



Caltrans Native Grass Evaluation Pilot Program (Placer County Report)

**The California Department of Transportation
Landscape Architecture Program
1120 "N" Street, Sacramento, CA 95816**

Presented by:



P&D Environmental

999 Town & Country Road, 4th Floor

Orange, CA 92868

TABLE OF CONTENTS

EXECUTIVE SUMMARY	ES-1
ES.1 Overview of the Executive Summary	ES-1
ES.2 Research	ES-1
ES.3 Project Design Concept.....	ES-1
ES.4 Installation.....	ES-2
ES.5 Program Results	ES-2
ES.5.1 Recommended Native Grasses for the Central Valley (Placer County)	ES-2
ES.5.2 Recommended Native Grasses for Central Coast (San Luis Obispo).....	ES-3
ES.5.3 Recommended Native Grasses for the Central Valley (Fresno County)	ES-3
ES.5.4 Recommended Native Grasses for the Central Inland (Monterey County)	ES-3
ES.5.5 Recommended Native Grasses for the Inland Desert (Riverside County)	ES-3
ES.6 Recommended Installation Techniques	ES-3
ES.7 Soil Additives.....	ES-4
ES.8 Native Grass Sod.....	ES-4
ES.9 Project Summary.....	ES-4
1.0 PROGRAM OVERVIEW.....	1-1
2.0 RESEARCH	2-1
3.0 TEST SITE LOCATIONS AND PLANTING DESIGNS.....	3-1
3.1 Test Site Locations.....	3-1
3.2 Planting Designs	3-1
4.0 SITE PREPARATION AND EVALUATION OF PLANTING TECHNIQUES....	4-1
4.1 Site Preparation.....	4-1
4.2 Planting Techniques and Evaluation of the Planting Techniques.....	4-1
4.2.1 Hydroseeding	4-1
4.2.2 Drill Seeding	4-2
4.2.3 Imprinting	4-2
4.2.4 Nursery Grown Grass Plugs and Sod.....	4-3
5.0 SUPPLEMENTAL ADDITIVES	5-1
5.1 Use of Supplemental Additives	5-1
5.2 Mycorrhizal Soil Inoculum.....	5-1
5.3 Soil Polymers (Water Absorbing Crystals).....	5-1
5.4 Terragraf Blankets	5-2
6.0 INSTALLATION SUMMARY.....	6-1

7.0	YEAR ONE SUMMARY	7-1
7.1	Overview of the Year One Summary.....	7-1
7.2	Year One Summary for the Placer County Site.....	7-1
7.2.1	Year One Test Summary for the Placer County Site	7-1
7.2.2	Year One Maintenance Summary for the Placer County Site	7-1
8.0	YEAR TWO SUMMARY.....	8-1
8.1	Overview of the Year Two Summary.....	8-1
8.2	Year Two Summary for the Placer County Site	8-1
8.2.1	Year Two Test Summary for the Placer County Site	8-2
8.2.2	Year Two Maintenance Summary for the Placer County Site.....	8-2
9.0	YEAR THREE SUMMARY.....	9-1
9.1	Overview of the Year Three Summary.....	9-1
9.2	Year Three Summary for the Placer County Site	9-2
9.2.1	Year Three Test Summary for the Placer County Site	9-2
9.2.2	Year Three Maintenance Summary for the Placer County Site.....	9-2
10.0	FINDINGS.....	10-1
10.1	Findings of the Program.....	10-1
10.1.1	Overview	10-1
10.1.2	Site Design	10-1
10.1.3	Site Preparation	10-2
10.1.4	Seed Design Specification.....	10-2
10.1.5	Planting Techniques	10-3
10.1.6	Erosion Control	10-3
10.1.7	Fire Control	10-3
10.1.8	Weed Control	10-3
10.1.9	Sod Installation.....	10-3
10.1.10	Annual Maintenance.....	10-4
10.2	Future Considerations and Recommendations.....	10-5
11.0	REFERENCES.....	11-1
12.0	PHOTOGRAPHS	12-1
13.0	LIST OF PREPARERS.....	13-1
13.1	California Department of Transportation.....	13-1
13.2	P&D Consultants, Inc.	13-1
13.3	Sub-Consultants	13-1

APPENDICES

Appendix A

LIST OF EXHIBITS

3-1 Typical Test Site Planting Layout..... 3-3

LIST OF TABLES

6-1 Installation Summary 6-1

7-1 Native Grass Test Plot Evaluation Summary for Year One for the Placer County Site.. 7-2

7-2 Year One Summary for the Placer County Site 7-2

8-1 Native Grass Test Plot Evaluation Summary for Year Two for the Placer County
Site 8-4

8-2 Year Two Summary for the Placer County Site 8-4

9-1 Native Grass Test Plot Evaluation Summary for Year Three for the Placer County
Site 9-3

9-2 Year Three Summary for the Placer County Site 9-3

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

ES.1 OVERVIEW OF THE EXECUTIVE SUMMARY

P&D Consultants was retained by the California Department of Transportation (Caltrans) to lead in the research and development of a Native Grass Evaluation Pilot Program. The goal for this Program was to test and evaluate native grass species and planting techniques that could be used to reduce the need for chemical roadside spraying to control weed growth along Caltrans rights-of-way on highways throughout the state and to reduce the potential for fire and storm water runoff. The activities conducted for this Program and the major program findings are summarized briefly in this Executive Summary.

ES.2 RESEARCH

P&D conducted an extensive review of existing literature, research and test projects regarding native grass installation programs. This research included review and analysis of site soil preparation, plant installation techniques, soil additives and maintenance programs. These reports offered numerous findings and information potentially useful in the design and development of this test program. However, most of the research programs were developed using controlled situations or were too costly to be implemented on a massive scale such as the goal for this Program. In addition, a lot of the test results and other available information contradicted each other, making it difficult to decipher the correct information.

P&D accompanied by Caltrans' Project Manager reviewed several existing projects and toured several seed companies, sod farms and nurseries to coordinate information and evaluate existing programs. Based on the available research and these field visits, P&D and Caltrans developed a test research program using typical Caltrans roadsides and existing planting techniques. The program evaluated and confirmed existing research, and tested and evaluated the use of native grasses as a cost effective weed, fire and erosion control solution.

ES.3 PROGRAM DESIGN CONCEPT

The design concept for this Program was to develop a statewide program which included several locations selected by Caltrans based on climate region and availability. Test sites were selected in the Central Valley (Placer County), Central Coastal (San Luis Obispo), Central Valley (Fresno County), Central Inland (Monterey County) and Inland Desert (Riverside County). These sites represent typical Caltrans road conditions for a selected group of specific climate regions.

The design concept was to test and evaluate individual native grass species and planting concepts and installation techniques. The Program also evaluated the potential of established roadside plant communities, to control weeds and reduce storm water and fire potential. Individual native grass species were selected based on the regional growing characteristics and climate conditions. These grass lists were also reviewed by a number of experts and maintenance operations managers prior to final design. In addition, blended seed mixes were developed using a variety of grasses, which had the ability to adapt to specific areas in each region. The test plots were set

up in the five different regions in the state. Each test plot location was set-up identically, to test various live native grass plugs, grass sod, blended seed mixes and different planting techniques. Each site was set up to test 12 to 14 different types of native grass species grown as grass plugs, sod and blended seed mixes. Grass plugs were grown in monoculture individual test plots, to monitor each grass species' growing characteristics and survivability rates. In addition, the blended seed mixes were tested and installed using various mass planting techniques, which included hydroseeding, drill seeding and imprinting.

ES.4 INSTALLATION

Most of the test sites were initially covered with numerous weeds and non-natives grasses. All the sites were chemically sprayed for weed control 14 days prior to planting. In addition, due to the highly compacted soils at all the sites, all the sites were ripped using a skiploader with a rototiller attachment and tilled to a depth of nine inches. This technique was very effective and cost efficient and loosened the soil to a compaction rate of 70 to 80 percent which was ideal for the plant installation.

Grass plugs and sod were grown at Speedling and GreenHart Nurseries and were of the highest quality. Both grass plugs and sod installed easily and provided excellent cover and valuable research information for this program.

ES.5 PROGRAM RESULTS

This Program developed and tested various native grass species grown and installed using various planting mediums and installation techniques at five different locations throughout the state. A key finding of this Program was that native grasses can be developed as a sustainable roadside vegetation community which also has the potential for weed, erosion and fire control. However, there is a limited number of native grass species that will work under the harsh conditions of a typical Caltrans roadside project and with the growth characteristics to be easily maintained. The following are recommended native grasses, planting techniques and soil additives that showed success for each of the five climate regions.

