LARGE-FLOWERED FIDDLENECK

(Amsinckia grandiflora)

RECOVERY PLAN

1997

U. S. Department of the Interior

Fish and Wildlife Service

LARGE-FLOWERED FIDDLENECK

(*Amsinckia grandiflora*)

RECOVERY PLAN

Prepared by

Region 1
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Date SEP 29 1997

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EXECUTIVE SUMMARY OF THE RECOVERY PLAN FOR LARGE-FLOWERED FIDDLENECK

Current Species Status: The large-flowered fiddleneck (*Amsinckia grandiflora*) is federally listed as endangered with critical habitat designated. Two natural populations exist. One population consists of two small colonies on U.S. Department of Energy land in Corral Hollow, Alameda and San Joaquin Counties. The second population was recently found in western San Joaquin County. The species has also been introduced into six sites; however, only two of these reintroductions appear to be successful.

Habitat Requirements and Limiting Factors: The continued existence of *Amsinckia grandiflora* is threatened by: loss of habitat from urban and agricultural conversion, and livestock grazing; competition and/or interference from associated plants (mostly nonnative annual grasses); and environmental and genetic stochasticity. The critically low number of individuals, the uncertainty regarding restoring or repopulating suitable habitat, and the great potential for catastrophic or stochastic extinction, all severely complicate establishment of a quantified delisting objective at this time.

Recovery Objective: Downlisting to threatened.

Recovery Criteria: *Amsinckia grandiflora* may be downlisted to threatened status when:

1) A minimum of six management areas, including at least two natural populations, are secured and protected from the threats that caused listing initially, including urbanization, agricultural conversion, competition with invasive vegetation, and livestock grazing.

2) Sufficient information has been obtained to ensure perpetuation of native grassland communities in perpetuity, and appropriate management, based on this information, is being implemented at each management area.

3) Each management area has a minimum of 1,500 reproductive individuals, with sufficient acreage of suitable habitat to support an expanded population and provide an appropriate buffer (see task 42).

4) The six management areas concurrently demonstrate self-maintenance at or above this level for at least one precipitation cycle without intensive management intervention (e.g. hand-pollination, seed collection, off-site propagation) needed to prevent population decline.

Actions needed:

1. Conserve the genetic diversity of *Amsinckia grandiflora.*
2. Secure and protect the habitat for at least six management areas within the historical range.
3. Enhance, manage and monitor populations in at least six management areas.
4. Determine delisting criteria.

Recovery Costs ($1,000):

Year	Need 1	Need 2	Need 3	Need 4	Total
1998	2.5	69.5	170.0	0.0	242.0
1999	5.0	42.5	197.0	0.0	244.5
2000	2.5	26.0	103.0	0.0	131.5
2001	2.5	24.0	74.0	6.0	106.5
2002	0.0	28.0	52.0	6.0	86.0
2003	0.0	28.0	25.0	6.0	64.0
2004	0.0	28.0	25.0	6.0	59.0
2005	0.0	28.0	25.0	0.0	53.0
2006	0.0	16.0	25.0	0.0	41.0
2007	0.0	16.0	25.0	6.0	47.0
2008	0.0	16.0	15.0	10.0	41.0
2009	0.0	16.0	15.0	10.0	41.0
Grand Total	12.5	338.0	756.0	50.0	1156.5*

Date of Downlisting: Downlisting should be initiated in 2009, if downlisting criteria are met.

* Recovery cost is likely to differ from this figure. The costs for several tasks needed for recovery have not been determined yet.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART I. INTRODUCTION

The large-flowered fiddleneck, *Amsinckia grandiflora* A. Gray, is an herbaceous plant in the borage family. Although it was probably never abundant, its decline has been exacerbated by the decline of its native grassland habitat in central California. *Amsinckia grandiflora* is currently classified as an endangered plant by both the Federal (50 Federal Register 19374, May 8, 1985) and State (California Fish and Game Commission, April 16, 1982) governments. Critical habitat has been designated for the species (50 FR 19374). It has been assigned a recovery priority number of 5[1]. Studies, monitoring and recovery actions have been ongoing for the large-flowered fiddleneck even prior to the species' listing. This plan summarizes current knowledge of the ecology, life history, taxonomy, restoration efforts, distribution, and extent of known colonies. Criteria are presented to downlist this endangered species to threatened status.

A. Description and Taxonomy

Amsinckia grandiflora A. Gray, was first collected April 16, 1869, by Dr. Albert Kellogg and William G. W. Harford. It was first described as a variety of *Amsinckia vernicosa* by Asa Gray (1876). Edward L. Greene (1894) considered the large-flowered fiddleneck's distinctive features sufficient to recognize it as a full species.

Amsinckia grandiflora is an annual herb with bright orange, trumpet-shaped flowers (Figure 1). The fused petals, 12-18 millimeters (mm) (0.5-0.75 inch) long, are conspicuously marked with deep orange spots on the corolla tips. The erect plants grow 3-6 decimeters (1-2 feet) high and branch at the middle or above. Coarse stiff hairs densely cover the leaves and stems. The flowers occur in dense, two-ranked clusters

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[1] Priority numbers range from 1C-18 based on magnitude and immediacy of threat as well as recovery potential, with priority number 1C being given the highest priority number and 18 the lowest. A priority of 5 indicates that *A. grandiflora* is a species subjected to a high degree of threat, with a low recovery potential (48 FR 43104).

Figure 1. Illustration of *Amsinckia grandiflora*. Illustration drawn by Linda Ann Vorobik. Illustration courtesy of Ms. Vorobik and the California Native Plant Society.

along a central stem that is tightly coiled at the end into a "fiddleneck", hence the generic vernacular name. *Amsinckia grandiflora* can be separated from other species of *Amsinckia* by the following combination of characteristics: its three- to four-lobed calyx; green, hispid (hairy) leaves and stems; smooth nutlets (seeds) with conspicuous, nearly median, lance-ovate attachment scars; relatively large (12-55 mm [0.5-2.2 in] long) red-orange distylic (see description below) flowers; and dimorphic, tricolporate (refers to shape) pollen (Ray and Chisaki 1957a, Jepson 1943, Macbride 1917).

Amsinckia grandiflora belongs to a small but taxonomically complex annual genus of the Borage family (Boraginaceae). Although Munz (1968) recognizes 11 *Amsinckia* species, most field workers follow Ray and Chisaki (1957a), who recognize 15 California species. Four of these species appear to be rare endemics whose highly restricted distributions contrast conspicuously with other more weedy, small-flowered members of the genus (Ganders 1975, Ornduff 1976). In this group of rare California endemics, *A. grandiflora* is the most restricted in its distribution, with only two extant natural populations (Figure 2) occurring near Corral Hollow, western San Joaquin County, California. The three other restricted California *Amsinckia* species are *A. lunaris* Macbr., which grows in the central Coast Range; *A. vernicosa* Hook. & Arn. var. *furcata* (Suksd.) Hoover, which occurs on the western edge of the San Joaquin Valley in Fresno and San Luis Obispo Counties; and *A. douglasiana* A. DC., which grows in the southern Coast Range in Monterey, San Benito, northern Santa Barbara, and western Kern Counties.

Plants of *Amsinckia grandiflora* and at least four other *Amsinckia* species produce two flower forms, or morphs, referred to as pin and thrum flowers (Ray and Chisaki 1957a). All the flowers on a particular plant consist of only one type (morph), either "pin" or "thrum". In pin flowers, anthers are situated within the corolla tube and the stigma extends beyond the corolla lip, supported by a long stalk, or style (Figure 3). In thrum flowers, anthers extend beyond the mouth of the corolla; the stigma, on a short style, occurs well within the flower tube. This condition, where separate plants have different

