the establishment of submerged species that occur in the deep and open water zones, because reduced light penetration can limit photosynthesis. Under those conditions, rooted species with floating leaves are more likely to dominate than submerged species (Hammer 1997). Information describing the influence of soil type and water chemistry on Upper Klamath Lake wetland plant distributions is not available. However, because many wetland species are tolerant of a broad range of soil types (Allen et al. 1989, Hammer 1997), soil type is not likely to be a major factor driving species distributions. In terms of water chemistry, it is reasonable to assume that most of the potential species are tolerant of the current conditions because the majority of the species are currently present at the preserve or at Hanks Marsh. Exposure to wave energy from Upper Klamath Lake could limit the establishment or influence the composition of emergent vegetation (Dunsmoor et al. 2000). Some species, such as giant bur-reed (*Sparganium eurycarpum*), may not establish unless protected from high wave energy. However, this effect is likely to occur only near levee breaches since the remaining sections of levee would protect the interior of the wetland from wave energy.

4.3 Distribution of plant community types

The expected hydrologic regime associated with each restoration option was used to predict the distribution of plant community types. Options considered were the current management condition and hydrologic reconnection of the Williamson River Delta Preserve to Upper Klamath Lake and the Williamson River by the breaching of levees.

Current management condition

The hydrologic regime associated with the current management condition was determined using ground surface elevations for the preserve and staff gauge data collected on the preserve in 2002. One foot resolution ground surface elevations were obtained from a digital elevation model (DEM) created for the preserve. Staff gauges installed in 1998 across the Tulana portion of the preserve monitor changes in water surface elevations. Data were collected every two weeks to every month from April to November in 2002.

Monthly water depths were calculated by subtracting ground surface elevations from water surface elevations. Calculations were made separately for each of six water management units (Fields 2-5, Fields 6-7, Fields E1 and Strip Field, North Pump and

Seachlight Fields, Riverbend, Campfields, and South Pasture), because water has been managed differently in each of these former agricultural fields. Field locations are shown in Figure 1. Potential plant community types were assigned to a range of ground surface elevations based on maximum water depth and timing of drawdown, as provided in Table 1. Duration of flooding could not be calculated because staff gauge data was not collected for the entire year. Instead, the flooding regime during the growing season was assessed when assigning potential plant community types. Ground surface elevations associated with each plant community type are shown in Table 2.

Arcview GIS 3.3 was used to create potential vegetation maps and to calculate acreage of each plant community type.

Hydrologic reconnection scenarios

The hydrologic regimes associated with the hydrologic reconnection scenarios were determined using ground surface elevations for the preserve and the expected monthly water elevations in Upper Klamath Lake as stated in the U.S. Fish and Wildlife Service's Biological Opinion on the 10-year Operation Plan for the Klamath Project (U.S Fish and Wildlife Service 2002). In this plan, water management can vary year to year based on the expected hydrologic conditions and corresponding "water year type". The four water year types identified by the Bureau of Reclamation include Above Average, Below Average, Dry, and Critically Dry. No average water year type was identified, therefore each of the four different water year types were used for this analysis. Lake elevations associated with each water year type are shown in Table 3. One foot resolution ground surface elevations were obtained from a digital elevation model (DEM) created for the preserve.

Monthly water depths for each water year type were calculated by subtracting ground surface elevations from expected water elevations. Potential plant community types were assigned to a range of ground surface elevations based on maximum water depth, duration of flooding, and timing of drawdown as provided in Table 1. Ground surface elevations associated with each plant community type are shown in Table 2.

Arcview GIS 3.3 was used to create potential vegetation maps and to calculate acreage of each plant community type.

5. Results and Discussion

5.1 Potential wetland species and community types

A list of 57 potential wetland plant species for the Williamson River Delta Preserve was compiled from the three reference sources (Table 4). Not included in this list are the introduced species that are currently present at the preserve and are likely to continue to be a component of the plant communities regardless of restoration actions.

Table 5 lists the potential species and their water depth and duration of flooding requirements within each plant community type. Several species that have broad water depth tolerances are listed in more than one plant community type. Species listed within each plant community type will not necessarily occur together within any given area with the appropriate hydrologic regime. Although many species are listed for each potential plant community type, it is more likely that plant communities will be dominated by a few species (eg. *Scirpus acutus* and *Eleocharis palustris* in emergent plant communities), as is currently the case in many areas on the preserve. In restored wetlands, rapid colonization by a few species is common following the restoration of the hydrologic regime, while less common or dispersal-limited species are slower or unlikely to colonize (Zedler 2000, Galatowitsch and van der Valk 1996). The restoration of species diversity in previously disturbed wetlands is often constrained by elevated nutrient supplies, depleted seed banks, limited dispersal mechanisms, and low site microtopographic heterogeneity (Zedler 2000).

Riparian/wet prairie plant communities are likely to be dominated by annual native and introduced species, at least in the short-term. Perennial species in wet prairie plant communities are often slow to establish in restored wetlands (Zedler 2000). Low annual seed production by the sedges (*Carex* sp.) that dominate wet prairie communities limit the availability of seeds for dispersal (Galatowitsch and van der Valk 1996). In deep water plant communities, establishment of rooted emergent species (eg. *Scirpus acutus*) may be slow because drawdowns needed for seed germination will not occur. Establishment of rooted emergent species will depend on vegetative spread from existing plants. In all potential plant community types, species with limited dispersal mechanisms (eg. *Nuphar lutea ssp. polysepala* in emergent and deep water plant communities) or without local seed sources are likely to occur only as a result of active revegetation efforts.