ES.5.1 RECOMMENDED NATIVE GRASSES FOR THE CENTRAL VALLEY (PLACER COUNTY)

Botanical Name

Agrostis pallens

Elymus glaucus 'Elton'

Elymus multisetus

Hordeum brachyantherum

Nassella cernua deawned

Nassella pulcha

ES.5.2 RECOMMENDED NATIVE GRASSES FOR CENTRAL COASTAL (SAN LUIS OBISPO)**Botanical Name**

Elymus trachycaulus 'Major'

Elymus glaucus 'Berkeley'

Melica californica

Melica imperfecta

Nassella pulchra deawned

Nassella cernua deawned

ES.5.3 RECOMMENDED NATIVE GRASSES FOR THE CENTRAL VALLEY (FRESNO COUNTY)**Botanical Name**

Achnatherum speciosum

Elymus trachycaulus

Muhlenbergia rigens

Nassella cernua

ES.5.4 RECOMMENDED NATIVE GRASSES FOR THE CENTRAL INLAND (MONTEREY COUNTY)**Botanical Name**

Elymus glaucus 'Berkeley'

Elymus trachycaulus 'Major'

Melica californica

Melica imperfecta

Nassella pulchra deawned

Nassella cernua deawned

ES.5.5 RECOMMENDED NATIVE GRASSES FOR THE INLAND DESERT (RIVERSIDE COUNTY)**Botanical Name**

Nassella pulchra deawned

Nassella lepida deawned

ES.6 RECOMMENDED INSTALLATION TECHNIQUES

Based on the experience during this Program, the following installation techniques are recommended for native grass vegetation projects, depending on the individual site conditions:

- Drill seeding: this technique was cost effective and had the fastest germination rates and highest survivability. It is recommended for use in all flat areas and areas up to 4:1 slopes.

- **Hydroseeding:** this technique was also cost effective, had little slower germination rate than drill seeding and good survivability. It is recommended in all areas of slopes 4:1 and over, and areas with accessibility problems.

ES.7 SOIL ADDITIVES

As part of this program, research was conducted on various planting materials and soil additives including mycorrhizal inoculum, water polymers and erosion control blankets. Mycorrhizal inoculum fungi was tested and incorporated into the soil of certain sections at all the sites and showed a dramatic increase in root growth and plant mass and height. It is easily incorporated into the soil and is very cost effective. Based on the observations of this Program, it is recommended that mycorrhizal inoculum be incorporated as a soil additive in future projects.

Other additives showed some promise, but were tested on a more limited basis and, therefore, no definitive recommendation is made on the use of these types of additives in future projects.

ES.8 NATIVE GRASS SOD

During this Program, various types of native grasses grown in sod form were developed and tested. Each of the various grasses tested were also grown in a monoculture sod form. These sod grass plots were installed in January prior to the seasonal rains and did not receive additional supplemental watering. In year two additional sod test plots were developed using mixtures of blended native grasses species developed into a large sod blanket. Most of these native grass sod tests developed into a lush, well developed and woven together sod mat ideally for sod installation. Most sod varieties were very dense and prevented the invasion of weeds and non-native grasses.

In year one of the Program, 18"x18" sod test plots were developed and installed in monoculture plots for each native grass species at each test site location. During year one, 60 percent of the sod varieties survived, with the survival decreasing to 30 percent the second and third years. Most grasses had a problem developing proper root growth deep enough into the soil and, as a result, were susceptible to harsh climate conditions. The successful species were heartier and developed deeper root structures and, in general, survived better. These sod plots also successfully generated seed and kept out invasive weeds and non-native grasses.

In year two, additional sod test plots were developed using a blended variety of native grasses. These test plots were much bigger (10' x 50'). Two different test plots at three different site locations were tested in year two. These sod test plots germinated quickly in the nursery and developed a 4" root structure within six to eight weeks. These test plots were very aesthetically pleasing, developing a nice bright green sod turf. They survived the first summer well, but like other sods, weathered after the second year because the root structures failed to develop deep enough into the soil. However, these grasses did help suppress weed growth and provided instant erosion control.

With additional sod testing of various native grass species and different growing methods, this installation medium has great potential.

ES.9 PROJECT SUMMARY

At the start of this Program, a number of previous studies were reviewed and provided an excellent starting point for the development of the specific Program for state highway rights-of-way. Although preliminary indications were that substantial data on native grass vegetation programs were available, a lot of the research information contradicted other research or was not practical for a mass production project such as this Program. Much of the available information was also developed from controlled situations or was too costly to be implemented on the massive scale anticipated under this Program.

This Program was developed using field trials and cost efficient installation techniques. This resulted in a tremendous amount of useful information on both the effective and less effective elements in the Program. The most important thing learned from this program is that native grasses can grow anywhere and are generally very hearty. They can be implemented several different ways and can be easily maintained. They are also effective for erosion control and some have some potential for fire control. However, there are over 350 native grass species that grow throughout California and only about 20 different species have been thoroughly researched and tested for application in this type of Program. With less than 10 percent of potential native grasses researched and tested to date, there are substantial opportunities for considering other native grasses for applications in this type of Program.

During this Program, 28 different types of native grasses were tested at the five different test areas. At every site, some species were successful, regardless of the adverse conditions at the sites. A key finding of this program was that many of the grass species recommended by various experts and from previous research failed. Clearly, insufficient research is currently available for making substantial recommendations for the development of this type of program. Based on the experience of this Pilot Program, some previous research may be in error or inappropriate for application in a program for using native grasses statewide in highway rights-of-way. This type of program and development of native grass roadside installations has the ability to be successful, but further research and evaluation of additional native grass species needs to be conducted, including testing and implementing in real life situations to allow for a more complete understanding of these species' effectiveness in providing attractive, easily maintained, self sustaining landscape in areas like highway rights-of-way. A key finding from this Pilot Program is the need for a much greater understanding of the potential for this type of program to be implemented on a very large scale throughout the state. It is recommended that additional research be conducted on a statewide basis, with an on going program developed to coordinate and develop this into an industry standard installation and sustainable program for Caltrans' rights-of-way throughout California.

SECTION 1.0
PROGRAM OVERVIEW

SECTION 1.0 PROGRAM OVERVIEW

P&D Consultants was retained by the California Department of Transportation (Caltrans) to lead the research and development of a Native Grass Evaluation Pilot Program. The goal for this Program was to test and evaluate native grass species and planting techniques that could be used to reduce the need for chemical roadside spraying to control typical weed growth along Caltrans rights-of-way on state routes throughout California and to reduce the potential for storm water runoff and fire in vegetated areas. P&D worked with Caltrans representatives, Speedling and GreenHeart Nurseries, S&S Seed Company, Conservaseed Seed Company and California State Universities Riverside and Davis to develop the Program goals, methodology and planting concepts.

The identified objectives of the Program were to:

- (1) identify native grass species that are suitable for the purposes of reducing fire risk and improve water quality and reduce erosion along state highways.
- (2) develop efficient installation techniques for planting these species.
- (3) develop a program for converting state highway road edges from weeds to self-sustaining perennial native grass plant communities.

The Pilot Program and the Program findings are described in detail in the following sections of this Report:

Section 2.0 Research. This Section briefly summarizes the review of existing studies and research regarding native grass installations, soil preparation and maintenance program regimens.

Section 3.0 Test Site Locations and Planting Designs. This Section describes the selected Program test sites and the three planting designs used in the Program.

Section 4.0 Site Preparation and Evaluation of Planting Techniques. This Section describes the Program test sites, their pre-Program conditions and how the sites were prepared prior to planting. This Section also summarizes the evaluation of the three planting techniques.

Section 5.0 Supplemental Additives. This Section describes the supplemental additives which were added to the soils at some test sites, to evaluate their effectiveness in assisting in the germination and survivability of the native grasses.

Section 6.0 Installation Summary. This Section briefly summarizes the site installation, germination and survivability rates and recommendations and analysis for the three planting techniques.

Section 7.0 Year One Summary. This Section describes the activities conducted at the five Program test sites including the performance of the native grasses installed at each site and the site preparation and maintenance activities conducted at each site in year one of the Program.

Section 8.0 Year Two Summary. This Section describes the activities conducted at the five Program test sites including the performance of the native grasses installed at each site and the site preparation and maintenance activities conducted at each site in year two of the Program.

Section 9.0 Year Three Summary. This Section describes the activities conducted at the five Program test sites including the performance of the native grasses installed at each site and the site preparation and maintenance activities conducted at each site in year three of the Program.

Section 10.0 Findings. This Section summarizes the findings of this Program including site design, site preparation, seed design specifications, maintenance, erosion control, fire control, weed control and sod installation.

Section 11.0 Site Photos. This Section provides sample photos from test plots and various planting techniques.

Section 12.0 References. This Section lists the references researched during the conduct of this Program.