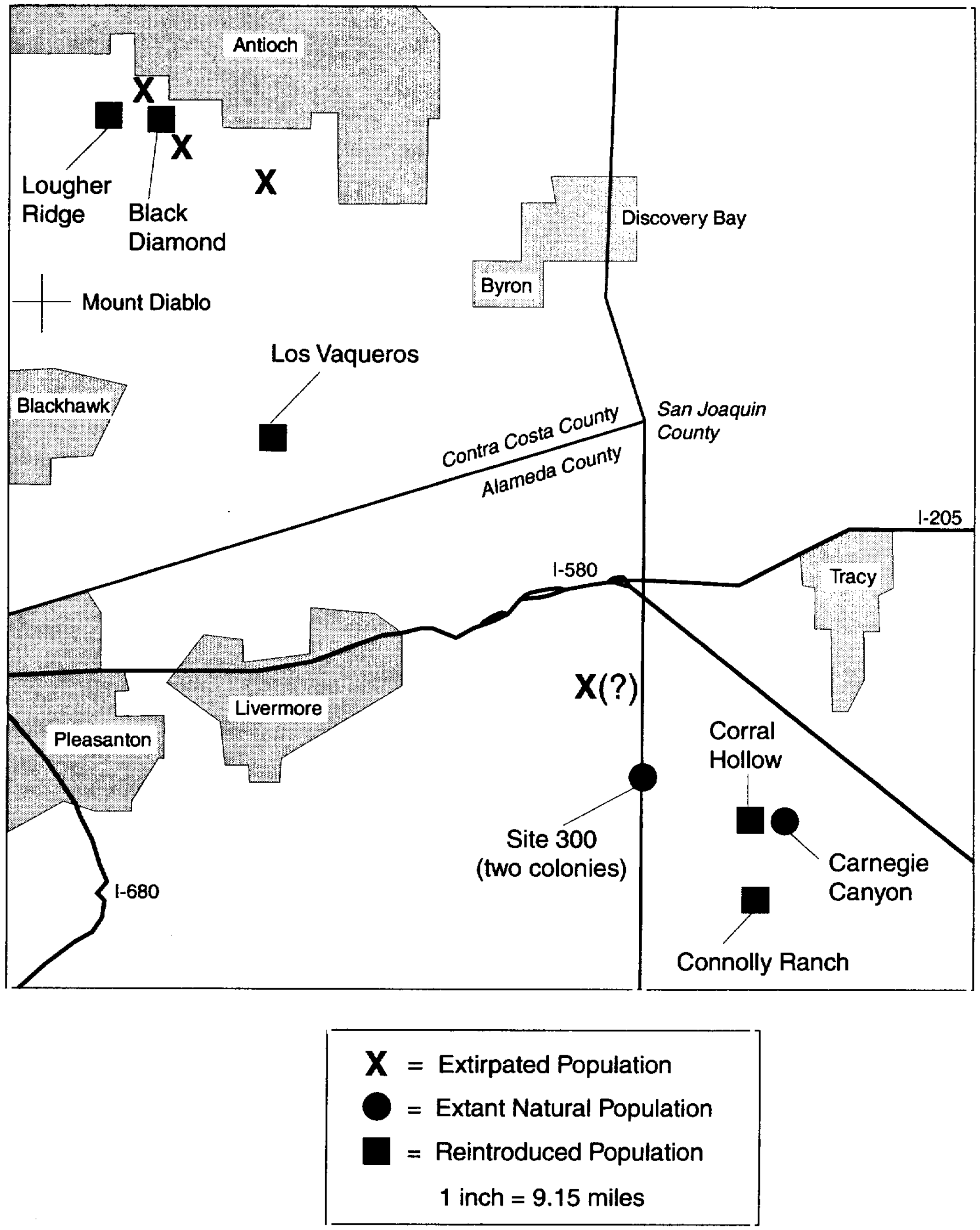

Figure 2. Natural, extirpated, and re-introduced populations of *Amsinckia grandiflora* near Corral Hollow, San Joaquin, Alameda, and Contra Costa Counties, California.

flower forms, is called distyly and flowers may be referred to as distylous or distylic (two style types) or heterostylous (different style types). The smooth-coated fruits, called nutlets (which are the seeds), occur at the base of the style. The ovary is four lobed and four fruits potentially could develop per flower; however *A. grandiflora* seldom produces four nutlets. The species' low fecundity led to pollination studies, as described below.

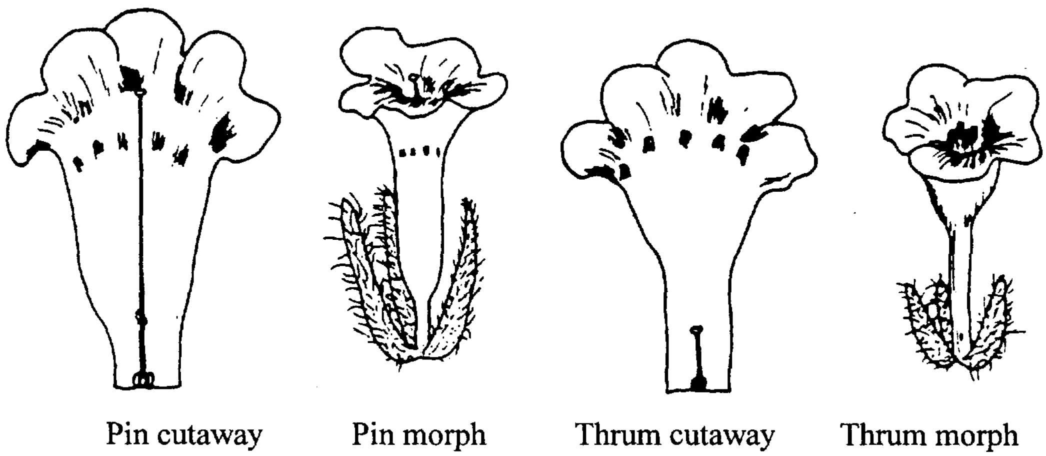

Figure 3. The two floral morphs of *Amsinckia grandiflora.*

B. Life History and Habitat

Amsinckia grandiflora is an annual herb that must germinate, grow, flower, and set seed before it dies each year. Although Ornduff (1976) and Weller and Ornduff (1977) and Pavlik (1988) have conducted studies of the reproductive biology, and to a lesser extent, the life history of *A. grandiflora*, gaps exist in our knowledge of the species' life history and ecology.

Germination.--Little is known of the germination requirements for natural populations of *Amsinckia grandiflora*, though it is likely similar to congeners (other members of the genus *Amsinckia*) and other annual grassland forbs. Typically, many grassland forbs begin germination in the fall after adequate rainfall (Heady 1977, Connor 1965, Friend 1977). The plants grow slowly during winter, increase their growth during early spring, shortly thereafter mature, flower, set seed, and die by early summer. Although little information is available, seed dormancy and multi-year seed carry-over in the soil is expected, based on life histories of similar annual grassland forbs (Major and Pyott 1966, Bartolome 1976). The low percentage germination rates observed in both natural and introduced *A. grandiflora* populations 1996 and 1997 may be associated with higher than average winter rainfall and temperatures in those years (Pavlik 1996; Bruce Pavlik, Mills College, Oakland, CA, pers. comm. 1997).

In studying nutlet production and germination requirements of cultivated populations of *Amsinckia grandiflora*, Pavlik (1988) found that larger plants were more fecund than smaller plants. There was a strong relationship among nutlet output, shoot length, shoot weight, and total inflorescence length. In addition, Pavlik (1988) determined that the germination percentages of large nutlets (six months post-production) were high and therefore germination probably would not be a significant barrier to the growth of populations. In studies at Lawrence Livermore National Laboratory (LLNL), germination of seeds was found to be highly sensitive to environmental conditions, particularly to temperature and presence or absence of leaf litter. This sensitivity has implications in considering fire as a management tool, because it considerably changes the microclimatic temperature and leaf litter cover (Tina Carlson, LLNL, in litt. 1994, Carlson 1996).

Flowering and Pollination.--Ornduff (1976), studying the Corral Hollow population at the Droptower site, found that the number and density of plants fluctuate from year to year. In 1974, he noted that pin morphs dominated the population and hypothesized that this could be the result of random fluctuations from season to season. Ornduff (1976) also found variation in pollen and seed production, pollen viability, grain size, and composition of the stigmatic pollen loads among the sample years (Table 1). The reasons for these observed variations are not known but may relate to differences in pollinator positioning between pin and thrum flowers (Ganders 1976). Although one might expect these variations to have significance to the reproductive status of subsequent generations, Ornduff (1976) suggests that such variations have had little effect on pollination or seed production. Tables 1 and 2 provide data on fruit and pollen production, and pollen stainability for the years 1967, 1974, and 1975 from Ornduff (1976); 1986 from Biosystems Analysis, Inc. (1986); and 1987 from Taylor (1987). Table 3 details the nine taxa of insects recorded visiting *Amsinckia grandiflora* at Droptower 858 (Ornduff 1976). Bees, primarily *Anthophora edwardsii* (a solitary wood-boring bee in the family Megachilidae), were the most consistent visitors to *A. grandiflora*. However, there is no direct evidence of actual pollination by *Anthophora*. The low incidence of foreign pollens suggests that *Anthophora* may be highly and consistently attracted to *A. grandiflora*. In addition, observations by the U.S. Fish and Wildlife Service (Service) and the California Department of Fish and Game (CDFG) in 1986 found several beetles (family Chrysomelidae, subfamily Chrysomelinae - two species, subfamily Clytrinae - one species; and family Staphylinidae, subfamily Omaliinae - one species) common in the flowers of the fiddleneck. Whether these beetles and the bees are effective pollinators is unknown and will require additional study.

Ornduff (1976) noted that pin stigmas received a significantly greater pollen load (66 percent) than did thrum stigmas, and pin pollen constituted an average of 70 percent of the pollen present on pin stigmas. In contrast, thrum pollen constituted an average of only 20 percent of the pollen on thrum stigmas. Despite the differences in stigmatic pollen loads between the two flower morphs, the occurrence of approximately equal numbers of pin and thrum progeny in subsequent generations led Weller and Ornduff (1977) to conclude that *Amsinckia grandiflora* possesses a cryptic self-incompatibility. The result is that thrum ovules are fertilized almost exclusively by pin pollen and pin ovules almost exclusively by thrum pollen, regardless of the presence of intermorph

Table 1. Pollen characters of *Amsinckia grandiflora* for sample years 1967, 1974 and 1975 (from Ornduff 1976).

Year	No. Flowers	Style length	Mean # grains per flower	Range	Stainability (Viability)
1967	10	Pin	32,220	20,000-39,550	-
		Thrum	33,175	17,105-43,105	-
1974	10	Pin	33,530	23,775-40,550	96%
		Thrum	29,920	26,000-35,550	93%
1975	5	Pin	33,109	- -	96%
		Thrum	22,853	- -	75%

Table 2. Fruit production statistics for *Amsinckia grandiflora* on Site 300 (Droptower) by year. Data for 1967 and 1974 are from Ornduff (1976). Mean and Standard Error of the Mean are given for 1986 and 1987 data, Biosystems Analysis, Inc. (1986) and Taylor (1987).