5.2 Distribution of plant community types

Current management condition

The distribution of plant community types for the current management condition is shown in Figure 2. Acreages of each plant community type are summarized in Table 6. Under this option, less than 1% of the preserve would be composed of open water, with 2% deep water wetland, 42% emergent wetland, 14% riparian/wet prairie, and 42% upland. These percentages exclude the portions of the preserve that are currently managed for agricultural production.

Hydrologic reconnection scenarios

The distributions of plant community types for the hydrologic reconnection scenarios in an Above Average year, a Below Average year, a Dry year and a Critically Dry year are shown in Figures 3, 4, 5, and 6, respectively. Acreages of each plant community type are summarized in Table 7. In all four water year types, approximately 5-18% of the preserve would be composed of open water, with 18-30% deep water wetland, 33-34% emergent wetland, 6-15% riparian/wet prairie, and 15-21% upland. The percentages of each plant community type are unlikely to shift with year-to-year changes in lake level management, instead the response of the vegetation will likely be an integration of each lake level management regime.

Under the hydrologic reconnection scenarios, there are approximately 3,000 additional acres of wetland and upland plant community types compared to the current management condition. This is primarily due to the large proportion of the preserve currently in agriculture and thus not considered under the current management condition. When comparing just the Tulana portion of the preserve, the main difference between the two restoration options is that under the hydrologic reconnection scenarios large areas are composed of the deep water and open water plant community types. This is largely a result of soil subsidence at the west end of Tulana that has caused ground surface elevations to drop below historic levels. Reconnection with Upper Klamath Lake and the Williamson River will cause a transition from the current emergent wetland plant communities to these deeper water plant community types.

6. Conclusions

Although the Williamson River Delta Preserve has been substantially altered by a century of drainage and agriculture, there is significant potential to reestablish thriving wetland plant communities at the site. This can be achieved through volunteer recruitment, but species diversity is likely to be enhanced if some species with limited dispersal mechanisms are actively planted.

7. References

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Table 1. Maximum water depths and duration of flooding associated with each potential plant community. Duration of flooding refers to the percentage of the year that flooding occurs. Drawdown month refers to the month when standing surface water is no longer present.

Potential plant community	Max water depth (ft)	Duration of flooding (%)	Drawdown month
open water	13	100	no drawdown+
deep water wetland	9	100	no drawdown+
emergent wetland	5	50-100	July-none*
riparian/wet prairie	2	33	June-July
upland	0.5	0-17	dry-June

*drawdown occurs later than July or not at all

+although drawdown does not occur, water depths decrease during the growing season

Table 2. Ground surface elevations associated with each potential plant community for the current management condition and the hydrologic reconnection scenarios.

	Plant community type				
	open water	deep water wetland	emergent wetland	riparian/wet prairie	upland
Current management condition					
Fields 2-5	-	4130	4131-4133	4134	4135+
Fields 6-7	4122-4128	4129-4131	4132-4133	4134	4135+
Campfields	4131-4136	4137-4138	4139-4141	4142	4143+
Riverbend	4133-4134	4135-4137	4138-4141	4142	4143+
E1 and Strip Fields	4131	4132-4137	4138-4140	4141	4142+
North Pump and Seachlight Fields	4128-4131	4132-4136	4137-4139	4140	4141+
South Pasture	4132	4133-4137	4138-4140	4141	4142+
Hydrologic reconnection scenarios					
Above average year	4130-4133	4134-4138	4139-4141	4142	4143+
Below average year	4130-4133	4134-4137	4138-4140	4141-4142	4143+
Dry year	4130-4132	4133-4137	4138-4140	4141	4142+
Critically dry year	4130-4132	4133-4136	4137-4140	4141	4142+

Table 3. Upper Klamath Lake end-of-month, minimum elevations for the Above Average, Below Average, Dry, and Critically Dry year types as stated in the U.S. Fish and Wildlife Service's Biological Opinion on the 10-year operation plan for the Klamath Project (U.S. Fish and Wildlife Service 2002).

	Water year type			
	Above Average	**Below Average**	**Dry**	**Critically Dry**
October	4139.7	4138.8	4138.2	4137.3
November	4140.3	4139.0	4139.0	4138.1
December	4141.0	4138.8	4139.7	4138.9
January	4141.5	4139.5	4140.3	4140.1
February	4141.9	4141.7	4140.4	4141.1
March	4142.5	4142.7	4141.7	4142.0
April	4142.9	4142.8	4142.2	4141.9
May	4143.1	4142.7	4142.4	4141.4
June	4142.6	4142.1	4141.5	4140.1
July	4141.5	4140.7	4140.3	4138.9
August	4140.5	4139.6	4139.0	4137.6
September	4139.8	4138.9	4138.2	4137.1

Table 4. Potential wetland species for the Williamson River Delta Preserve.