Section 13.0 List of Preparers. This Section lists the persons and agencies who participated in this Pilot Program and who contributed to the preparation of this Report.

SECTION 2.0
RESEARCH

SECTION 2.0 RESEARCH

P&D conducted extensive review of existing studies regarding native grass installations, site soil preparation and plant installation techniques, soil additives and maintenance programs. These reports offered numerous findings and information potentially applicable to the Native Grass Evaluation Pilot Program. However, most of the available research data were developed from controlled situations or were too costly to be implemented on the large scale proposed for the statewide Native Grass Program. In addition, some reports and information contradicted each other and, therefore, their applicability to this Program was uncertain. As a result, P&D and Caltrans' Project Manager developed a project specific test research program, using typical Caltrans roadsides and planting techniques, to evaluate and confirm existing research, and test and evaluate implementing native grasses as a cost effective weed and erosion control program for Caltrans state route rights-of-way.

The existing studies and research which were reviewed for this Pilot Program are listed in Section 12.0 (References).

SECTION 3.0
TEST SITE LOCATIONS AND PLANTING DESIGNS

SECTION 3.0 TEST SITE LOCATIONS AND PLANTING DESIGNS

3.1 TEST SITE LOCATIONS

The Program test site locations were selected by Caltrans based on climate region and availability. Test pilot sites were selected in the Central Valley (Placer County), Central Coastal (San Luis Obispo), Central Valley (Fresno County), Central Inland (Monterey County) and Inland Desert (Riverside County). These sites represent the typical conditions for each of these specific climate regions. These sites included a 10 foot wide area from road edge out for the length of the test site. This area was selected because it represents the fire zone strip that generally requires the most maintenance. At each test site, extensive site analysis was conducted which included visual analysis of existing site conditions and vegetation. In addition, P&D took soil samples for analysis and conducted soil compaction tests at each of these sites.

During these analyses, most of the test sites were observed to have over compacted soils ranging from 90 to 95 percent compaction, average to somewhat poor soil nutrients conditions and approximately nine inches of soil over the existing roadbase material. Sites that were compacted from 93 to 95 percent generally had no weed or plant growth. These sites also had poor nutrient soils levels. Sites with lower compaction rates had significant amounts of plant growth. The Fresno County site had the worst site conditions, with extreme temperatures over 100 degrees Fahrenheit (F) in the summer, poor soil nutrients and three inches of gravel on the surface with minimal soil. All the other test sites had milder climates, with a minimum of nine inches of soil cover over the existing roadbase material. However, the San Luis Obispo and Placer County sites had extremely dense weed cover and non-native grasses. Both these sites also had large open areas of weeds and non-native grasses adjacent the test sites, which were expected to make it difficult to establish new grass species on these test sites.

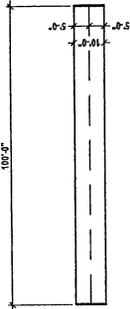
3.2 PLANTING DESIGNS

The native grass planting designs were developed based on practical mass production techniques that could be easily installed by Caltrans or a contractor at a reasonable cost. Various planting techniques were analyzed and selected that could be installed at a cost ranging from \$0.04 to \$0.08 per square (SF), plus the cost for the seed.

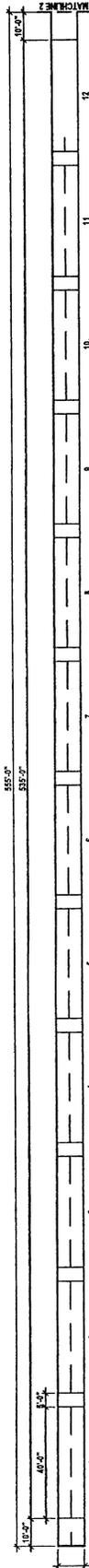
Native grass seed mixes were developed based on the regional growing characteristics for the individual test sites. Seed mixes were developed using a variety of grasses, focusing on grasses which would have the ability to adapt to the specific areas in each region. These mixes were developed based on existing research and were reviewed and recommended by several native grass experts, seed growers, nurseries and maintenance operations managers. The concept was to develop a seed mix for each individual climate region. Each mix would have a variety of native grasses that would successfully grow in that specific region. These mixes would have a variety of grasses that would work for the whole region. The blending of grass species would provide an easy way of specifying roadside planting per region and creating more random, natural looking roadside plantings.

The test plots were set up in the five different regions throughout the state. Each test plot location was set up identically, to test the effectiveness of various live native grass plugs, native grass sod and different types of planting techniques. Each site was set up testing 12 to 14 different types of grass species grown into grass plugs and grown in a monoculture individual test plots to monitor each grass species' growing characteristics and survivability rates. These grass plugs were grown in 1.5 and 2.5 inch plug containers and planted at 6" and 12" spacing. Individual 18" x 18" grass sod test plots were grown and planted for each individual native grass species. Each site also tested blended native grass mixes and planted using various mass planting techniques, which included hydroseeding, drill seeding and imprinting. Exhibit 3-1 provides a typical test site planning layout.

Photographs of these planting techniques are provided later in Section 12.0.

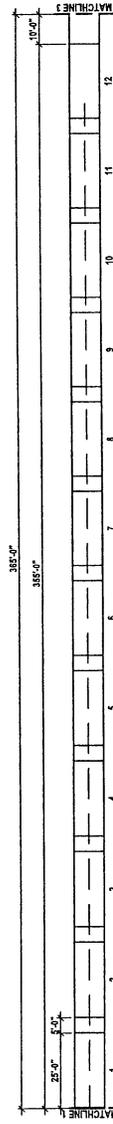


A SPECIFIED MIX (HAND SEEDING) "SO EASY" SEED MIX
SCALE: NONE



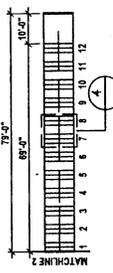
1 MONOCULTURE 242 CELL
SCALE: NONE

NOTE:
242 CELL PLUGS PLANTED AT 6" O.C. 1/200
PLANTS PER TEST BLOCK.



2 MONOCULTURE 72 CELL
SCALE: NONE

NOTE:
72 CELL PLUGS PLANTED AT 12" O.C. 240
PLANTS PER TEST BLOCK.



3 SOD MONOCULTURE MIX
SCALE: NONE

SOW EZ SEEDING METHOD

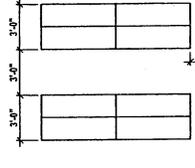
Yuba County (RTE 65, PM 7.0-8.0)	Quantity
Sow EZ Seeding Method	23,232
1 Bromus carinatus (Ice House)	8
2 Dimorphis callionictum	2
3 Elymus alypoides	8
4 Elymus glaucus (Ice House)	8
5 Elymus multisetus	2
6 Koeleria macrantha	4
7 Lolium perenne	4
8 Lolium scoparium	2
9 Melica californica	5
10 Melica hirtifolia	5
11 Poa secunda (Ice House)	5
12 Vulpia microstachya	5
Total	62
Total SowEZ™ (seed X.4) 248 lbs./acre equivalent	

LEGEND:

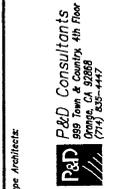
- 242 CELL PLUGS (MONOCULTURE) QUANTITY: 23,232
- 72 CELL PLUGS (MONOCULTURE) QUANTITY: 3,456
- 72 CELL PLUGS (MIXED SEED) QUANTITY: 720
- SOD TRAY (MONOCULTURE) QUANTITY: 48
- SOD TRAY (MIXED SEED) QUANTITY: 20

PLANTING LEGEND

Planting Area	Container Size	6" O.C.		12" O.C.	
		Spreading	Plant/Box	Spreading	Plant/Box
1	Agrostis pallens	8	4	72	4
2	Nassella pulchra	8	4	4	4
3	Melica californica	8	4	4	4
4	Hordium trachyantha subsp. californicum (prostrate form)	8	4	4	4
5	Poa secunda subsp. secunda	8	4	4	4
6	Koeleria macrantha	8	4	4	4
7	Achnatherum hymenoides	8	4	4	4
8	Elymus multisetus	8	4	4	4
9	Nassella arvensis (downward)	8	4	4	4
10	Elymus glaucus "Ebon"	8	4	4	4
11	Elymus alypoides	8	4	4	4
12	Festuca subsericea	8	4	48	48
Totals		23,232	3,456	10	20
Mixed Seed Mix					