Flower Morph	Total Nutlets				Nutlets Per Flower				Nutlets Per Plant	
	1967	1974	1986	1987	1967	1974	1986	1987	1986	1987
Pin	1085	149	815	206	1.51	0.91	0.99±.05	1.01±.07	7.5±0.8	4.1±1.4***
Thrum	684	168	375	201	1.01	0.72	0.58±.05	0.98±.09	4.4±0.6	3.0±0.9
Total/ Combined	1769	317	1190	407	1.26	0.81	0.78±.04	1.00±.06	6.0±0.5	3.6±0.8

*** Difference in mean number of nutlets per plant in pin flowers between 1986 and 1987 is significant (p=0.007, Mann-Whitney U-test).

Table 3. Insect visitors to *Amsinckia grandiflora,* early May 1976 (from Ornduff 1976). Sexes indicated by f = female w = worker.

Insect	Family	Sex	Number Collected	No. Thrum Pollen Grains	No. Pin Pollen Grains	% Thrum Pollen	No. Foreign Pollen Grains
Unidentified	Syrphidae	-	1	245	65	79.0	6
*Apis mellifera**	Apidae	w	1	483	16	96.8	1
Scatophaga stercoraria	Anthomyiidae	f	1	0	0	0.0	0
*Bombus edwardsii**	Apidae	w	1	487	11	97.8	2
*Andrena cressonii**	Andrenidae	f	1	490	6	98.8	4
Dialictus orthocarpi	Halictidae	f	1	443	51	89.7	6
*Anthophora edwardsii**	Anthophoridae	f	9	2461	1529	61.68	10

*Asterisk indicates pollen was from scopae or corbiculae (specialized pollen-collecting structures); other pollen obtained elsewhere on the insect body.

pollen. More recent information from Weller and Ornduff (1989) indicates that self-incompatibility may be the result of differential pollen tube growth. This incompatibility system may further restrict the fecundity of the species.

Taylor (1987) hypothesized that the ratio of pins/thrums is a function of demographic stochasticity. He also suggested that thrum plants may have slightly greater drought tolerance. The 1987 population also showed differences in fecundity that were at variance from data reported earlier (Table 2). Taylor also noted reduced seed production (66 percent decline in 1987) and significantly smaller plants.

Habitat-- Historically, *Amsinckia grandiflora* occurred in native perennial bunch grass communities, which were dominated by species such as *Stipa pulchra* (needlegrass), in association with *Aristida hamulosa*, *Poa scabrella*, and *Elymus* spp. Sometimes referred to as California prairie or valley grassland, this perennial bunchgrass community type originally covered well-drained areas from sea level to 1200 m (3940 ft) around the Central Valley in California (Barbour and Major 1988). European settlement resulted in permanent alterations to the pristine native grassland, as a result of introducing: (1) alien plants (particularly prolific annual grasses), (2) nonnative grazing animals whose grazing patterns differed from those of the native species they replaced, (3) agriculture, and changes in patterns and timing of fire. As a result of these changes, extensive native bunchgrass communities have been largely eliminated from the state.

The present occurrence of *A. grandiflora* at few sites makes characterization of suitable and potential habitat tenuous at best. Ornduff (1977) characterized its habitat at the Livermore Laboratory Site 300 near Droptower as a steep grassland slope in a small ravine. He described the fiddleneck population as occurring on "light" soils. Alice Q. Howard (University of California, Berkeley, pers. comm. 1982) provided herbarium label notes by P. Kamb (now Dr. Peter M. Ray, Stanford University), collection #2184, March

29, 1952, indicating that the species occurred in heavy clay soil at an altitude of 300 m (1000 ft) . Jepson (1943) noted that the plants occur on "somewhat alkaline clay soil."

Visits by personnel from the Service, CDFG, The Nature Conservancy (TNC) and other botanists indicate the population at Droptower grows on light-colored soils with a relatively substantial clay content as indicated by the friability. The extreme south-facing east edge of the slope near the fiddleneck population clearly is composed of fill soils and asphalt debris deposited in the past during droptower construction.

As part of an effort to create new populations of *A. grandiflora* within its historical range, Pavlik and Heisler (1988) characterized and evaluated the most important biological factors affecting *Amsinckia grandiflora* to select potential sites for experimentally reintroducing *A. grandiflora* within its historical range. They used existing data on the ecology and distribution of the species. Biological and land use factors were chosen and evaluated by botanists most familiar with the biology of *Amsinckia grandiflora* and its biotic community. Each botanist ranked the relative importance of slope, aspect, soil, disturbance, and community type to the vigor of the populations. These scores were averaged and ranked once again to test for consensus. There was considerable concordance among members of this *ad hoc* recovery group on the importance of soil and community type, especially in terms of how these factors would affect moisture availability and interspecific competition. Similarly, slope, aspect, and disturbance were viewed as most relevant within the context of the same two factors. *A. grandiflora* tended to occur in soils that had neutral or slightly basic pH, low conductivity, high organic matter content, and loamy or clayey structure.

C. Historical and Current Distribution

Historically, the species was reported from a few locations in the northern Diablo Range, part of the inner South Coast Range of California (Sharsmith 1945). Jepson (1943) includes the following field note:

> On April 9, 1938, *Amsinckia grandiflora* was discovered on a hillside about one mile north of Corral Hollow, very near the boundary between San Joaquin and Alameda counties. The plants, abounding in a somewhat alkaline clay soil and forming essentially one large colony, made a bright orange spot on the hill visible for several miles. No other existent locality is known. At the original locality, in the vicinity of Antioch, it is perhaps exterminated.

Additional historic locality information is scarce. Table 4 lists all known reported collections of *Amsinckia grandiflora.*

At present, two natural populations exist. One consists of one or two colonies on U.S. Department of Energy (DOE) land (LLNL), in the hills east of Livermore, Alameda and San Joaquin Counties, California (Figure 2). The other is a recently discovered population on private land in Carnegie Canyon, San Joaquin County.

Until March 1988, only one colony on U.S. DOE land (Droptower) was known to remain and was the subject of the original listing and critical habitat designation. Although the Droptower colony occupies only approximately 1/8 acre, the designated critical habitat, which contains the constituent elements of a steep west-and south-facing slope with light-textured but stable soils, includes an area of approximately 160 acres, located entirely on DOE land in San Joaquin County, California,. The metes and bounds of the critical habitat are: California, San Joaquin County, Mount Diablo Meridian, T3S R4E Section 28 w1/2 NW1/4 and W1/2 SW1/4. Results of population censuses of the Droptower site are presented in Figure 4.

The second colony, discovered in March 1988 by Gene Draney (Site 300 Manager for LLNL) in Draney Canyon, covered a much smaller area (only a few square feet), about 3/4 mile west of the original colony, in Alameda County. This population contains fewer

Table 4. Reported collection locations of *Amsinckia grandiflora.* Asterisk indicates the site presumably is the same as the extant colonies on DOE land.

Locality	County	Collector and collection number	Date	Herbarium	Comments
Antioch	Contra Costa	Kellogg s.n.	May 1883	CAS	
Antioch	Contra Costa	Kellogg s.n. Harford s.n.	16 April 1869	CAS	
Livermore Valley (probably same as Corral Hollow)	?	Greene s.n.	1889	UC?	Reported by Rhoads and Sauls (1980)
Corral Hollow*	San Joaquin	Eastwood & Howell s.n.	April 1935	UC	Reported by Rhoads and Sauls (1980)
Corral Hollow*	Alameda (?)	Eastwood & Howell 5296	26 April 1938	CAS	Reported by Rhoads and Sauls (1980)
Corral Hollow*	San Joaquin	Rose s.n.[2]	26 April 1958	UC	
Corral Hollow*	Alameda (?)	Eastwood & Howell 5800	24 May 1938	CAS	Reported by Rhoads and Sauls (1980)

Table 4. (cont'd.) Reported collection locations of *Amsinckia grandiflora* - cont. Asterisk indicates the site presumably is the same as the extant colonies on DOE land.

Locality	County	Collector and collection number	Date	Herbarium[1]	Comments
Corral Hollow*	San Joaquin	Hoover 2866	19 March 1938	UC, CAS, DS	
Corral Hollow*	San Joaquin	Hoover 3021	9 April 1938	UC, RSA, DS	
Corral Hollow*	San Joaquin	Hoover 3357	7 May 1938	UC, DS	
Corral Hollow*	San Joaquin	Raven 1578	26 March 1950	CAS	Biosystems Analysis, Inc. 1986
Corral Hollow*	San Joaquin	Kamb 2184	29 March 1952	UC	Biosystems Analysis, Inc. 1986
Corral Hollow*	San Joaquin	Chisaki 664	5 April 1956	UC	
Corral Hollow*	San Joaquin	Heckard & Ornduff 1470	16 April 1966	JEPS	
Judsonville	Contra Costa	T. Brandegee	?	UC	Jepson (1943)
Stewartsville	?	?	?	?	Reported by Ornduff

Table 4. (cont'd.) Reported collection locations of *Amsinckia grandiflora* - cont.

Locality	County	Collector & Collection number	Date	Herbarium[1]	Comments
Mines Road	Alameda	Freeman 54	16 March 1974	CAS	Unconfirmed 13 mi. south of Livermore, oak woodland, elev. 800' Cedar Mt. (R. York, CNPS)
Second Site 300 population	Alameda	Draney	15 March 1988	--	Colony of approximately 12 plants.
Copernicus Peak	Santa Clara	Corelli	26 April 1986	--	Unconfirmed report to CNDDB[1] near Mt. Hamilton, along Chuck-a-doe trail, on west facing slope.