Scientific name	Common name	Family	Wetland Status	Reference source
Agrostis exarata	spike bentgrass	Poaceae	FACW	WRDP species list
Alisma plantago-aquatica	American water-plantain	Alistmataceae	OBL	WRDP species list
Alopecurus aequalis	shortawn foxtail	Poaceae	OBL	WRDP species list
Atriplex patula	spear saltbush	Chenopodiaceae	FACW	WRDP species list
Azolla mexicana	mexican water fern	Salviniaceae	OBL	Salas (1996)
Bidens cermua	nodding beggarticks	Asteraceae	FACW+	WRDP species list
Bidens frondosa	devil beggarticks	Asteraceae	FACW+	WRDP species list
Carex angustata	widefruit sedge	Cyperaceae	FACW+	WRDP species list
Carex athrostachya	slenderbeak sedge	Cyperaceae	FACW	WRDP species list
Carex feta	green-sheathed sedge	Cyperaceae	FACW	WRDP species list
Carex nebrascensis	Nebraska sedge	Cyperaceae	OBL	Christy (1996)
Ceratophyllum demersum	coontail	Ceratophyllaceae	OBL	Salas (1996), WRDP species list
Deschampsia caespitosa	tufted hairgrass	Poaceae	FACW	Christy (1996)
Distichlis stricta	inland saltgrass	Poaceae	FACW	WRDP species list
Eleocharis acicularis	needle spike-rush	Cyperaceae	OBL	WRDP species list
Eleocharis ovata	ovate spike-rush	Cyperaceae	OBL	WRDP species list
Eleocharis palustris	creeping spike-rush	Cyperaceae	OBL	WRDP species list
Elodea canadensis	Canadian waterweed	Hydrocharitaceae	OBL	Salas (1996), WRDP species list
Euthamia occidentalis	western goldtop	Asteraceae	FACW	WRDP species list
Glyceria sp.	mannagrass	Poaceae	OBL	Christy (1996)
Gratiola neglecta	clammy hedgehyssop	Scrophulariaceae	OBL	WRDP species list
Helenium autumnale	common sneezeweed	Asteraceae	FACW	WRDP species list
Hippuris vulgaris	common mare's tail	Hippuridaceae	OBL	WRDP species list
Hordeum brachyantherum	meadow barley	Poaceae	FACW-	Christy (1996)
Juncus balticus	Baltic rush	Juncaceae	OBL	WRDP species list
Juncus bufonius	toad rush	Juncaceae	FACW+	WRDP species list
Lemna minor	common duckweed	Lemnaceae	OBL	Christy (1996), Salas (1996), WRDP species list
Limosella aquatica	water mudwort	Scrophulariaceae	OBL	WRDP species list
Ludwigia palustris	marsh seedbox	Onagraceae	OBL	WRDP species list
Lycopus asper	rough bugleweed	Lamiaceae	OBL	WRDP species list
Mimulus guttatus	seep monkeyflower	Scrophulariaceae	OBL	WRDP species list
Myriophyllum sibiricum	shortspike watermilfoil	Haloragaceae	OBL	WRDP species list
Nuphar lutea ssp. polysepala	yellow pond lily, wocus	Nymphaeaceae	OBL	Christy (1996), Salas (1996)
Phragmites australis	common reedgrass	Poaceae	FACW+	Christy (1996), WRDP species list
Polygonum amphibium	water smartweed	Polygonaceae	OBL	Salas (1996)
Polygonum hydropiperoides	swamp smartweed	Polygonaceae	OBL	WRDP species list
Potamogeton epihydrus	ribbonleaf pondweed	Potamogetonaceae	OBL	WRDP species list
Potamogeton natans	floating-leaf pondweed	Potamogetonaceae	OBL	WRDP species list
Potamogeton pectinatus	leafy pondweed	Potamogetonaceae	OBL	WRDP species list
Potamogeton pusillus	small pondweed	Potamogetonaceae	OBL	Salas (1996)
Potentilla anserina	silverweed cinquefoil	Rosaceae	OBL	WRDP species list
Ranunculus aquatilis	water crowfoot	Ranunculaceae	OBL	Salas (1996)
Ranunculus sceleratus	cursed buttercup	Ranunculaceae	OBL	WRDP species list
Rumex maritimus	golden dock	Polygonaceae	FACW+	WRDP species list
Sagittaria cuneata	arumleaf arrowhead	Alistmataceae	OBL	WRDP species list
Salix geyeriana	Geyer's willow	Salicaceae	FACW+	WRDP species list
Salix lucida ssp. lasiandra	Pacific willow	Salicaceae	FACW+	WRDP species list
Scirpus acutus	hardstem bulrush	Cyperaceae	OBL	Christy (1996), Salas (1996), WRDP species list
Scirpus americanus	American bulrush	Cyperaceae	OBL	WRDP species list
Scirpus maritimus	cosmopolitan bulrush	Cyperaceae	OBL	WRDP species list
Sparganium eurycarpum	giant bur-reed	Sparganiaceae	OBL	Salas (1996), WRDP species list
Suaeda occidentalis	Pursh seepweed	Chenopodiaceae	FACW	WRDP species list
Typha latifolia	broadleaf cattail	Typhaceae	OBL	Christy (1996), WRDP species list
Veronica americana	american speedwell	Scrophulariaceae	OBL	Salas (1996)
Veronica anagallis-aquatica	water speedwell	Scrophulariaceae	OBL	WRDP species list

Table 5. Potential plant species and hydrologic requirements associated with each plant community type for the Williamson River Delta Preserve. Duration of flooding refers to the percentage of the year that flooding occurs.