4 SOD PLANTING SECTION
SCALE: NONE

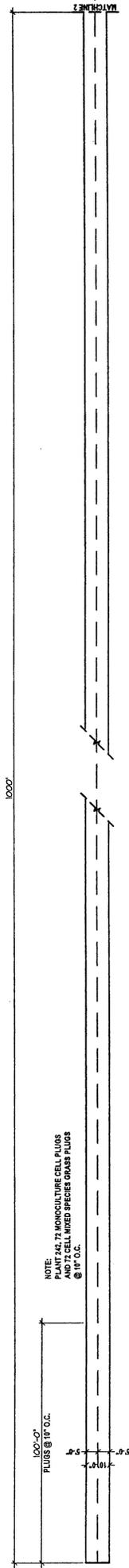


Developer:
Landscape Architects
P&D Consultants
589 Tom & County, 4th floor
Marysville, CA 95901
(707) 452-1472

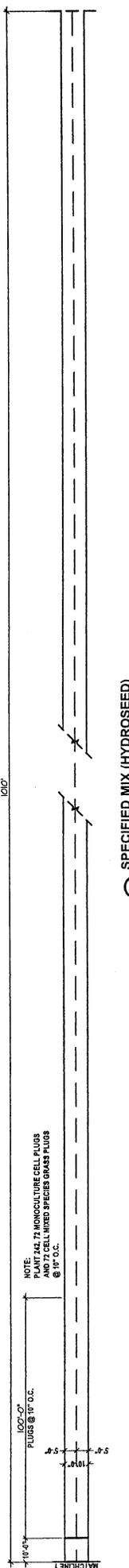
PROJECT SITE
**YUBA COUNTY
TEST SITE
(RTE 65, PM 7.0-8.0) NORTH BOUND**

TYPICAL PLANTING BLOCK FOR
INPRINTING, HYDROSEEDING & DRILL
SEEDING:

24 CELL PLUGS	1,130
72 CELL PLUGS	139
72 CELL PLUGS (MIXED)	24
TOTAL	1,483



1 SPECIFIED MIX (DRILL SEEDING)
SCALE: NONE



2 SPECIFIED MIX (HYDROSEED)
SCALE: NONE

Developer:

Landscaper Architects:

P&D Consultants
5550 Town & Country, 4th Floor
Orange, CA 92668
(714) 262-7777

PROJECT SITE:
**YUBA COUNTY
TEST SITE
(RTE 65, PM 7.0-8.0) NORTH BOUND**

LANDSCAPE ARCHITECT REGISTERED LANDSCAPE ARCHITECT VINCE J. CLARK
HARRY CLARK
No. 3811
Exp. 2002

DATE	DESCRIPTION	REVISIONS

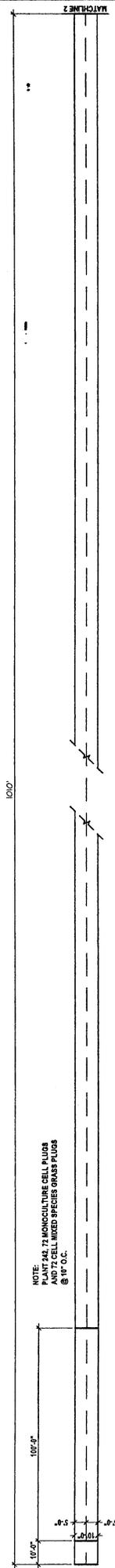
JOB: _____ DWG: _____ SHEET 2 OF 3

TYPICAL PLANTING BLOCK FOR
MIXED SEEDING & DRILL
SEEDING:

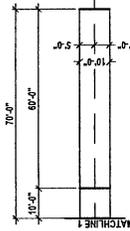
244 CELL PLUGS	1,320
72 CELL PLUGS	139
12 CELL PLUGS (MIXED)	4
TOTAL	1,463

PLANT SPACING QUANTITIES
(10'x30')

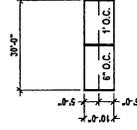
3" O.C.	8,000
6" O.C.	2,000
9" O.C.	875
12" O.C.	500



1 SPECIFIED MIX (IMPRINTING)
SCALE: NONE



2 OPTIONAL MIX (DRILL SEEDING)
SCALE: NONE



2A LEYMUS TRITICOIDES
SCALE: NONE

Developer:

Landscape Architects:



DATE	DESCRIPTION	REVISIONS



PROJECT SITE
**YUBA COUNTY
TEST SITE
(RTE 65, PM 7.0-8.0) NORTH BOUND**

JOB

DWG

SHEET 3 OF 3

14.776

SECTION 4.0
SITE PREPARATION AND EVALUATION OF
PLANTING TECHNIQUES

SECTION 4.0 SITE PREPARATION AND EVALUATION OF PLANTING TECHNIQUES

4.1 SITE PREPARATION

Most of the test sites were covered with numerous weeds and non-native grasses. All the sites were chemically sprayed using Round-Up Pro for weed control 14 days prior to planting. In addition, because of the highly compacted soils at all the sites, all sites were ripped using a skip loader with a roto-tiller attachment and roto-tilled to a depth of nine inches. This technique effectively and cost efficiently loosened the soil to a compaction rate of 70 to 80 percent. This provided excellent conditions to effectively install the seed and grass plugs using the various planting techniques. Mycorrhizal inoculum was incorporated into the soil for the second five feet from the roadway at each test site location to test its effects on germination and growing of native grasses.

4.2 PLANTING TECHNIQUES AND EVALUATION OF THE PLANTING TECHNIQUES

The planting techniques were selected based on research regarding mass production and performance for germination and survivability. For this Program, hydroseeding, imprinting, drill seeding and installation of live grass plugs were selected as the planting techniques. These techniques and their effectiveness for this Program are discussed in the following Sections. Photographs of these techniques are provided later in Section 12.0.

4.2.1 HYDROSEEDING

Description of the Hydroseeding Technique

Hydroseeding has been used in the landscape industry for years and is very effective. This technique uses a mixture of water and wood fiber mixed with seed in a tank to form a slurry that can be pumped through a hose and sprayed directly on a site. For this project, the hydroseed mix was applied in two stages or applications. The first application was installed using 80 percent of the total seed for the area and only 20 percent of the fiber mulch, with no binder added. This application put most of the seed directly in contact with the soil and used enough mulch to evenly spread the material on the site. The second application was installed using the remaining 20 percent of the seed, 80 percent of the mulch and the binder additive. This was done to cover the seed, to protect it from drying out and to seal it in place. In addition, at the San Luis Obispo site, straw was added on top of the hydroseeded area to help retain moisture and improve seed germination.

Evaluation of the Hydroseeding Technique

The installation of native grass seed using hydroseeding techniques was very cost effective and efficient. Hydroseeding was the best technique for slopes and areas with access problems where drill seeding was not possible. The hydroseeded grass areas germinated about four to five weeks

after application, but did not have as high of rate of germination and survivability as areas that were drill seeded. However, it was determined that some grass species did germinate better using the hydroseeding technique than the drill seeding technique. Further studies will need to be conducted to study which grass seed species germinate better using which planting technique.

4.2.2 DRILL SEEDING

Description of the Drill Seeding Technique

Drill seeding has been used successfully in the agriculture industry for a very long time. This is a very simple and cost effective installation technique. This technique uses a tractor that pulls a machine which resembles a plow. This machine has numerous disks spaced approximately four to six inches apart that run along the soil, cutting grooves into the soil, placing the seed into the grooves and then covering the grooves with soil.

Evaluation of the Drill Seeding Technique

Drill seeding was the most cost effective technique and provided the fastest germination rates of all the installation techniques considered in this Program. However, drill seeding cut groves into the soil and seeded the grass like crops, which resulted in uniform rows of native grasses. Although effective in terms of seed germination and survivability, the native grasses on the drill seeded sites did not appear natural. At the Monterey test site, the drill seeded areas were gone over four times, but still yielded the same row like appearance. One option for minimizing the artificial appearance of grasses planted using drill seeding would be to add a light screed to be dragged behind the drill seeder, which might assist in displacing the uniform rows and improve the randomness of the seed installation.

4.2.3 IMPRINTING

Description of the Imprinting Seeding Technique

Imprinting is a relatively new technique for installing plant seeds. Only five or six companies have developed machines specifically for this type of seeding operation which have been proven to be successful in large mass production projects. The imprinting technique consists of a machine that looks much like a steam roller, except the roller has flat small feet that push the seeds into the ground as it is rolled over the site. This technique is very efficient and cost effective, but must be carefully monitored to ensure proper imprinting techniques are followed or the installation may result in much lower than normal germination rates.

Evaluation of the Drill Seeding Technique

Imprinting was a very efficient and cost effective installation technique. However, this technique did not result in as quick or as high of germination rates as the drill seeding technique. One reason is that not all seed was properly pushed into the ground and a large amount of seed was either blow away by wind or eaten by birds. Some sites had higher germination rates, but long term survivability declined after two months because the seed was not rooted properly into

the soil and as not protected from the harsh climate conditions. However, hydroseeding did produce more natural appearing grass cover, but had a little lower germination success rate experienced in the hydroseeded and drill seeded plots.