[1] UC = University of California, Berkeley
CAS = California Academy of Sciences
DS = Dudley, Stanford Univ. now housed at Calif. Acad. Sci.
JEPS= Jepson Herbarium
RSA = Rancho Santa Ana Botanic Garden
CNDDB = California Natural Diversity Data Base
[2] UC accession number 33210

than 30 plants (California Natural Diversity Database 1994) (Figure 5). The Draney colony, including the seedbank, may have been lost in a landslide during the winter of 1997 (T. Carlson, pers. comm. 1997).

The other known natural population was discovered in Carnegie Canyon, southeast of the Droptower site, in 1993. This population occurs on the steep, north-facing slope of the west-draining canyon at an elevation of about 300 m (1000 ft). The population is contained in an area of approximately 50 by 52 meters, the upper edge coming within 25 meters of the ridge crest and the lower edge within 10 meters of the canyon bottom. Within this area, the plants occur in patches of varying size and density (Pavlik 1996). This population is considerably larger than the LLNL population (Table 5).

In addition to the two extant natural populations, several attempts have been made to reintroduce populations of *Amsinckia grandiflora*. Based on the consensus of experts referred to above, Pavlik and Heisler (1988) recommended selection of 12 sites for possible reintroduction. A site located at Black Diamond Mines Preserve at the historic community of Stewartville (Contra Costa County) was selected for reintroduction of *A. grandiflora* on the basis of the site's high potential as habitat (a mesic grassland climate on or near soils of the Altamont-fontan complex), its public status as part of the East Bay Regional Park system, and its being within the historical range of *A. grandiflora*. In 1989, Pavlik completed the first experimental reintroduction of *A. grandiflora* at Lougher Ridge, within the Black Diamond Preserve. Pavlik also has experimentally reintroduced *A. grandiflora* into five other sites, one at the Black Diamond Preserve, one at the Connolly Ranch (San Joaquin County), two located at Los Vaqueros (Contra Costa County), and one in Corral Hollow (San Joaquin County).

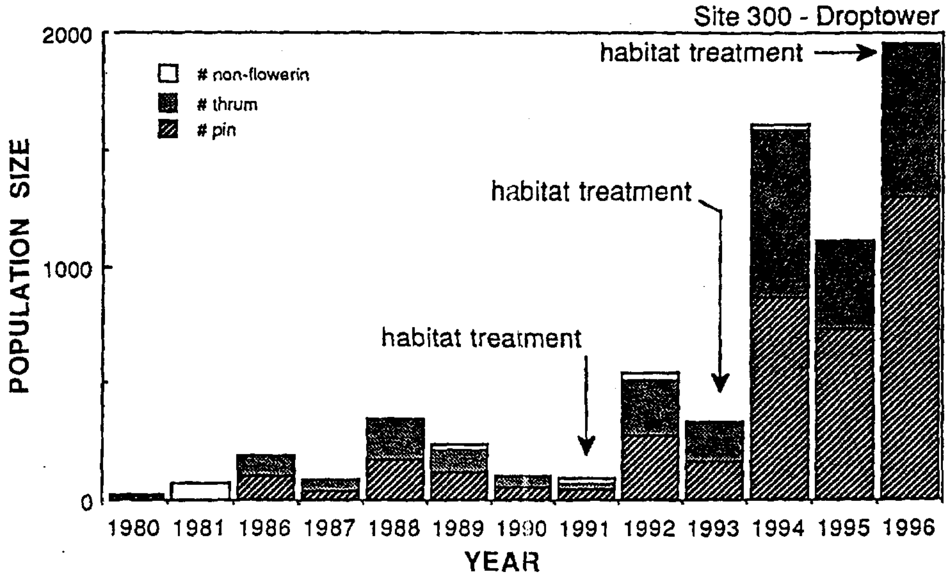

Figure 4. Spring census of the Droptower population of *Amsinckia grandiflora*. Total population size and the proportions of pin and thrum individuals are shown (Pavlik 1996).

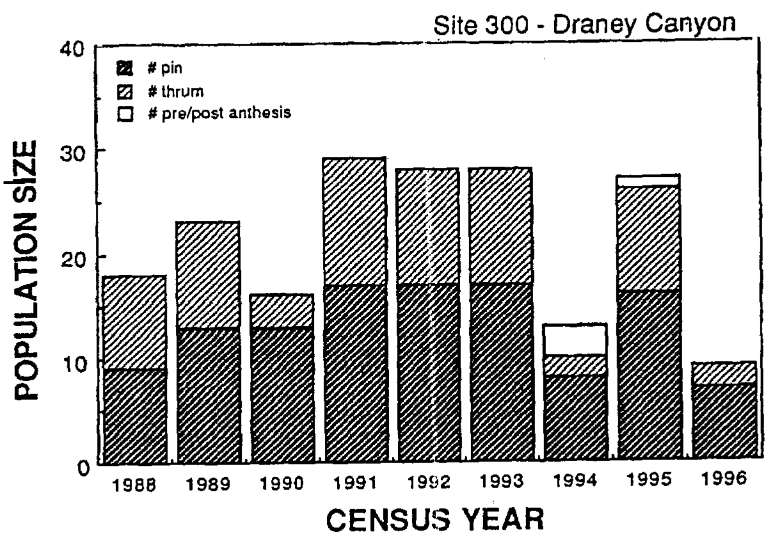

Figure 5. Spring census of the Draney Canyon population of *Amsinckia grandiflora*. Total population size and proportions of pin and thrum individuals are shown (Pavlik 1996).

Table 5. List of known natural and re-introduced *Amsinckia grandiflora* locations (From Pavlik 1996)

Recovery Area/Population	Ownership[2]	(Year) 1990	1991	1992	# Plants 1993	1994	1995	1996	1997	Status[3]
Northern										
1. Lougher Ridge (R[1])	EBRPD	1101	1301	1640	682	1106	442	30	n/a[4]	?
2. Black Diamond II (R)	EBRPD	--	--	70	6	0	0	0	"	X
Central										
1. Los Vaqueros I (R)	CCWD	--	374	9	0	1	0	0	"	X
2 Los Vaqueros II (R)	CCWD	--	--	136	0	0	0	0	"	X
Southern										
1. LLNL site 300	LLNL									
Droptower (N)		104	92	546	392	1606	1104	1949	333	I
Draney (N)		16	29	28	28	13	27	9	1	X?
Droptower Exp'tl (R)		--	--	--	220	205	403	720	616	S
2. Carnegie Canyon (N)	Private	--	--		3-4K	2.5-3K	2-3K	1.5-2.5K	n/a	?
3. Connolly Ranch (R)	Private	--	580	707	133	23	8	0	n/a	D
4. Corral Hollow (R)	CDFG	--	--	64	81	157	173	18	n/a	I

[1] R = Reintroduced population; N = Natural population
[2] CCWD = Contra Costa Water District
CDFG = California Department of Fish and Game
EBRPD = East Bay Regional Park District
LLNL = Lawrence Livermore National Laboratory
[3] S = Stable; I = Increasing; D = Declining; X = Extirpated
[4] n/a = not available

An additional population was established, using greenhouse-grown seedlings, within critical habitat on DOE land in 1993, primarily for the purposes of conducting research (T. Carlson pers. comm.1997). This population has tripled in size since its establishment (Table 5). Annual census results for all known natural and introduced populations are presented in Table 5. An intense fire occurred at the Lougher Ridge site in June of 1997, and the fate of the population is yet to be determined (B. Pavlik pers. comm. 1997).

D. Reasons for Decline and Threats to Survival

Presumably, historical reductions in range and population numbers of *Amsinckia grandiflora* resulted from extensive modification of its native perennial bunchgrass habitat for agricultural use, intensive livestock grazing, urban development, and other competing land uses. The species' relatively primitive reproductive system and low fecundity (Ornduff 1976), coupled with low population levels, may further restrict the fiddleneck's ability to thrive with the more "aggressive", nonnative grassland plant species that grow in the same area. The precise reasons for the species' decline are not known, but several factors appear to be responsible.

First are the species' inherent biological characteristics. The distylous reproductive system is considered primitive and relatively inefficient, especially when the species occurs in numerically low populations, or where pollinators may be limited or erratically available (Ray and Chisaki 1957b, Ornduff 1976, Ganders 1975). Thus, the displacement of *Amsinckia grandiflora* by aggressive, largely homostylous fiddleneck species or highly competitive nonnative grasses may be the result of its primitive and relatively poor seed-producing (less fecund) reproductive system (Ornduff 1976, Ganders 1975, Ganders 1976, Biosystems Analysis, Inc. 1986). However, recent pollination studies by Carlson (1996) indicate that *A. grandiflora* is not completely self-incompatible and, under greenhouse conditions, this species' nutlet output can approach that of *A. tessellata,* a self-compatible, homostylous species. D. Pantone (University of California, Davis, pers.

comm. 1986) suggests and Pavlik *et al.* (1993) present evidence that the low fecundity of *A. grandiflora* is the result of intense competition with nonnative grasses, especially *Avena*, *Bromus*, and *Hordeum*. Competition with exotic annual grasses resulted in a logarithmic decrease in *Amsinckia grandiflora* nutlet production, while the species' nutlet production decreased linearly in response to competition from native perennial grasses (Carlson 1996).

Second, Heady (1977) discussed the permanent alterations to pristine grassland ecosystems of California that resulted from the influx of Europeans including: 1) invasion by alien (and aggressive) plant species preadapted to the Californian climate; 2) changes in the grassland fauna and flora as a result of introduced grazers, including selective elimination of native grazers and predators; 3) cultivation; and 4) changes in grassland fire regimes. Recently, Pavlik's recovery work pointed at complex herbivory relationships. One reintroduced population, excluded from direct and indirect effects of cattle grazing, was decimated by rodents.