Plant community	Scientific name	Common name	Water depth tolerance (ft.)	Duration of flooding (%)	citation*
Open water					
	Azolla mexicana	Mexican water-fern	unknown	unknown	2
	Ceratophyllum demersum	coontail	1-13	90-100	1
	Elodea canadensis	Canadian waterweed	1-23	90-100	1,4,5
	Lemna minor	duckweed	no max.	90-100	1,4
	Myriophyllum hippuroides	western watermilfoil	1-16	90-100	4,5,8
	Potamogeton epihydrus	ribbonleaf pondweed	up to 9	unknown	2
	Potamogeton natans	floating-leaved pondweed	unknown	90-100	4
	Potamogeton pectinatus	leafy pondweed	1-24	90-100	1,5
	Potamogeton pusillus	small pondweed	unknown	90-100	4
Deep water wetland					
	Ceratophyllum demersum	coontail	1-13	90-100	1
	Elodea canadensis	Canadian waterweed	1-23	90-100	1,4,5
	Hippuris vulgaris	common mare's-tail	up to 6	unknown	2
	Lemna minor	duckweed	no max.	90-100	1,4
	Myriophyllum hippuroides	western watermilfoil	1-10	90-100	4,5,8
	Nuphar lutea ssp. polysepala	yellow pondlily, wocus	2-9	90-100	1,4,8,9
	Potamogeton epihydrus	ribbonleaf pondweed	up to 9	unknown	2
	Potamogeton pectinatus	leafy pondweed	1-24	90-100	1,5
	Ranunculus aquatilis	water buttercup	up to 6	unknown	11
	Scirpus acutus	hardstem bulrush/ tule	0-6	75-100	1,4,8,9,12
Emergent wetland					
	Eleocharis palustris	creeping spikerush	0-3	50-100	1,4
	Hippuris vulgaris	common mare's-tail	up to 6	unknown	2
	Limosella aquatica	water mudwort	unknown	unknown	
	Ludwigia palustris	marsh seedbox	unknown	unknown	
	Nuphar lutea ssp. polysepala	yellow pondlily, wocus	2-9	90-100	1,4,8,9
	Phragmites australis	common reed	0-2	70-100	1,3,10
	Polygonum amphibium	water smartweed	0-3	50-100	1,3
	Ranunculus sceleratus	cursed buttercup	unknown	unknown	
	Sagittaria cuneata	arumleaf arrowhead	0-1.5	50-100	4,7
	Scirpus acutus	hardstem bulrush/ tule	0-6	75-100	1,4,8,9,12
	Scirpus americanus	American bulrush	0-2	75-100	1,4,7
	Scirpus maritimus	alkalai/cosmopolitan bulrush	0-3	75-100	1,4,7
	Sparganium eurycarpum	giant bur-reed	0-4	70-100	1,12
	Typha latifolia	broadleaf cattail	0-2.5	70-100	1,4,13
Riparian/wet prairie					
	Agrostis exarata	spike bentgrass	unknown	unknown	
	Alisma plantago-aquatica	American water-plantain	0-1	26-100	1
	Alopecurus aequalis	shortawn foxtail	unknown	unknown	
	Atriplex patula	spear saltbush	unknown	unknown	
	Bidens cernua	nodding beggarticks	unknown	unknown	

Plant community	Scientific name	Common name	Water depth tolerance (ft.)	Duration of flooding (%)	citation*
Riparian/wet prairie					
	Bidens frondosa	devil beggarticks	unknown	unknown	
	Carex angustata	widefruit sedge	0-1	50-100	3,4,5
	Carex athrostachya	slenderbeak sedge	0-1	50-100	3,4,5
	Carex feta	green-sheathed sedge	0-1	50-100	3,4,5
	Carex nebrascensis	Nebraska sedge	0-2	50-100	3,4,6
	Deschampsia caespitosa	tufted hairgrass	unknown	unknown	6
	Distichlis stricta	inland saltgrass	unknown	unknown	
	Eleocharis acicularis	needle spikerush	unknown	50-100	2,4
	Eleocharis ovata	ovate spikerush	0-0.5	50-100	1,4
	Eleocharis palustris	creeping spikerush	0-3	50-100	1,4
	Euthamia occidentalis	western goldtop	unknown	unknown	
	Glyceria sp.	mannagrass	0-1	0-100	3,4
	Gratiola neglecta	clammy hedgehyssop	unknown	unknown	
	Helenium autumnale	common sneezeweed	unknown	unknown	
	Hordeum brachyantherum	meadow barley	unknown	unknown	
	Juncus balticus	Baltic rush	0-0.5	50-100	7,1
	Juncus bufonius	toad rush	unknown	unknown	
	Ludwigia palustris	marsh seedbox	unknown	unknown	
	Lycopus asper	rough bugleweed	unknown	unknown	
	Mimulus guttatus	seep monkeyflower	unknown	unknown	
	Polygonum hydropiperoides	swamp smartweed	0-1	50-100	1
	Potentilla anserina	silverweed cinquefoil	unknown	unknown	
	Ranunculus sceleratus	cursed buttercup	unknown	unknown	
	Rumex maritimus	golden dock	unknown	unknown	
	Sagittaria cuneata	arumleaf arrowhead	0-1.5	50-100	4,7
	Salix geyeriana	Geyer's willow	0-1.5	50-100	8,9,1,4
	Salix lucida ssp. lasiandra	Pacific willow	0-1.5	50-100	8,9,1,4
	Suaeda occidentalis	Pursh seepweed	unknown	unknown	
	Veronica americana	American brooklime	unknown	unknown	
	Veronica anagallis-aquatica	water speedwell	unknown	unknown	

* citations are as follows: 1=Thunhorst (1993), 2=Hamel and Parsons (2001), 3=Hammer (1997), 4=Kadlec and Knight (1996), 5=Stephenson et al. (1980), 6=Walsh (1995), 7=USDA (2002), 8=Perala and McClure (1999), 9=Gearheart et al. (1996), 10=Davis (1995), 11=U.S. Army Corps of Engineers, 12=Dunsmoor et al. (2000), 13=Motavins and Apfelbaum (1987)

Table 6. Acreage of each potential plant community type at the Williamson River Delta Preserve for the current management condition. Total acres and percent of total acreage does not include the portion of the preserve remaining in agriculture.