4.2.4 NURSERY GROWN GRASS PLUGS AND SOD

Nursery Grown Grass Plugs and Sod Technique

Description of the Grown Grass Plugs and Sod Technique

Extensive research was conducted and review of various nurseries and seed farms to evaluate and develop the design of producing native grass plugs and sod. P&D and Caltrans decided to use Speedling and GreenHeart Nurseries to grow and develop the native grass plugs and sod. Both these nurseries are designed to grow mass production plant material using the latest in growing techniques. Grass plugs were developed using various size containers to test differences in survivability based of root mass and root depth at initial planting. Various grass species were also grown in sod form to test if these grass species could be grown in a mass production sod blanket that could be easily installed and provide instant weed and erosion control. The growing of native grasses in sod form worked much better than expected and germinated into a useable sod matt within six to seven weeks.

Evaluation of the Nursery Grown Grass Plugs and Sod Technique

The first year native grass sod was grown in 18" x 18" test sections for each of the different grass species and was very successful. In year two, 10' x 50' sections of sod were grown using a variety of three to five different grass species for each fifty foot section. Each of these sod sections germinated extremely well at the nursery, growing an extensive four inch root structure within six weeks.

Although this was only tested on a limited basis, the sod worked much better than expected and has great potential, and should be studied more extensively.

Live Grass Plugs

Description of the Live Grass Plugs Technique

Based on the research and consultations with native grass experts, it was believed that planting live native grass plugs without supplemental irrigation would result in 100 percent fatality within the first year. Going against the research and recommendations of other native grass experts, P&D and Caltrans Project Manager Jack Broadbent decided to try growing native grass plugs. It was thought that native grass plugs could be successful if plants with a deep root structure and established prior to the first summer to increase plant survivability. In addition, it was felt that native grasses should be heartier and should have a stronger possibility in survivability without supplemental water. The grass plugs were grown as a mono culture planting to evaluate their growth characteristics, survivability and ability to out compete invasive weeds and non-native grasses.

The native grass plugs for this Program were installed by hand using a five foot bar to poke holes and inserting the grass plugs into these holes by hand.

A mass production planting machine was recently developed that can automatically insert grass plugs at various spacings, which would minimize the need for manually hole punching and plug insertion when using native grass plugs. This would dramatically reduce the installation costs for this technique which would make it a more viable mass production technique.

Evaluation of the Live Grass Plugs Technique

Despite the research and recommendations found in previous studies, the growing and installing live native grass plugs proved to be very successful in this study. The native grass plugs germinated within weeks, were fully developed in the containers within five weeks and produced beautiful visual pleasing grasses. Grass plugs were very effective at quickly determining growth characteristics and survivability of each different grass species for each climatic region. However, this was a very expensive installation technique compared to other planting techniques because of the high level of manual activities associated with it. The grass plugs technique produce quick plant cover for weed and erosion control and had a very good survivability rate.

Native Grass Sod

Description of the Native Grass Sod Technique

Native grass sod was developed and tested to find a product that could be quickly installed and established and that could out-compete local weeds and non-native grasses. This system would be used where weed growth is extremely high and other planting techniques would not be able to out-compete local weed populations. This planting technique could also be used for instant erosion control for specific project needs.

Sod test plots were developed during the first year for each of the various test grass species. These were grown in a mono culture in 15" x 15" test plots. Sod was grown with a 0.5 inch soil base and germinated within six to eight weeks, depending on the particular grass species. They formed dense sod mats. These test plots survived the first year very well and kept out invasive weeds and non-native grasses very well.

In year two, additional larger test plots were developed using a mixture of three to five different native grass species, to develop more information about native sod. These sod test samples were grown in 10' x 50' sections and germinated within 6 to 8 weeks. The sod root growth was substantial, growing four inches in depth in six weeks and producing an attractive dense sod mat. This sod performed well the first year, but died back after the second summer because the sod had too much exposed root structure and not enough soil to protect the sod from the summer heat.

In year three, review of the sod test plots throughout the state found that most of the sod plots had died. However, a few sod test plots did survive and performed extremely well. These

successful sod test plots were reseeded and the sod had actually out-competed the surrounding weed populations. Although most species failed, this test did show that native sod could work if the right native grass species and sod techniques were established.

Evaluation of the Native Grass Sod Technique

The development of a native grass sod that can out-compete weeds and non-native grasses has great promise. However, this technique will need additional development and test trials to determine which species and combination of species can be established into long term sod and establish itself in the harsh roadside environment.

SECTION 5.0
SUPPLEMENTAL ADDITIVES

SECTION 5.0 SUPPLEMENTAL ADDITIVES

5.1 USE OF SUPPLEMENTAL ADDITIVES

As part of this project, a number of supplemental additives and products were tried on a limited basis to determine their ability to assist in the germination and growth potential of native grasses. These included the use of mycorrhizal, polymers and native grass blankets and other types of seed application. As described in this Section, some of these showed significant improvements in seed germination, plant growth and others did not.

5.2 MYCORRHIZAL SOIL INOCULUM

Mycorrhizal inoculum was added to project test site locations and incorporated into the soil during the site preparation part of the project. Mycorrhizal was incorporated in the second five-foot of each of the test plots, away from the road shoulder in each ten foot wide section.

Mycorrhizal are symbiotic associations that form between the roots of most plant species and fungi. These symbioses are characterized by bi-directional movement of nutrients where carbon flows to the fungus and inorganic nutrients move to the plant, thereby providing a critical linkage between the plant root and soil.

During the testing program, there was a distinct difference in the growth characteristics in the native grasses which were in soils inoculated with mycorrhizal. The inoculated soils had a much higher survivability rate, and the native grasses grew taller and fuller and had an approximate 30 to 40 percent increase of root growth. This program confirms existing research that mycorrhizal inoculum is extremely beneficial in the germination and establishment of native grasses. This application was also very cost effective costing approximately .50 per 100 square feet. It is recommended that mycorrhizal inoculum be added to future similar planting projects.

5.3 SOIL POLYMERS (WATER ABSORBING CRYSTALS)

TeraGel crystals were added to a small part of some of the test areas during the second year of the project. These crystals were added to the part of the sod installation areas and incorporated into a few rows of the grass plugs.

TeraGel crystals are a potassium based co-polymer crystal which absorb hundreds of times its weight in water, and on demand, will release the moisture to plants. In dry form, the crystals are white, crystalline granules with a neutral pH, and when hydrated they become a gel which retains fluids. These crystals are supposed to be able to rehydrate thousands of time in their life span and last for approximately seven years.

During the limited testing of these crystals, it was observed that the polymers were retaining moisture for a prolonged term and some grasses did show better survivability if they were in soils treated with these crystals. However, during the second year, there was a minimal visual

: :

difference in the grasses and there were no visual signs of crystals rehydrating themselves. However, this testing was conducted on a very limited basis and no conclusions can be made based on this limited testing. There is potential for soil polymers to benefit future planting programs and further testing to determine the actual long term benefits is recommended.

5.4 TERRAGRAF BLANKETS

As part of this project, TerraGraft Blankets were tested on a limited basis. A TerraGraft blanket is a pre-seeded erosion control blanket. These blankets come premade, seeded to meet site specific needs. They are provided in one meter wide and 20 meter long blankets. These blankets are made using several layers of a hydro-degradable paper impregnated with seed and laminated to biodegradable jute netting or poly-woven material that attaches to the soil. The TerraGraft blanket will melt away when wet (either through irrigation or rain), encapsulating the seed and attaching to the soil.

This system was tested in two small test sites and performed very well. Seed quickly germinated and attached itself securely to the soil. However, there were potential concerns regarding the blankets becoming detached from the soil due to vehicle traffic and could become a hazard to travelers on the road. However, because of the potential benefits in assisting in seed germination, it is recommended that additional testing of this technique be conducted in the future.

2 2

1 1

SECTION 6.0
INSTALLATION SUMMARY

SECTION 6.0 INSTALLATION SUMMARY

All the project test sites were sprayed for weeds, soils tilled and planted using drill seeding, hydroseeding, imprinting, live grass plugs and sod planting techniques. These techniques are shown in the photos in Section 12.0. All these techniques except live grass plugs were easily and cost effectively installed. All installation techniques were successful and had adequate germination rates. Table 6-1 summarizes the individual installation costs, germination time, survivability and recommendations.