Third, and more recently, urbanization within the range of the species, especially in the vicinity of Antioch and Livermore, has eliminated substantial areas of former grassland habitat. The extent to which urbanization has affected the species is unknown, but Jepson (1943) intimated that the growth of Antioch may have extirpated the population there.

Finally, because of the small number of natural populations known at this time and their small sizes, the most immediate threat stems from the high likelihood of stochastic (chance) extinction. The risk of extinction is most acute in small, isolated populations (Frankel and Soulé 1981, Pickett and Thompson 1978, Soulé 1983, Beardmore 1983). In such circumstances otherwise relatively minor events, such as a short dry spell, wildfire, consumption by small herbivores, insects, or domestic animals, or a local disease outbreak, can easily result in the extinction of a small population at a single site. The highly clustered arrangement of the plants at each of the Corral Hollow sites makes this possibility even greater. Without additional populations, stochastic events remain a significant potential threat that could easily cause the extinction of *Amsinckia grandiflora.*

E. Conservation Efforts

Since its discovery and description in the late 1800's, *Amsinckia grandiflora* has stimulated considerable interest among California botanists and those concerned with protecting native California plants and their habitats. Jepson (1943) was perhaps the first to note the rarity of the species, indicating its likely extirpation from the "vicinity of Antioch" and restriction to the Corral Hollow area. Subsequent investigators such as Ray and Chisaki (1957a,b), Ganders (1975, 1976), Ornduff (1976), and Weller and Ornduff (1977) were particularly interested in studying the peculiar rarity and geographic restriction of *A. grandiflora* and other heterostylous congeners and comparing their biological attributes with the notably aggressive and weedy homostylous taxa.

Ornduff (1977) and Walter Knight (East Bay Regional Park District, pers. comm. 1980) became increasingly concerned that the species would soon go extinct without some immediate efforts to enhance population levels. Consequently, Knight collected seed from the population at Droptower and attempted to establish a second colony in similar habitat somewhere north of Corral Hollow. Although the seed sown into the wild failed to produce mature plants, potted plants were evidently maintained for several years. Thus, artificial propagation may provide a consistent seed source (Ron Kelley, University of California, Davis, pers. comm. 1986), but at the expense of genetic variation (Pavlik et al. 1993; Pavlik 1996). Since the Federal government acquired the DOE property in 1955, LLNL has been made keenly aware of the significance of and concern for this plant. The laboratory personnel maintain strict control of human entry into the entire Site 300 property for national security reasons. Access to the populations is now permitted only by special arrangement with the laboratory site manager. Moreover, the laboratory placed a chain link fence around the Droptower asphalt parking area and roadway, which prevents activities around the Droptower site from affecting *Amsinckia grandiflora*.

The highly vulnerable condition of the population and its reduced "competitive" ability prompted the Service to list *Amsinckia grandiflora* as endangered and designate its critical habitat under the Endangered Species Act on May 8, 1985 (50 Federal Register 19374). The California Fish and Game Commission also recognizes *A. grandiflora* as an endangered species under the California Native Plant Protection Act and California Endangered Species Act. The California Fish and Game Commission also listed *A. grandiflora* as a rare species under the California Native Plant Protection Act on October 6, 1978, and then changed it to endangered status on April 16, 1982.

The CDFG has been monitoring the status of the plant since 1978. Several other conservation organizations, most notably TNC and California Native Plant Society, also have periodically monitored *Amsinckia grandiflora*. The Service, in cooperation with CDFG, is now attempting to develop a formal memorandum of agreement with DOE to initiate a cooperative monitoring and recovery program for the species.

Since 1988, Dr. Bruce Pavlik, supervised by CDFG, has been gathering data on ecology, determining abiotic and biotic requirements, monitoring, and reintroducing populations of *Amsinckia grandiflora*. Pavlik has experimentally reintroduced *A. grandiflora* into six sites, two at the Black Diamond Preserve, one at the Connolly Ranch, two at Los Vaqueros, and one in Corral Hollow (Table 5). Only two of these introductions appear to be successful (Table 5). The recent declines of these populations, and of the natural population at Carnegie Canyon, may be due to the relatively wet and warm winter conditions over the past two years (Pavlik 1996). These weather conditions apparently inhibit germination of most seeds. Pavlik (1996) notes the existence of a small proportion of seeds that are apparently adapted to germinating under these relatively unfavorable conditions. Given the presence of well-established seed banks at these sites, it is likely that population numbers will rebound under more favorable weather conditions in the future (B. Pavlik, pers. comm. 1997).

Pavlik estimates that a viable seed bank may be present, even in the absence of growing plants, for up to five years. Under this criterion, two of the experimental reintroduction sites (Los Vaqueros I and II) have failed, probably due to microclimatic factors, and an additional site (Black Diamond II) is also not likely to contribute to recovery, due to decimation by rodents (Pavlik 1996).

In addition to Dr. Pavlik's efforts, the Site 300 Environmental Chemistry and Biology Group at LLNL has been conducting recovery efforts since the fall of 1992. Work funded through discretionary funds of the LLNL director is currently focused on quantifying and comparing the competitive effects of exotic annual grasses and native perennial bunch grasses on *Amsinckia grandiflora*. Field interspecific competition studies are being complemented by a greenhouse intraspecific competition study. As shown in Figure 4, controlling competing annual grasses has great potential for enhancing *A. grandiflora* reproduction.

F. Recovery Strategy

The recovery strategy for *Amsinckia grandiflora* consists of a two-pronged approach, focusing on: 1) increasing the size of existing populations and establishing new ones, and 2) at population sites, restoring, to the extent possible, ecological conditions of the native perennial bunchgrass communities in which *Amsinckia grandiflora* evolved, so that the species may thrive without the continued need for intensive management intervention, such as hand pollination, seed collection, off-site propagation, etc. The Service recognizes, however, that limited management, possibly including fencing and periodic burning, may continue to be necessary, even following downlisting, until such time as the species' habitat is restored on a large-scale.

As mentioned above, the small number and size of existing *Amsinckia grandiflora* populations and the highly clustered distribution of individuals within the populations leaves the species vulnerable to local extinction events. Consequently, this recovery plan calls for increasing the number of individuals in the existing populations and establishing additional colonies throughout the presumed historical range. This will be accomplished within the framework of six management areas, located in three geographic areas, as follows (refer to Figure 2):

Northern (north of Mt. Diablo) - two management areas
Central (south of Mt. Diablo and north of Highway 580) - two management areas
Southern (south of Highway 580) - two management areas.

At least two of the six management areas shall comprise natural populations.

The second prong of the recovery strategy focuses on the need for continued management and eventual habitat restoration of existing populations, and of those established in the future. The threats that originally contributed to the species' decline, particularly competition with nonnative vegetation, livestock grazing, and changes in fire regimes, should be managed over the long term to promote the survival and recovery of *Amsinckia grandiflora* and its native grassland associates. Such management will require a more thorough understanding of the biotic and abiotic factors that support the species in its ecosystem. The eventual goal, and a requirement for downlisting to threatened status, is to reestablish a functional community that approximates the natural community in which *Amsinckia grandiflora* evolved, and in which the species may flourish without the need for continued intensive "gardening" efforts. As mentioned above, the Service would consider "intensive" to include the need for hand-pollination, seed collection and off-site propagation. While native grassland restoration techniques are being developed, continued protection and frequent monitoring of *Amsinckia grandiflora* are of paramount importance.

PART II. RECOVERY

A. Objective

Insufficient information is available to determine biologically sound delisting criteria to ensure the long-term (greater than 100 years) self-maintenance of the species. Therefore, the interim objective of this recovery plan is to recover the species to the point where it can be downlisted to threatened. Obtaining the demographic, life history, and ecological information needed to quantify the parameters for delisting has become incorporated into the recovery tasks outlined in this plan.

B. Criteria

Amsinckia grandiflora may be downlisted to threatened status when:

1) A minimum of six management areas, including at least two natural populations, are secured and protected from the threats that caused listing initially, including urbanization, agricultural conversion, competition with invasive vegetation, and livestock grazing.

2) Sufficient information has been obtained to ensure perpetuation of native grassland communities in perpetuity, and appropriate management, based on this information, is being implemented at each management area.

3) Each management area has a minimum of 1,500 reproductive individuals, with sufficient acreage of suitable habitat to support an expanded population and provide an appropriate buffer (see task 42).

4) The six management areas concurrently demonstrate self-maintenance at or above this level for at least one precipitation cycle[2] without intensive management intervention (e.g. hand-pollination, seed collection, off-site propagation) needed to prevent population decline.

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[2]A precipitation cycle is defined as a series of years which encompass average, above-average, and below-average rainfall conditions, starting and ending with average precipitation. The populations must demonstrate the ability to survive both precipitation extremes.

Self-maintenance will be measured by demographic monitoring, focusing on seed production, germination, and survival, to determine if populations are stable or increasing. These criteria may be revised as more information becomes available through recovery efforts undertaken in conformance with this plan.

The selection of a population size of 1,500 reproductive plants is based upon data presented by Pavlik (1990, 1991, 1992, 1996) and is a "best guess" at a minimum number necessary to support stable populations of an annual grassland forb such as *Amsinckia grandiflora.* The requisite distribution of management sites is based upon historical distribution.

Achievement of the downlisting objective will be influenced by the availability of sufficient suitable habitat, life history characteristics of the species, and future environmental events. In addition, the date of downlisting will be influenced by commitments of time, money, and personnel of cooperating agencies, organizations and, possibly, private landowners.