Potential plant community	Acres	% of total acreage
open water	12.0	0.3
deep water wetland	78.0	2.2
emergent wetland	1479.6	41.6
riparian/wet prairie	481.6	13.5
upland	1509.8	42.4
Total	3560.9	100.0

Table 7. Acreage of each potential plant community type at the Williamson River Delta Preserve for the hydrologic reconnection scenarios in an above average year, below average year, dry year, and critically dry year.

	Above Average Year		Below Average Year		Dry Year		Critically Dry Year	
Potential plant community	**Acres**	**% of total acreage**	**Acres**	**% of total acreage**	**Acres**	**% of total acreage**	**Acres**	**% of total acreage**
open water	1199.0	18.1	1199.0	18.1	360.6	5.4	360.0	5.4
deep water wetland	1797.3	27.1	1158.3	17.5	1996.7	30.1	1805.7	27.2
emergent wetland	2238.3	33.8	2295.6	34.6	2295.6	34.6	2196.4	33.1
riparian/wet prairie	401.3	6.1	982.9	14.8	581.6	8.8	872.5	13.2
upland	991.7	15.0	991.7	15.0	1393.0	21.0	1393.0	21.0
Total	6627.6	100.0	6627.6	100.0	6627.6	100.0	6627.6	100.0

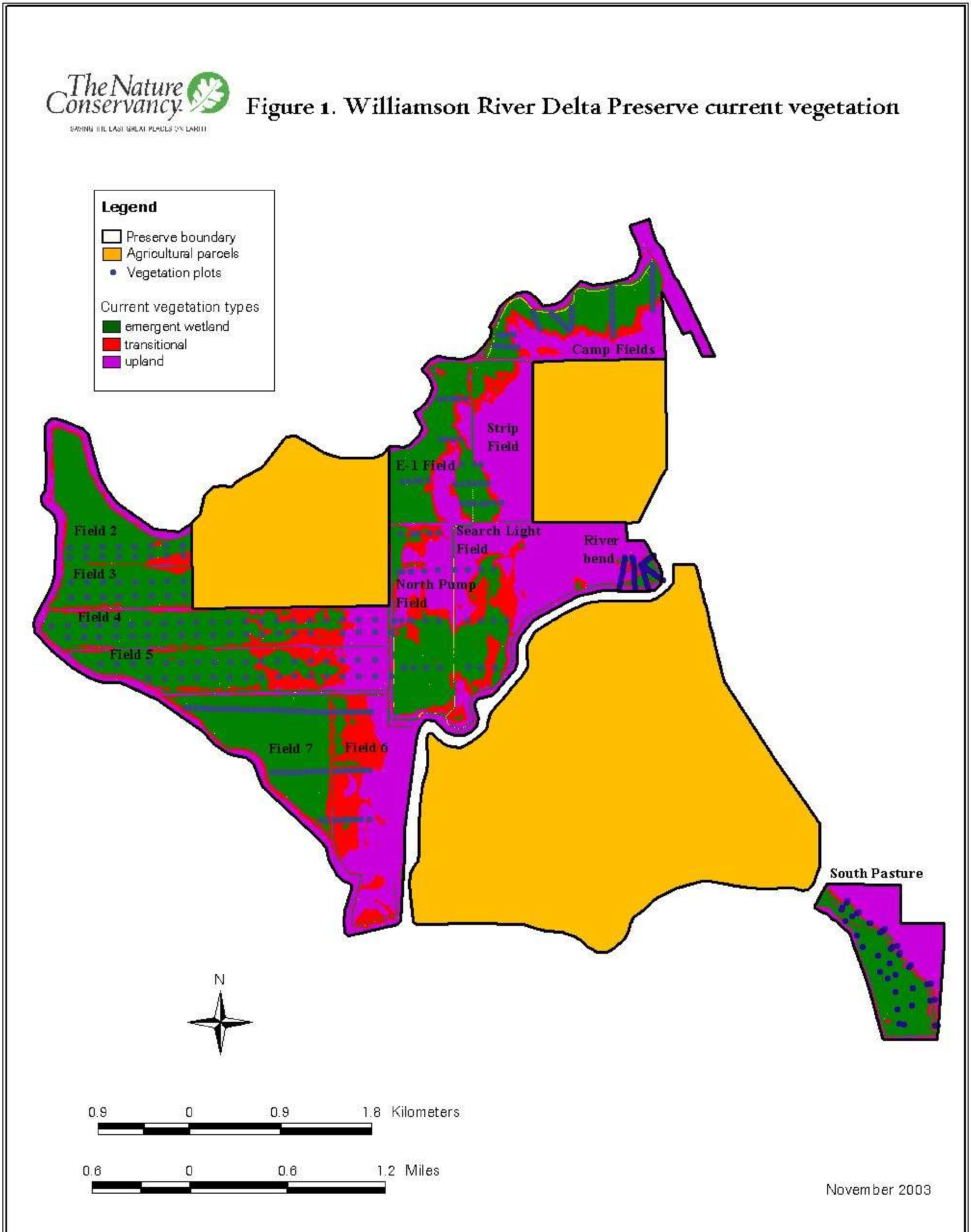
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Figure 1. Williamson River Delta Preserve current vegetation
Legend
Preserve boundary
Agricultural parcels
Vegetation plots
Current vegetation types
emergent wetland
transitional
upland
Camp Fields
Strip Field
E-1 Field
Field 2
Field 3
Field 4
Field 5
Search Light Field
River bend
North Pump Field
Field 7
Field 6
South Pasture
N
0.9 0 0.9 1.8 Kilometers
0.6 0 0.6 1.2 Miles
November 2003