**TABLE 6-1
INSTALLATION SUMMARY**

Technique	Cost per Square Foot	Germination Time	Survivability	Recommendations
Imprinting	\$0.035	5 to 7 weeks	Low	Large areas only
Hydroseeding	\$0.03	4 to 6 weeks	Medium	Slopes
Drill Seeding	\$0.025	2 to 3 weeks	High	Flat areas

In comparison to imprinting and hydroseeding drill seeding was the most cost effective techniques based on cost, germination ratio and survivability. Drill seeding is highly recommended for all areas accessible by the equipment. Hydroseeding was also a good technique, was cost effective, had a good germination rate and is recommended for slope areas and areas not accessible by drill seeding equipment. Imprinting was not practical for this type of project because of the equipment availability and oversight needed to ensure proper procedures, and site conditions needed to successfully imprint seed using this technique. Therefore, this technique is not recommended for narrow roadside projects.

SECTION 7.0
YEAR ONE SUMMARY

SECTION 7.0 YEAR ONE SUMMARY

7.1 OVERVIEW OF THE YEAR ONE SUMMARY

P&D conducted a site analysis 90 days after construction installation and again one year later for each of the planting test site locations, to determine the success of each of the grass species and the performance of the various planting techniques. The performance results showed almost a 100 percent survival for grass plugs at the Monterey County site and 85 to 90 percent at the San Luis Obispo and Placer County sites. The Fresno County and Riverside County sites are desert sites and had much lower survivability rates. Overall, the sites performed better than expected in the first year. The following Sections discuss the performance of each of the test sites after one year. The tables cited in this Section are provided following the last page of text in this Section.

Photos of the year one conditions at the five test site locations are provided later in Section 12.0.

7.2 YEAR ONE SUMMARY FOR THE PLACER COUNTY SITE

The Placer County site is located on the northbound side of State Route 65, between PMs 7.0 and 8.0. This site was another good site with an average survivability rate of 90 percent with several species at 100 percent after year one. The drill seeding technique was again the fastest germinating technique and had the highest survivability rate. Hydroseeding also germinated 3 to 4 weeks slower and had a good survivability rate. The imprinting technique was not used at this site because of limited space and availability of the equipment. The monoculture plantings of grass plugs definitely showed the differences in adaptability and survivability of the different grass species at this location. Several grasses did extremely well and reseeded themselves. This site also had a grow-kill period implemented for weed control prior to construction, but the site was impacted with weeds and non-native grasses. This was attributed to weed and non-native grass seed being blown onto the site from adjacent large fields of weeds and non-native grasses. This was one of the hardest sites at which to control weeds.

7.2.1 YEAR ONE TEST SUMMARY FOR THE PLACER COUNTY SITE

Tables 7-1 and 7-2, provided following the last page of text in this Section, summarize the performance of the native grasses in year one at the Placer County site.

7.2.2 YEAR ONE MAINTENANCE SUMMARY FOR THE PLACER COUNTY SITE

Annual maintenance of the site including hand pulling of thistle and mowing of the grass test site area to four inches in height. This site had invasive weeds in the grass plug, drill seeding and hydroseeding test areas. Chemical spraying on a limited bases was applied to a couple of grass plug areas.

**TABLE 7-1
NATIVE GRASS TEST PLOT EVALUATION SUMMARY
FOR YEAR ONE FOR THE PLACER COUNTY SITE**

Placer County Species	240 cell container			72 cell container		
	# Planted	# Alive	% Survival	# Planted	# Alive	% Survival
<i>Agrostis pallens</i>	525	489	93.1	218	200	91.7
<i>Nassella pulchra</i>	615	581	94.4	245	219	89.3
<i>Melica californica</i>	610	453	74.2	210	177	84.2
<i>Hordeum brachyantherum</i> ssp. <i>californicum</i>	485	424	87.4	236	207	87.7
<i>Poa secunda</i> ssp. <i>secunda</i>	0	0	0	0	0	0
<i>Koeleria macrantha</i>	478	368	75.3	220	166	75.4
<i>Achnatherum hymenoides</i>	0	0	0	0	0	0
<i>Elymus multisetus</i>	610	517	84.7	242	215	88.8
<i>Nassella cernua</i> deawned	619	596	96.2	272	252	92.6
<i>Elymus glaucus</i> 'Elton'	547	499	91.4	265	244	92.0
<i>Elymus elymoides</i>	495	385	77.7	266	222	83.4
<i>Festuca idahoensis</i>	600	547	91.1	283	255	90.1
Planting Technique			% Survival			
Hydroseeded Area			88.4			
Drill Seeded Area			89.5			

**TABLE 7-2
YEAR ONE SUMMARY FOR THE PLACER COUNTY SITE**

	Grass Species	Plugs	Sod
1	<i>Agrostis pallens</i>	E	G
2	<i>Nassella pulchra</i>	E	E
3	<i>Melica californica</i>	F	F
4	<i>Hordeum brachyantherum</i> ssp. <i>Californicum</i>	G	G
5	<i>Poa secunda</i> ssp. <i>Secunda</i>	N	N
6	<i>Koeleria macrantha</i>	F	F
7	<i>Achnatherum hymenoides</i>	N	N
8	<i>Elymus multisetus</i>	G	F
9	<i>Nassella cernua</i> deawned	E	E
10	<i>Elymus glaucus</i> 'Elton'	E	E
11	<i>Elymus elymoides</i>	F	G
12	<i>Festuca idahoensis</i>	E	G

E: Excellent

G: Good

F: Fair

P: Poor

NA: not applicable; this planting technique was not used at this site.

SECTION 8.0
YEAR TWO SUMMARY

SECTION 8.0 YEAR TWO SUMMARY

8.1 OVERVIEW OF THE YEAR TWO SUMMARY

During year two, P&D conducted two site analyses at each of the test plot areas, once during the rainy season and again in the summer, to monitor and track the success of each of the grass species and the performance of the various planting techniques. The performance results of the year two analysis are summarized in this Section. These results showed a decline in grass plugs and sod survivability, but numerous grass plugs species still had over 90 percent survivability. The Monterey site was the best with over a 90 percent survivability rate for grass plugs and the seeding techniques also performed well. The San Luis Obispo and Placer County sites also were performing well, with numerous grass plugs survivability over 85% and seeding techniques also doing well. However, at the Fresno County site, the grass plugs declined severely with most species dieing off. Three grass plug species survived at that site and were doing well. Seeded areas at this site did not germinate the first year due to lack of rain, but germinated during the second year, but at a lower rate than other test areas. The Riverside County site which had died the first year because of unusually hot dry winter was replanted prior to the season's first rains. However, this site was already showing severe die back by the end of summer.

During year two additional native grass sod plots were developed to test native grass sod on a larger scale. Two ten by fifty foot test plots were developed and installed at the San Luis Obispo, Monterey and Placer County sites. These additional sod test plots germinated extremely fast and developed into a beautiful lush sod mat with a thick four inch root structure at the nursery. Overall, these new test plots did well throughout their first year.

Additional grass plugs were also developed during the second year for the Fresno County site. These new grass plugs were developed using a deeper container tray that produced plugs with a root structure of six inches in depth. It was anticipated that this extra depth would give the grass plugs a better jump start and a greater ability to secure their roots into the soil to protect themselves from the harsh desert climate. These deeper plugs did significantly better than the previous year's smaller and shorter grass test plugs.

The following Sections discuss the performance of each of the test sites after year two. The tables cited in this Section are provided following the last page of text. Photos of the test sites during year two are provided in Section 12.0.

8.2 YEAR TWO SUMMARY FOR THE PLACER COUNTY SITE

This site was performing at an average level, with most of the grass plugs with survival rates of 70 to 80 percent. This is mostly because of the harsher climate and extreme summer temperatures at this site, compared to the other test sites. There was also a distinct difference in the grass plugs that had their soils amended with mycorrhizal inoculum. These grasses showed significant increase in root growth, plant mass and height.

Nessella cernua, *Nessella pulchra*, *Agrostis pallens* and *Elymus glaucus* did exceptionally well at this site. The *Festuca idaoensis* was short in stature, dark green in color and was the best looking grass. Most of the bunch grasses stayed green longer than the other grasses and, therefore, should be considered for use on roadsides where fuel reduction is critical.

It was also observed that the soil at this site did not recompact itself as much as the other sites. With these lower compaction rates and the presence of adjacent fields of weed and non-native grasses, this site was invaded by weeds and non-native grasses. The prevailing winds spread large numbers of weed seed from these fields. It is anticipated that these weed and non-native grass species will eventually overrun this site.

The new native grasses at this site generated seed, but it was a small amount compared to the weed and non-native grass seeds from adjacent fields. As a result, the new native grasses were only able to minimally reseed themselves at this site. Because the adjacent areas contain significant amounts of weed and non-native grasses and generated large amounts of seed, this site was severely impacted by this unwanted and undesirable seed.