Recovery efforts have been ongoing since 1988. Therefore, some recovery tasks have been fully or partially completed. The ordering of the tasks in the following stepdown outline and narrative is not necessarily sequential; many tasks are being, or could be, accomplished concurrently.

C. STEPDOWN OUTLINE AND NARRATIVE

1. Conserve genetic diversity of *Amsinckia grandiflora*.

As added insurance against extinction, seeds shall be collected from all natural populations. This seed will be available to use for augmentation or reintroduction, if remaining natural populations decline or are extirpated. It is important to ensure that the collected seeds are representative of the entire range of the species' genetic variability, as indicated in Pavlik 1996.

Because of the small number of natural populations known at this time, it is very important that propagules be taken in such a way that the donor plants or populations are not reduced. Possible impacts of seed collection or removal of plants from natural populations must be closely monitored to detect any effect harvest may have on source populations.

11. Select source plants.

Genetic variability within a population will determine the amount of collection necessary at all known natural sites. Because of the small sizes of existing populations, selection of source plants shall be done only under the direction of CDFG and the person designated by CDFG for recovery.

12. Collect seeds and store them at an established seed bank facility.

To maintain high seed viability, seeds shall be stored in accordance with the latest seed storage technology. An agreement will be reached to store the seed in at least two facilities that are working under contract with the Center for Plant Conservation to ensure seeds are available in case one site is destroyed. As soon as the storage facilities are chosen and contracts are approved, seeds should be collected from natural populations at appropriate times. To protect genetic diversity, it is important that seed be collected at all known natural populations during multiple years. Because of the small sizes of existing populations, collection of seeds shall be done only under the direction of CDFG and the person designated by CDFG for recovery and in accordance with standards set by the Center for Plant Conservation.

2. Locate additional populations and reintroduction sites needed for recovery.

To meet the downlisting criteria, at least six management areas need to be established. At least two of these management areas shall comprise natural populations. Habitat also needs to be surveyed for reintroduction sites. If new populations are discovered and confirmed as *A. grandiflora*, the areas where they occur should be protected and enhanced by appropriate means.

21. Identify potential habitats.

Efforts to identify potential habitats that either support additional natural populations, or can be used for reintroductions are ongoing. Information gathered in Tasks 52 and 53 will supplement these efforts. The area studied for potential habitats includes the known and historical distribution for *Amsinckia grandiflora*, from northern Contra Costa County south to San Joaquin County. As indicated above, potential habitat has been characterized based upon biological and land use factors (Pavlik and Heisler 1988). During this process, fifty-five initial candidate sites were delineated on U.S.G.S. 7.5' quadrangle overlays. Field surveys were performed, and a list of 35 nominee sites was compiled. Based upon further analysis of the available map and field data, 12 finalist sites were selected (Pavlik and Heisler 1988). This site selection process should be reviewed, and possibly conducted again, in light of more recently collected information on populations, threats, and cultural requirements.

22. Search potential habitats.

Using the information gathered in Tasks 21, 52 and 53, and with landowner permission, searches of potential habitat should be continued to identify new populations and possible reintroduction sites. Both natural populations are needed to meet the stated downlisting objectives. If the owner of the recently discovered private site does not want to participate in recovery efforts, additional natural populations must be discovered in order to meet recovery criteria.

3. Contact landowners

To downlist to threatened status, at least six viable management areas must be protected by perpetual administrative agreements with the landowners on whose land *A. grandiflora* or essential habitat for *A. grandiflora* is found. Landowner contact constitutes the first step in this process.

31. Develop an agreement with DOE to formalize *Amsinckia grandiflora* protection.

Access to the populations on LLNL is currently gained through a relatively informal arrangement with the laboratory site manager. Access limitation should be continued to prevent human trampling or collection impacts on the populations. LLNL and DOE maintenance, use, and other activities at the Droptower and Draney Canyon sites near the fiddleneck populations demand that facility personnel be aware of potential effects to the plant. The Service should develop an agreement with DOE to formalize protection and coordinate activities.

32. Determine ownership of potential management areas.

Determining land ownership is the initial stage in securing sites and, later, developing management plans to enhance populations. This task has been completed for the known populations and selected management areas. Land ownership of the existing sites is as follows:

Northern - Lougher Ridge and Black Diamond II are owned by the East Bay Regional Parks District.

Central - Los Vaqueros I and Los Vaqueros II are owned by Contra Costa Water District.

Southern - The Droptower and Draney colonies at LLNL Site 300 are owned by LLNL.
Carnegie Canyon is privately owned.
Connolly Ranch is privately owned.
Corral Hollow is owned by CDFG

33. Ascertain willingness of landowners to participate in recovery efforts.

The landowners of most known sites are aware of the existence of *Amsinckia grandiflora* on their property. They should be continually informed of the ongoing recovery effort. Federal agencies should be contacted and asked to assist with recovery planning. Private landowners should be contacted and asked if they are interested in participating and protecting their populations and should be included in the recovery process. Achieving downlisting goals will be based on willing participants. Management agreements should ultimately be developed with landowners of all reintroduction sites (Task 71). Some preliminary information concerning willingness of landowners to participate in recovery efforts is discussed below as background to the selection process (Task 41).

The landowners of Lougher Ridge, Black Diamond II, and Los Vaqueros I and II have been contacted by CDFG and have expressed strong interest in recovery activities and long term management. The lessee of Connolly Ranch has been contacted by CDFG and has been very cooperative in allowing a reintroduction on his land. This individual is now also the lessee of the property on which the Carnegie Canyon natural population occurs. Owners of any newly discovered populations should be similarly approached and their participation in the *Amsinckia grandiflora* recovery process solicited.

4. Establish six management areas and maintain or enhance populations of *Amsinckia grandiflora* that may occur within any area.

Despite much ongoing habitat work, *Amsinckia grandiflora* management areas have not yet been designated. Until sites are selected, as many of the natural and reintroduced sites as possible shall be protected. Once the sites have been selected, management areas need to be established. Establishing management areas will include delineating boundaries of each area and securing and protecting habitat within the boundaries. At least two management areas shall contain natural populations.

41. Select management areas.

The Service, in consultation with LLNL, CDFG, East Bay Regional Parks District, and other landowners and knowledgeable parties, should choose at least two management areas in the northern recovery area, two in the central recovery area, and two in the southern recovery area, for establishment and maintenance of the six populations necessary to meet downlisting requirements. This selection may require additional analysis of site characteristics (Task 2.1). Currently, the sites being recommended for selection include Lougher Ridge, Connolly Ranch, Lawrence Livermore National Laboratory, and Carnegie Canyon. The 1997 fire at Lougher Ridge may have affected the suitability of this site. To date, reintroduction efforts at Los Vaqueros and Black Diamond II have failed. Additional sites need to be chosen for the northern and central recovery areas.

42. Determine size and delineate boundaries of management areas.

The size of potential management areas needs to be determined. Sufficient acreages should be protected in management areas to ensure that *Amsinckia grandiflora* and the community in which it occurs are protected adequately to maintain ecosystem and evolutionary processes. Factors that need to be considered in determining the appropriate size of management areas include, but are not restricted to, the area needed for establishment, expansion, and buffering of several subpopulations of *A. grandiflora* within each management area; the area needed to minimize edge effects from nonnative plants, different environmental conditions along the edge of the management area, and chance catastrophic events; the area needed to manage periodic burns for maintenance of a perennial bunch grass community; the current and potential future land uses of surrounding land; the shape of the management area; and the area needed to support the interactions of key community members, including dispersal vectors and pollinators.

Figure 2 shows the general location of known extant populations. The population and subpopulation boundaries should be mapped at all selected management areas. The boundaries of each management unit should be drawn on maps at a scale not less than 1:6,000.

43. Secure and protect the habitat supporting each population.

Once the boundaries of the selected management areas have been delineated, mechanisms must be developed to protect the habitat from known threats (including urbanization, agricultural conversion, competition with invasive alien vegetation, and uncontrolled grazing from livestock) and to allow development of management plans to enhance populations.

431. Evaluate and implement appropriate long-term land protection mechanisms.

After landowners have been identified and contacted, an analysis must be made of the various protective alternatives available. If private owners are not interested in protecting populations, then attempts should be made to acquire (fee or easements) other sites, either by a Federal or State agency, or conservation group that would protect the populations.

432. Control invasive vegetation.

Within the sites occupied by *Amsinckia grandiflora*, introduced annual grasses (*Avena*, *Festuca*, *Bromus*) and aggressive congeners (*Amsinckia gloriosa*, and *A. intermedia*) compete with *A. grandiflora*, interfering with growth and seedling recruitment. Studies of competition among *Amsinckia* species is ongoing (T. Carlson, pers. comm. 1997). Selective control of annual grasses has proven effective in promoting the survival and vigor of *Amsinckia grandiflora* populations (Pavlik 1996). Although it is an essential immediate component of *Amsinckia grandiflora* management, use of herbicides should be viewed as an interim measure, as we develop overall methods for restoration of perennial bunch grass communities (Task 51).

433. Control rodents and insects, as necessary.

It may also be necessary to use herbivore or seed predator control measures such as insecticides, rodenticides, or snap-traps, as prophylactic measures for immediate threats. Monitoring should include identification of potential pests and diseases so that appropriate corrective measures can be undertaken. As with Task 432, this task should be considered an interim measure, during the natural community restoration process.

44. Supplement existing populations.

At present, low numbers of flowering individuals and apparent lack of significant recruitment demonstrate the need to supplement some existing populations. Using seed from available collections as much as possible, or in keeping with the guidelines enumerated in Task 12, seeds should be sown, or seedlings should be produced and then outplanted, in selected areas. Supplementation of natural populations, if conducted, should utilize only seed taken previously from that population. To the extent possible, all supplementations should be made in a manner that will permit tracking of the genetic source of introduced individuals.