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Figure 2. Williamson River Delta Preserve potential vegetation for TNC's current management condition

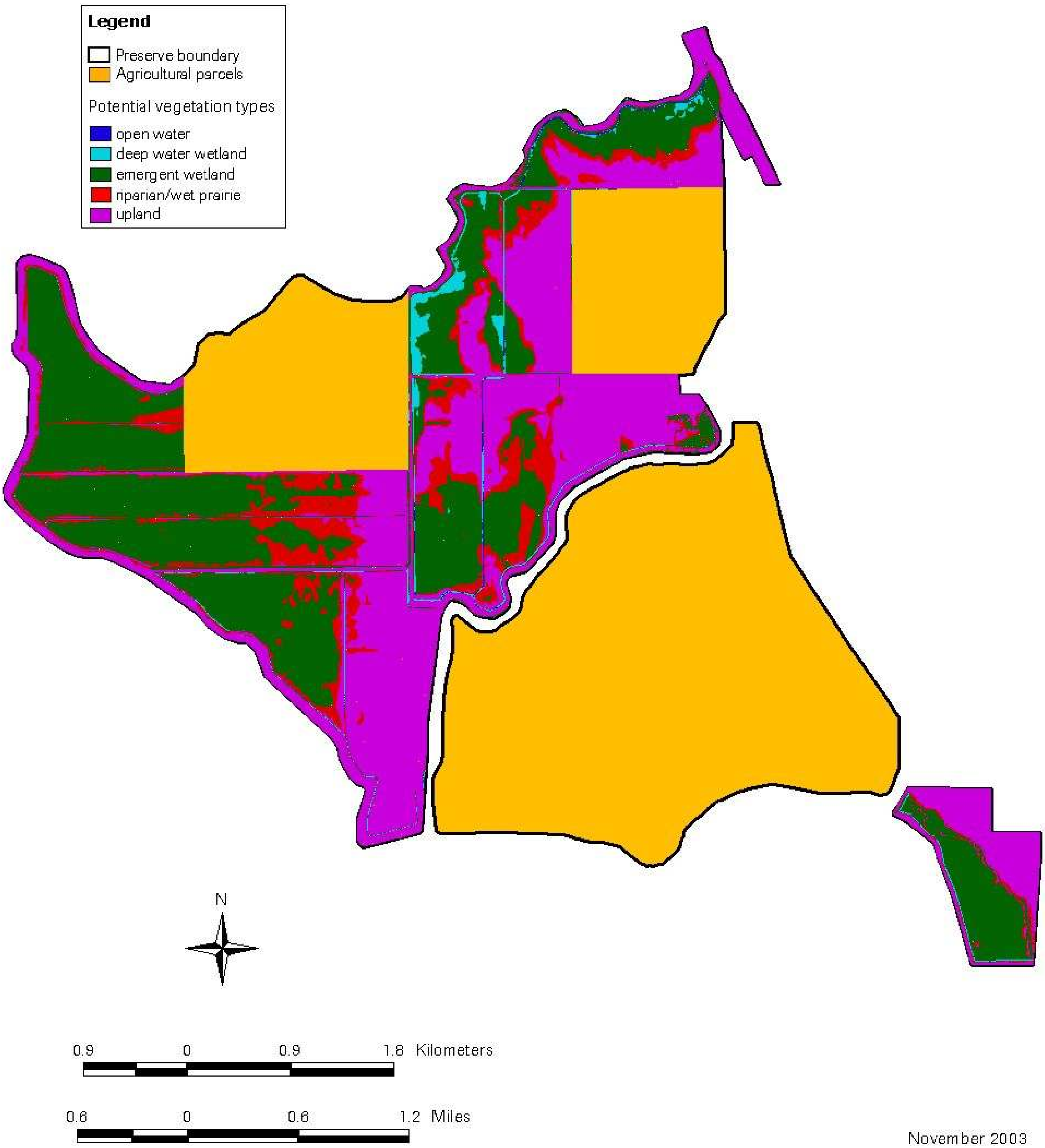

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Figure 3. Williamson River Delta Preserve potential vegetation for the breached levee hydrologic regime in an Above Average year, based the U.S Fish and Wildlife Service's Biological Opinion on the 10-year operation plan for the Klamath Project