Two additional 10'x 50' grass sod test strips were also installed at this site in year two. One sod test area was installed using three different grass species and the other using five different grass species. The test sod samples germinated in six weeks, grew a four-inch root structure and matted together well. These areas were planted in late January, prior the heavy winter rains. The ground was wet at the time the sod test strips were installed. The soil was roto-tilled and the sod test strips were laid in place. Water polymers were added to the soil for half of each section for each of the two sod areas. The sod was easy to install and had a healthy appearance after installation.

The planting techniques were reviewed and showed a significant difference when compared to the grass plugs testing. No imprinting was tested at this site. The hydroseeded areas were average and not all the various grass species germinated. Overall, the hydroseeded areas were natural looking and some of the grass species in the mix looked good. The drill seeded areas looked the healthiest but the rows that were evident looked artificial and not natural. Seeded areas were definitely under seeded. Seed rates at 100 seed per square feet need to be substantially increased to produce enough quick ground cover and seed to out-compete local weeds and non-native grasses.

8.2.1 YEAR TWO TEST SUMMARY FOR THE PLACER COUNTY SITE

Tables 8-1 and 8-2, provided following the last page of text in this Section, summarize the performance of the native grasses in year two at the Placer County site.

8.2.2 YEAR TWO MAINTENANCE SUMMARY FOR THE PLACER COUNTY SITE

The annual maintenance at this site included mowing of the grass plug test site area to four inches in height. The planting technique areas were not mowed. This site had a large amount of invasive weeds, thistle and non-native grasses as a result of seed blown from adjacent fields.

This will be a large problem with unwanted weed and grass seed spread to the test site by wind. No chemical spraying was done at this site in year two.

**TABLE 8-1
NATIVE GRASS TEST PLOT EVALUATION SUMMARY FOR YEAR TWO
FOR THE PLACER COUNTY SITE**

<i>Placer County</i>	240 Cell container			72 Cell container		
	# Planted	# Alive	% Survival	# Planted	# Alive	% Survival
<i>Agrostis pallens</i>	525	458	87.2	218	183	
<i>Nassella pulchra</i>	615	520	84.5	245	195	
<i>Melica californica</i>	610	416	68.1	210	165	
<i>Hordeum brachyantherum</i> ssp. <i>californicum</i>	485	395	81.4	236	203	
<i>Poa secunda</i> ssp. <i>secunda</i>	0	0	0	0	0	
<i>Koeleria macrantha</i>	478	217	45.3	220	161	
<i>Achnatherum hymenoides</i>	0	0	0	0	0	
<i>Elymus multisetus</i>	610	471	77.2	242	203	
<i>Nassella cernua</i> deawned	619	539	87.0	272	241	
<i>Elymus glaucus</i> 'Elton'	547	468	85.5	265	221	
<i>Elymus elymoides</i>	495	365	73.7	266	168	
<i>Festuca idahoensis</i>	600	518	86.3	283	219	
Planting Techniques						
Hydroseeded Areas			85			
Drill Seeded Areas			86			

**TABLE 8-2
YEAR TWO SUMMARY FOR THE PLACER COUNTY SITE**

	Grass Species	Plugs	Sod
1	<i>Agrostis pallens</i>	G	F
2	<i>Nassella pulchra</i>	G	F
3	<i>Melica californica</i>	F	P
4	<i>Hordeum brachyantherum</i> ssp. <i>californicum</i>	G	F
5	<i>Poa secunda</i> ssp. <i>secunda</i>	P	P
6	<i>Koeleria macrantha</i>	P	P
7	<i>Achnatherum hymenoides</i>	P	P
8	<i>Elymus multisetus</i>	P	P
9	<i>Nassella cernua</i> deawned	G	G
10	<i>Elymus glaucus</i> 'Elton'	G	F
11	<i>Elymus elymoides</i>	G	P
12	<i>Festuca idahoensis</i>	G	P

E: Excellent
G: Good
F: Fair
P: Poor

SECTION 9.0
YEAR THREE SUMMARY

SECTION 9.0 YEAR THREE SUMMARY

9.1 OVERVIEW OF THE YEAR THREE SUMMARY

Year three was the final year of the test plot study. During this year, P&D again conducted two bi-annual site analyses of each of the test plot areas, once during the rainy season and again in the summer, to monitor and track the success of each of the grass species and the performance of the various planting techniques. The performance results of year three analysis are summarized in this Section. Photographs of the test plots in year three are provided in Section 12.0.

In year three, P&D conducted no new test trials at any of the test plot sites and only performed bi-annual monitoring of the test sites. No annual maintenance was conducted at any of the test site locations. During year three, most of the test sites showed severe decline in grass plugs and sod survivability. This was typically because of impact to the test sites by vehicle traffic and by rodents damaging the plugs, and the plugs not being able to produce enough seed to reseed and establish themselves. It was also observed that rodents and deer preferred some grasses over others and some grasses were never touched and survived extremely well. In addition, roadside traffic heavily impacted several sites and severely damaged several grass test plots. The problem was that the low growing grasses and soft shoulders made the sites attractive roadside turnouts which were heavily used by truckers.

Sod test plots during year three also declined severely after the second summer. The second year sod test plots that were developed with a four-inch deep root structure could not get their root structures to penetrate deep enough into the soil to protect themselves from the harsh climate and steadily declined throughout the second summer. Most of these sod test plots had rooted themselves into the soil, but their grass root structures only penetrated four to six inches. However, there were some areas of these test plots where the root structures penetrated deeper and they survived much better. These root structures were observed to grow six to twelve inches deep and these sod areas look healthy. In addition, year one grass sod test plots that were developed with only a one-inch root structure did the best. Only a few of these grass sod species survived, but the ones that survived were virtually weed free and had rooted deep into the soil and were doing great.

Also observed in year three was the dramatic difference in the grasses that had their soil treated with mycorrhizal inoculum. They were taller, fuller and had a higher survivability rate. This was observed at all the test site locations and these areas showed a significant difference from year to year.

Other observations included the six-inch deep grass plugs that were developed and installed during the second year at the Fresno County site which had a much better survivability rate than the first year smaller grass plugs. Having a deeper root structure at initial installation gave these plugs the ability to root deeper into the soil, helped protect them from the harsh climate and dramatically increased their survivability.

The following Sections discuss the performance of each of the test sites in year three. The tables cited in this Section are provided following the last page of text.

9.2 YEAR THREE SUMMARY FOR THE PLACER COUNTY SITE

After three years, this site was performing at an average level. The soil at this test site had not recompacted and was being heavily invaded by non-native weeds and grasses. The grass plugs test plots were also doing well, but were so heavily impacted with weeds and non-native grasses they were hard to find. The grass plugs could not produce enough seed to reseed themselves and establish an expanding ground cover. Several of the native grass species were doing exceptionally well and several others were not. These test plots are very useful in determining the survivability and growing characteristics of each individual grass species and how each might be used in roadside restoration.

The large sod test plots conducted during year two had similar results as the Monterey and San Luis Obispo County sites. During the first year, they were surviving well. They made it through the first summer and turned green during first winter rains of the next year. They also had minimal weed growth within the sod boundary. They had choked out almost all the weeds and non-native grasses. After the second summer in year two, however they seem to die back significantly. Their root structures were attached to the soil, but the roots did not penetrate deeply into the soil as hoped. It is possible that the sod root structures were too well developed at the nursery and became rootbound prior to installation at the test site. However, there were areas in the larger sod plots where their root structures penetrated themselves six to twelve inches into the soil and the sod was performing great.

The planting techniques areas at this site also had mixed results. The drill seeded and hydroseeded areas were doing much better at this site and were producing enough seed to slowly start reseeding themselves. However, this was still not fast enough to out compete the weeds and non-native grasses. The seed rates recommended and used in these planting techniques appear to have been too low to produce sufficient grass necessary to ensure that the grass would be able to reseed itself and out compete invasive weeds and non-native grasses. An overseeding program needs to be implemented during years two and three to help improve survivability.

9.2.1 YEAR THREE TEST SUMMARY FOR THE PLACER COUNTY SITE

Tables 9-1 and 9-2, provided following the last page of text in this Section, summarize the performance of the native grasses in year three at the Placer County site.

9.2.2 YEAR THREE MAINTENANCE SUMMARY FOR THE PLACER COUNTY SITE

No maintenance was conducted at this test site in year three, so as to see impact of invasive weeds and non-native grasses on the test plots.