45. Monitor populations.

Pavlik (1990) has developed techniques for monitoring populations. A number of facets to demographic monitoring of the annual *Amsinckia grandiflora* exist, as follows:

1. Analyze population trends, through annual census (number of above-ground reproductive plants) at each site.
2. Assess population performance by determining pin/thrum ratio, plant size, and nutlet output, and by estimating percent cover and biomass.
3. Note and record any changes in habitat or land use that may impact the species.

These components of monitoring have been applied successfully to monitor both natural and reintroduced populations (Pavlik 1991, 1992, 1994, 1996).

451. Continue ongoing demographic monitoring

Continued monitoring of each natural and reintroduced population needs to be conducted several times each year to follow population trends (i.e., mortality, survivorship, recruitment and soil seed bank). Demographic monitoring is essential to establishment of reintroduced populations and assessment of natural populations to ensure that *Amsinckia grandiflora* is self-maintaining. These monitoring data may also forewarn of any impending crises. Demographic data should be gathered using only the most efficient and innocuous techniques available. Monitoring shall be performed by qualified personnel that are available for several years to insure continuity and quality control.

452. Develop monitoring plan.

Monitoring plans need to be developed for each site where natural and reintroduced populations exist. Intensive monitoring is critical to successfully reintroducing *Amsinckia grandiflora* and is also critical for assessing the management needs of natural populations. Site monitoring plans would include repeatable sampling design (grid, subplot, transect, etc., as appropriate) for each site. Sampling designs shall be comparable among all sites and shall minimize disturbance to the sites, to the extent possible. The monitoring plan would be "plugged into" the overall site management plans (Task 6), when these are completed.

453. Implement monitoring plans.

Monitoring plan implementation will continue and extend ongoing monitoring (Task 451) at each site. Monitoring shall be performed several times each year for at least six years (three years during the establishment phase of reintroduction and then during the following three years) to ensure that plants are completing all phases of their life cycle. In addition to techniques developed by Pavlik (1990) for monitoring, percent cover and total biomass of *Amsinckia grandiflora* should be estimated. After the initial 6 years of monitoring, if there are at least 1,500 reproductive plants at each site, all of the life cycle is being completed, and the trend is stable or improving, the sites should be resampled every third year. If there are fewer than 1,500 reproductive individuals at each site, or if populations are declining, remedial actions may need to be taken. Until management areas are established, monitoring shall continue at the existing sites.

5. Characterize habitat and management requirements.

An understanding of the population trends of each site, and interactions of key community members, including pollinators and dispersal vectors, is necessary to refine management plans and to revise management techniques. Many aspects of the basic life history and ecology of *Amsinckia grandiflora* are not known. Factors that would be the most important for increasing the population size of each natural population need to be determined. Information gained from appropriate studies is needed to establish recovery goals, and to effectively and efficiently manage and protect natural and reintroduced populations of the species and its habitat.

51. Develop bunchgrass habitat restoration techniques.

One of the primary limiting factors to the re-establishment of *A. grandiflora* is competition with annual weedy grasses. Complete recovery of *Amsinckia grandiflora* will not be possible without restoring the species' original habitat, to provide consistent natural seedling establishment and survival without intensive human intervention. Numerous other rare native grassland plants in California would also benefit from the development and implementation of grassland ecosystem restoration techniques. Pavlik (1990, 1991, 1992) has examined the effectiveness of various management techniques of exotics control, including hand manipulation, selective herbicides, and fire, in the reintroduction of *A. grandiflora* to several sites. These techniques could be built upon as a basis for ecosystem restoration. Grassland habitat restoration will not be a simple or inexpensive process. It will require a multi-year regime of judicious herbicide use, critically timed fires, and carefully controlled grazing, in various proportions, designed to gradually decrease the dominance of exotic annual grasses. This control of exotics should allow native members of the original bunchgrass community to reassert their dominance, where they still exist in the seedbank. Some outplanting of native grasses may be useful, but should not be attempted until annual grass control has been achieved.

Restoration of the native grassland ecosystem throughout its original range is, of course, beyond the scope of this recovery plan. However, any such restoration techniques developed and successfully implemented through this recovery plan could be applied by others, at a broader scale, to ensure long-term conservation of many other rare plants that were originally part of this ecosystem.

52. Determine biotic requirements.

Information on pollination requirements, insect visitors and their efficiency, fluctuations in seed production, seed predation, seed bank dynamics, gene flow distances, effective population sizes, and plant population levels comprise the basic data needed for the recovery management program. Although some data are available (Ornduff 1976, Pavlik 1988, Weller and Ornduff 1977), more detailed studies are needed to provide an adequate data base. Studies of biotic factors relevant to *A. grandiflora* recovery could be grouped as follows:

1. Seed predation - Recent observations at the Conolly Ranch reintroduction site indicate that predation of seeds by rodents, and possibly birds, may have been a primary factor in the rapid decline of this site. On a single night, 87 Sherman-type live traps captured 5 seed-eating rodents of 3 species (Pavlik 1996). The abundance and impact of seed predators requires further study. Low-impact methods of seed predator deterrence should be tested. Patterns of potential seed predator abundance should be carefully considered in the selection of future introduction sites.

2. Seed production - As an annual, *Amsinckia grandiflora* relies on yearly seed production for its continued existence. Seed production studies would include study of pollen production and viability, studies of insect pollinators, and pollination mechanisms. Pavlik has already collected much information on the relationship of plant size to seed production.

3. Seed germination/seedling survival - Recent information indicates that seed germination may be inhibited by excessive winter precipitation and/or relatively warm winter temperatures (Pavlik 1996). The effects of these factors, and factors affecting seedling survival, are particularly important to support cultivated populations of *Amsinckia grandiflora*. The effects of fire on germination are relevant to management of naturally occurring and

reintroduced populations. The occurrence of an extensive, hot burn at Lougher Ridge in June of 1997 provides a unique opportunity for study.

4. Seed bank characteristics - This would include determining extent of the soil seed bank, seed dormancy, seed losses, and seed longevity. An understanding of these factors, in combination with knowledge of seed germination requirements, will contribute to our understanding of the magnitude of year-to-year population fluctuations that can be expected in a "stable" population.

5. Demography - Studies of effective population sizes, year-to-year population fluctuations, gene flow distances, etc. are necessary for determining, or refining, recovery criteria. Such studies may also be accomplished as a part of Task 8.

53. Determine abiotic requirements.

An analysis of soil type and texture, slope aspect, and precipitation can provide information useful for maintenance and enhancement of natural populations. This information would also aid efforts to locate suitable habitat for reestablishment of *Amsinckia grandiflora* and identify areas where currently unknown populations may exist.

A preliminary survey has been undertaken within the presumed historical range to identify soil/vegetation associations that may provide appropriate conditions for successful reintroductions. LLNL has collected soil samples for texture, micro- and macroelement analyses from all extant populations. LLNL currently is analyzing the data and will make them available to the Service upon completion of the analyses. Thus, this task is partially completed.

6. Develop and implement site-specific management plan for each management area.

Management plans, which direct actions essential for preserving the populations as long as active management is deemed necessary, should be individually tailored to each management area. Because management actions, including habitat protection (Task 43), monitoring (Task 45), and population reintroduction (Task 7) are ongoing, these plans have, in practice, been partially completed. However, they should be written down, for the benefit of future managers and researchers, and to promote future management consistency.

6.1 Write site-specific management plan for each management area.

Development of management plans should be founded on a broad base of collected information, including population monitoring. The management plan should clearly and explicitly identify activities potentially affecting the populations. The plan should also include a protocol for conducting necessary testing, maintenance, and use activities that will be compatible with protection of the populations.

6.2 Implement site-specific management plans.

In implementing management plans, appropriate action should be taken to rectify problems identified in Task 45 for which corrective measures are available and feasible. Implementation of any management plan will require careful coordination among all interested parties including: the Service, CDFG, DOE, and the private sector. Until site-specific management plans are implemented, all ongoing efforts to take corrective management actions shall continue.

7. Reintroduce populations into management areas.

Downlisting and recovery of *Amsinckia grandiflora* require that additional populations be established and maintained. The interim goal, for downlisting, is to have at least six management areas with 1,500 reproductive plants each. To accomplish this goal, unless new populations are discovered, *A. grandiflora* must have success in reintroductions on four management areas. The potential sites must be identified and tested for suitability as reintroduction sites (Task 21). Specific establishment test sites must be selected (Task 41), secured (Task 43), and managed (Tasks 43, 62).

Pavlik (1988) has already developed techniques for introducing seeds to reintroduction sites. Population establishment using seedlings also appears promising (T. Carlson, pers. comm. 1997). Two or three of the previously reintroduced *Amsinckia grandiflora* populations appear to be successful and will likely contribute to the species' long-range recovery.

71. Develop agreements with owners of reintroduction sites.

Agreements with landowners should be developed that conform with the management plan for each site (Task 6). CDFG should contact landowners of appropriate non-Federal lands (Task 33). The agreement that the Service develops with DOE concerning management of Site 300 (Task 31) should also address management of the experimental population that has been established there.