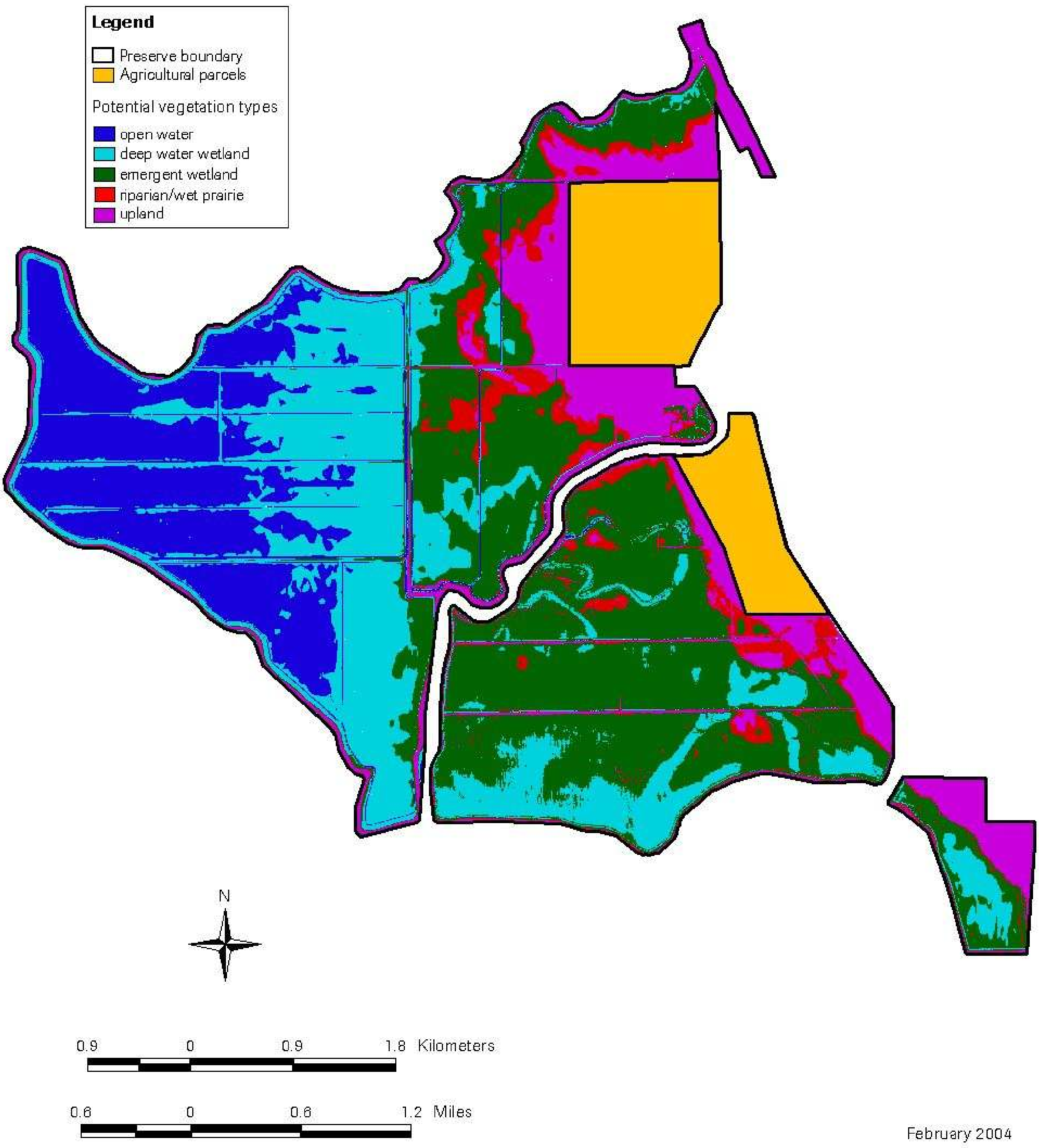

Figure 4. Williamson River Delta Preserve potential vegetation for the breached levee hydrologic regime in a Below Average year, based the U.S Fish and Wildlife Service's Biological Opinion on the 10-year operation plan for the Klamath Project

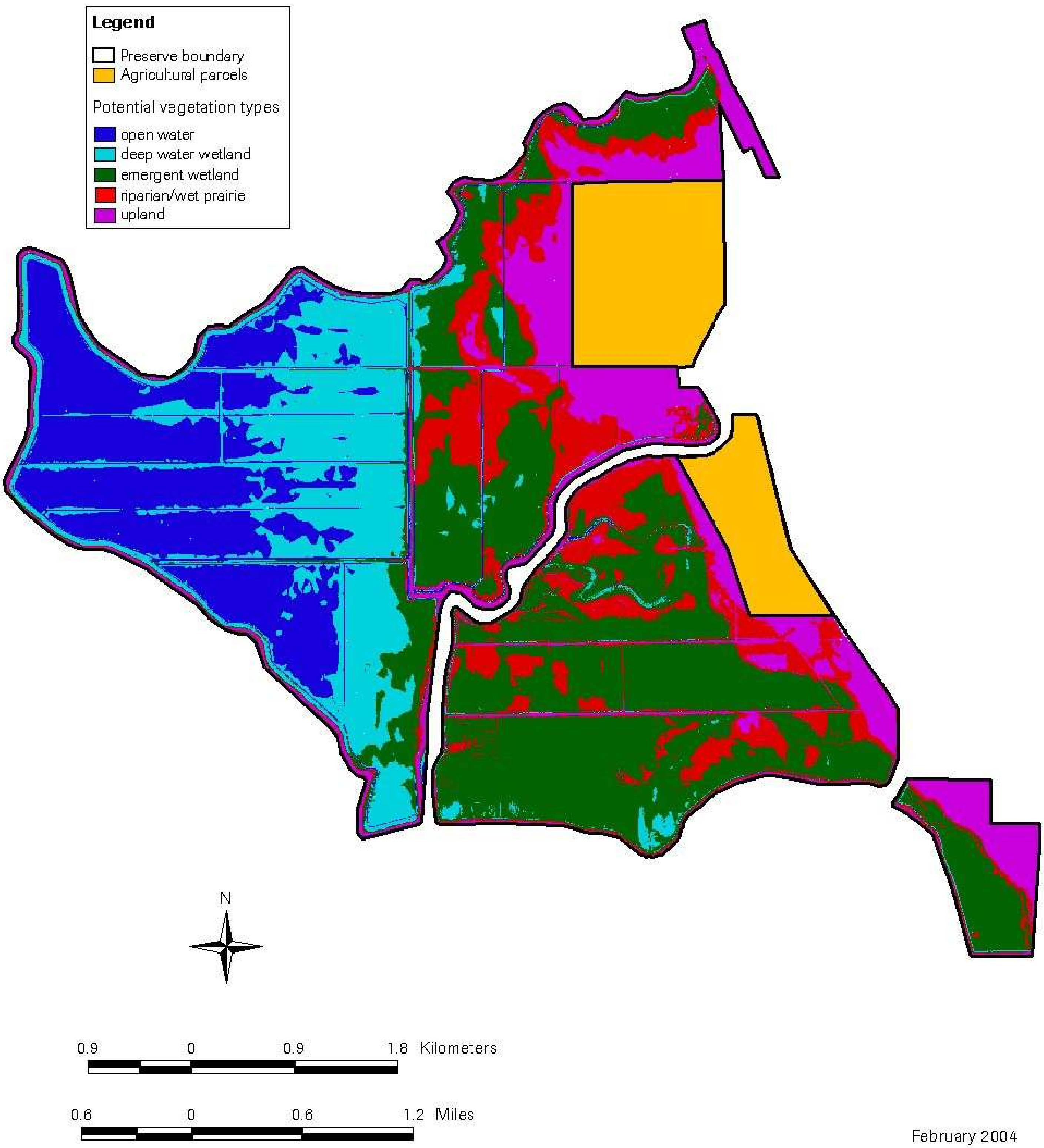

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Figure 5. Williamson River Delta Preserve potential vegetation for the breached levee hydrologic regime in a Dry year, based the U.S Fish and Wildlife Service's Biological Opinion on the 10-year operation plan for the Klamath Project

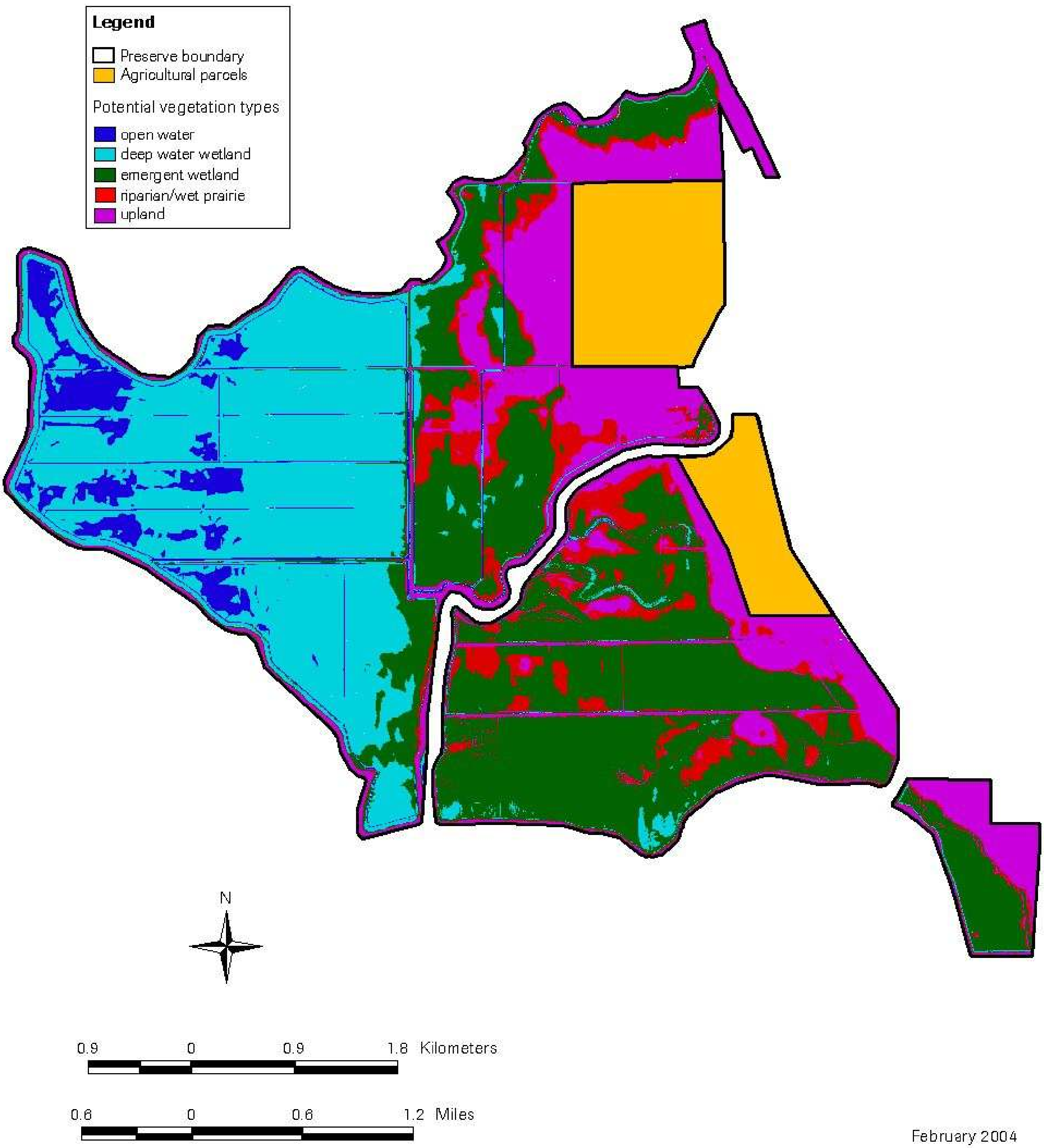

Figure 6. Williamson River Delta Preserve potential vegetation for the breached levee hydrologic regime in a Critically Dry year, based the U.S Fish and Wildlife Service's Biological Opinion on the 10-year operation plan for the Klamath Project