72. Conduct reintroduction and implement reintroduction plan for each management area.

Reintroductions should be conducted as specified in Pavlik (1988), or in accordance with more recent information, as appropriate. Implementation of any reintroduction plan, as part of the management plan for each area (Task 62) will include details of planting, monitoring, and maintenance, based on the results of landowner contacts/agreements (Task 71) and habitat studies (Task 5). Additional establishment sites may be needed if any reintroduction is unsuccessful. Reintroduction sites must meet all criteria of Task 4 and provide secure areas for reestablishment and sufficient area for self-maintenance in the face of variable environmental conditions. Until reintroduction plans are written, ongoing reintroduction efforts shall continue. Reintroduction site management will include monitoring at all reintroduction sites, as specified in Task 45. Appropriate action must be taken to rectify any problems identified through monitoring for which corrective measures are available and feasible.

8. Determine delisting criteria.

Information gathered through Tasks 451, 453, and 5 needs to be analyzed to establish delisting criteria. Genetic factors also need to be studied to determine if they are limiting.

81. Identify genetic factors that may be limiting.

The genetic variability of *Amsinckia grandiflora* should be compared with other closely related, nonendangered, distylous plants to determine if genetic variability is limiting the future population or species viability.

82. Develop a predictive computer model to test for long-term survivability of populations.

It is essential that the populations of *Amsinckia grandiflora* be capable of self-maintenance in perpetuity. To determine the critical population levels, a computer model shall be developed to predict population trends and to test for the long-term survivability of the populations. The model should incorporate appropriate physical and ecological data generated in various recovery tasks.

83. Conduct long-term population viability analysis using computer model.

Based on the results of Tasks 451, 453, 52, 53, 72, and 81, demographic data shall be incorporated into a population viability model for the species similar to the methods used by Menges (1986), to derive critical population levels. Then, using data from the habitat studies, a similar model shall be developed to identify the area requirements for each population and the number of populations necessary to ensure survival in perpetuity.

84. Establish acceptable survivability criteria for delisting.

Use information from Task 83 to determine the need to establish additional populations or increase minimum stable populations or other measures necessary to delist.

9. Coordinate implementation of the recovery program.

A recovery implementation team, consisting of botanists, ecologists, land owners or lessees, land managers, fire and grazing management specialists, representatives of the Service, CDFG, DOE (LLNL), and others, such as TNC and CNPS, as appropriate, will meet periodically (at least annually), to coordinate implementation of the recovery program. Team members will assist in tracking the progress of recovery tasks and provide scientific and management insights on matters related to recovery goals.

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PART III. IMPLEMENTATION SCHEDULE

The table that follows is a summary of scheduled actions and costs for the *Amsinckia grandiflora* recovery program. It is a guide to meet the objectives of the Recovery Plan, as elaborated in Part II, Narrative. This table indicates the task priorities, tasks to meet the objectives, agencies are responsible to perform the tasks, and the estimated costs to accomplish the tasks. Implementing Part III is the action of the recovery plan that, when accomplished, will bring about the recovery of this endangered species. Cost figures provided here are intended as gross estimates for general planning purposes. More detailed budget analyses will be necessary by the responsible agencies.

RECOVERY ACTION PRIORITIES

1 = Any action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2 = Any action that would prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction

3 = All other actions necessary to provide for full recovery.

ACRONYMS USED IN THE IMPLEMENTATION SCHEDULE

CDFG	California Department of Fish and Game
FWS-ES	U.S. Fish and Wildlife Service - Ecological Services
DOE	Department of Energy, administered through Lawrence Livermore National Laboratory
TBD	to be determined
cont.	continuing
*	Lead Agency

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR *AMSINCKIA GRANDIFLORA*

Prior-ity No.	Task No.	Task Description	Task Duration (Years)	Responsible Party	COST ESTIMATES ($1,000) Total Cost	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
1	11	Select source plants	2	CDFG * DOE FWS-ES	2.0 1.0 2.0	1.0 0.5 1.0	1.0 0.5 1.0										
1	12	Collect seeds and store them at established seed bank facility	3	CDFG * DOE FWS-ES	3.0 1.5 3.0		1.0 0.5 1.0	1.0 0.5 1.0	1.0 0.5 1.0								
TOTAL COST FOR NEED 1					12.5	2.5	5.0	2.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	9.	Coordinate recovery implementation	cont.	FWS-ES* CDFG	70.0 25.0	15.0 2.5	5.0 2.5	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0	5.0 2.0
1	21	Identify potential habitat	1	CDFG * FWS-ES	3.0 3.0	3.0 3.0											
1	22	Search potential habitat	1	CDFG * FWS-ES	4.0 2.0		4.0 2.0										
1	31	Develop an agreement with DOE to formalize protection	1	FWS-ES* CDFG DOE	2.0 1.0 1.0	2.0 1.0 1.0											
1	32	Determine ownership of potential management areas	done	CDFG FWS-ES	0.0 0.0												
1	33	Ascertain willingness of landowners to participate	3	CDFG * FWS-ES	3.0 3.0	1.0 1.0	1.0 1.0	1.0 1.0									
1	41	Select 6 management areas	3	CDFG FWS-ES* DOE	12.0 6.0 6.0		4.0 2.0 2.0	4.0 2.0 2.0	4.0 2.0 2.0								

Priority No.	Task No.	Task Description	Task Duration (Years)	Responsible Party	COST ESTIMATES ($1,000)													
					Total Cost	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	
1	42	Determine size and delineate boundaries of the management areas	4	CDFG FWS-ES DOE	31.0 31.0 16.0	15.0 15.0				4.0 4.0 4.0	4.0 4.0 4.0	4.0 4.0 4.0	4.0 4.0 4.0					
1	431	Evaluate and implement land protection	2	CDFG * FWS-ES	10.0 10.0	5.0 5.0	5.0 5.0											Does not include cost of acquisition
1	432	Control invasive vegetation	cont.	CDFG* FWS-ES* DOE	33.0 33.0 33.0		3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	3.0 3.0 3.0	
1	433	Control herbivory, as necessary	cont.	CDFG* FWS-ES* DOE	0.0 0.0 0.0			TBD TBD TBD										
TOTAL COST FOR NEED 2					338.0	69.5	42.5	26.0	24.0	28.0	28.0	28.0	28.0	16.0	16.0	16.0	16.0	
1	44	Supplement existing populations	3	CDFG* DOE	10.0 10.0	5.0 5.0	5.0 5.0											
1	451	Continue demographic monitoring	cont.	CDFG* FWS-ES	90.0 90.0	5.0 5.0	5.0 5.0	5.0 5.0	10.0 10.0	10.0 10.0	10.0 10.0	7.5 7.5	7.5 7.5	7.5 7.5	7.5 7.5	7.5 7.5	7.5 7.5	
1	452	Develop monitoring plans	2	CDFG* FWS-ES	10.0 30.0		5.0 15.0	5.0 15.0										
1	453	Implement monitoring plans	cont	DOE CDFG* FWS-ES	20.0 20.0 20.0	10.0 10.0 10.0	10.0 10.0 10.0	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	
1	51	Develop habitat restoration techniques		FWS-ES CDFG* DOE	40.0 40.0 40.0	20.0 20.0 20.0	20.0 20.0 20.0	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	

Priority No.	Task No.	Task Description	Task Duration (Years)	Responsible Party	COST ESTIMATES ($1,000) Total Cost	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
1	52	Determine biotic requirements	3	FWS-ES CDFG* DOE	21.0 21.0 21.0	7.0 7.0 7.0	7.0 7.0 7.0	7.0 7.0 7.0									
1	53	Determine abiotic requirements	1	FWS-ES CDFG * DOE	3.0 3.0 3.0	3.0 3.0 3.0											
1	61	Develop management plan for each management area	3	CDFG* DOE FWS-ES	12.0 12.0 24.0		4.0 4.0 8.0	4.0 4.0 8.0	4.0 4.0 8.0								
1	62	Implement management plan for each management area	cont.	CDFG* DOE FWS-ES	30.0 30.0 30.0	10.0 10.0 10.0	10.0 10.0 10.0	10.0 10.0 10.0	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD
2	71	Develop agreements with reintro. site owners	2	CDFG* FWS-ES TNC	6.0 2.0 4.0			3.0 1.0 2.0	3.0 1.0 2.0								
2	72	Conduct reintroduction and implement management plans	2 (cont.)	CDFG* FWS-ES	16.0 48.0				8.0 24.0	8.0 24.0	5.0 5.0	5.0 5.0	5.0 5.0	5.0 5.0	5.0 5.0	TBD TBD	TBD TBD
TOTAL COST FOR NEED 3					756.0	170.0	197.0	103.0	74.0	52.0	30.0	25.0	25.0	25.0	25.0	15.0	15.0

Priority No.	Task No.	Task Description	Task Duration (Years)	Responsible Party	COST ESTIMATES ($1,000)													
					Total Cost	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	
3	81	Identify limiting genetic factors	3	CDFG * FWS-ES	12.0 12.0				3.0 3.0	3.0 3.0	3.0 3.0	3.0 3.0						
3	82	Develop predictive computer model	2	CDFG * FWS-ES	9.0 9.0										3.0 3.0	3.0 3.0	3.0 3.0	
3	83	Conduct long-term population viability analysis	2	CDFG * FWS-ES	4.0 4.0											2.0 2.0	2.0 2.0	
3	84	Establish acceptable delisting criteria	2	CDFG FWS-ES*	0.0 0.0											TBD TBD	TBD TBD	
NEED 4		COST			50.0	0.0	0.0	0.0	6.0	6.0	6.0	6.0	0.0	0.0	6.0	10.0	10.0	
TOTAL YEARLY COST						242	244.5	131.5	106.5	86.0	64.0	59.0	53.0	41.0	47.0	41.0	41.0	
TOTAL COST					1156.5													

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