**TABLE 9-1
NATIVE GRASS TEST PLOT EVALUATION SUMMARY FOR YEAR THREE
FOR THE PLACER COUNTY SITE**

Placer County	240 cell container			72 cell container		
	Species	# Planted	# Alive	% Survival	# Planted	# Alive
<i>Agrostis pallens</i>	525		NA	200		NA
<i>Nassella pulchra</i>	615		NA	219		NA
<i>Melica californica</i>	610		NA	177		NA
<i>Hordeum brachyantherum</i> ssp. <i>californicum</i>	485		NA	207		NA
<i>Poa secunda</i> ssp. <i>secunda</i>	0		NA	0		NA
<i>Koeleria macrantha</i>	478		NA	166		NA
<i>Achnatherum hymenoides</i>	0		NA	0		NA
<i>Elymus multisetus</i>	610		NA	215		NA
<i>Nassella cernua</i> deawned	619		NA	252		NA
<i>Elymus glaucus</i> 'Elton'	547		NA	244		NA
<i>Elymus elymoides</i>	495		NA	222		NA
<i>Festuca idahoensis</i>	600		NA	255		NA
Planting Technique	# Planted	# Alive	% Survival			
Hydroseeded Area			85			
Drill Seeded Area			88			

**TABLE 9-2
YEAR THREE SUMMARY FOR THE PLACER COUNTY SITE**

	Grass Species	Plugs	Sod
1	<i>Agrostis pallens</i>	NA	NA
2	<i>Nassella pulchra</i>	NA	NA
3	<i>Melica californica</i>	NA	NA
4	<i>Hordeum brachyantherum</i> ssp. <i>californicum</i>	NA	NA
5	<i>Poa secunda</i> ssp. <i>Secunda</i>	NA	NA
6	<i>Koeleria macrantha</i>	NA	NA
7	<i>Achnatherum hymenoides</i>	NA	NA
8	<i>Elymus multisetus</i>	NA	NA
9	<i>Nassella cernua</i> deawned	NA	NA
10	<i>Elymus glaucus</i> 'Elton'	NA	NA
11	<i>Elymus elymoides</i>	NA	NA
12	<i>Festuca idahoensis</i>	NA	NA

NA: not applicable.

Note: Year three, this site became heavily invaded with weeds and non-native grasses making the inventory statically impossible and survivability was determined by averaging areas.

SECTION 10.0
FINDINGS

SECTION 10.0 FINDINGS

10.1 FINDINGS OF THE PROGRAM

10.1.1 OVERVIEW

In conducting this native grass test plot Program, an important finding was determining and understanding the harsh environmental conditions of the typical Caltrans roadside project and their limits and constraints in developing sustainable grassland communities along the state's highways.

Non urban Caltrans roadsides were found to have no irrigation, to have severely over compacted soils that were also low in nutrients, and to be covered with invasive weeds and non-native grasses. The sites also are generally heavily impacted by vehicle traffic and very susceptible to fire from a stray cigarette butt. These conditions are extreme and finding a non-irrigated native grass mix that will out compete local weeds and non-native grass species is very difficult. In addition, although there has been a large amount of research regarding the use of native grasses, there has not been a lot of research and study regarding using native grasses for a large mass installation and maintenance programs such as this potential application. A lot of the research that was gathered and reviewed contradicted each other and were disproved during this test Program.

The major findings for this Program are summarized in the following Sections. These include both positive findings of the Program as well as things to avoid in the future in implementing native grass plantings along roads.

10.1.2 SITE DESIGN

There are over 300 different native grasses in California and only about 20 are currently being used and studied in various native grass vegetation programs. A key finding of this Program was that, at every site, at least three or more native grass species were found to be successful, did not need extensive soil preparation and easily adapted to the existing site conditions. In addition, it was found that over-prepping the soils and placing additional soil amendments in the soil profile only made it easier for non-native grasses and weed to quickly germinate and spread in the test plots.

If was further observed that soil compaction rates played a key roll in the development of this Program. Areas that had soil compaction rates over 92% had minimum to moderate weed growth, but could sustain most native grasses. When soil compaction was reduced to 85% to 90%, weeds and non-native grasses quickly invaded the sites.

In developing this test Program, it was observed that native grasses grow everywhere and in almost any site environment without any preparation. A key part of the Program was to determine which grass species work best in each climate zone. The testing for this Program included 28 different native grass species. This resulted in the identification of a number of

grass species in each climate region under typical Caltrans roadside conditions which survived and produced good grass cover. In addition, the Program showed that drill seeding was the best installation technique, producing the fastest germination and highest survivability for flat roadside projects, and hydroseeding was the best for sloped and limited access areas. Imprinting had limited success, access problems and needed specific site conditions to produce successful germination rates; therefore, it is not recommended for this type of program.

10.1.3 SITE PREPARATION

Because a substantial part of the non-paved Caltrans rights-of-way currently consists of large amounts of weeds and non-native grasses, it was necessary to provide an appropriate weed grow kill period prior to plant installation for this Program. The Program found that the typical Caltrans contract methods and maintenance practices are acceptable to accomplish this goal.

It was observed during this study that the soils in the test areas were severely over compacted, with over 95 percent compaction. These highly compacted areas had few existing weeds or non-native grasses because the pressure on the plant root structures restricts their water intake.

The findings of this Program determined that the soils should be ripped using a skip loader and then roto-tilled to six to nine inches in depth. In addition, mycorrhiza inoculum should be incorporated in all soils, per the manufacture's specifications, prior to planting. This loosens the highly compacted soils and gives the plant materials some mycorrhiza bacteria to enhance plant root structure and jump start plant germination.

10.1.4 SEED DESIGN SPECIFICATION

As part of this Program, P&D used and consulted with various seed companies to develop various design concepts and installation techniques to evaluate and specify seed application rates for seedings and sod test plots. A key finding was that the recommended seed application rates specified from previous research were too low, resulting in poor plant establishment and, therefore, the native grasses did not produce sufficient seed to be able to out compete local weeds and non-native grasses. In addition, the native grasses were not sufficiently abundant to produce enough grass seed to reseed themselves and establish a long term native grass roadside. It is recommended that seeding rates be substantially increased over traditional seed calculation application rates to enable quicker and denser ground cover to out compete local weeds and non-native grasses. This would provide sufficient seed for the native grasses to reseed themselves and produce a self sustaining native grass roadside. Also additional overseeding of thin areas for the next few years may be necessary until the site can produce enough seed to become self sustaining. Typical overseeding program usually includes overseeding 10 percent of the total area each year for two years.

It was also observed that the soils that were roto-tilled and had no soil amendments added at initial installation recompact to their original compaction rates after one year. Adjusting and maintaining soil compaction rates directly influenced native grass growth and invasion of weeds into the sites.

10.1.5 PLANTING TECHNIQUES

Drill seeding was by far the most cost effective installation technique and had the highest germination rate of all the installation techniques evaluated. This technique is highly recommended for all areas accessible by drill seeding equipment. Hydroseeding was also a good application technique and was cost effective and had a good germination rate. Hydroseeding is recommended for slope areas and areas not accessible by drill seeding equipment. Imprinting was not practical for this type of project because of the equipment availability and oversight needed to ensure proper procedures and site conditions needed to successfully imprint seed using this technique. Therefore, this technique is not recommended for narrow roadside projects.

Drill seeding and hydroseeding were very effective and should be considered in ordered to be successful for revegetation.

10.1.6 EROSION CONTROL

During this test Program, a number of the native grass species were tested and observed to provide a viable groundcover for erosion control. It was also observed and determined that using a mixture of blended native grass species provides better ground cover for erosion control. Mixing grass species with different height and density characteristics provides a more natural looking ground cover which fills in faster and, therefore, produces an effective erosion control groundcover.

10.1.7 FIRE CONTROL

During this Program, several different species of native grasses were tested and observed for potential fire control for typical roadside projects. Native grasses provide an excellent groundcover and several are slow growing and short in stature. Bunch grasses did the best for staying green longer than other grasses. However, for this Program, only 28 different native grass species, of the total 300 species that grow in California, were tested. Additional research should be conducted to test and evaluate native grass species for growing characteristics and to see if, with additional minimal supplemental summer watering, they could stay green throughout the summer and, therefore, be used for fire control.

10.1.8 WEED CONTROL

Typical Caltrans standards for preconstruction grow-kill were reviewed and acceptable for this type of project. However, follow-up maintenance needs to be designed especially for native grass projects, as discussed later in the maintenance recommendations.

10.1.9 SOD INSTALLATION

During this Program, various types of native grasses grown in sod form were developed and tested. Each of the various grasses tested were also grown in a monoculture sod form installed in 18" x 18" test plots. In addition, in year two, additional blended native grass mixes were developed into sod mats approximately 10'x 50' in size. During year one, 60 percent of the sod

varieties survived, with the survival decreasing to 30 percent the second year. Most grasses had a problem developing proper root growth depth and, as a result, were susceptible to harsh climate conditions. The successful species were heartier and developed deeper root structures that protected them from the harsh climate conditions and were more successful. These successful sod plots also generated seed and kept out invasive weeds and non-native grasses.

The use of native grass to produce sod form can be successful. Additional research needs to be conducted and tested to determine appropriate seed rates, native species that can adapt into sod and the development of the sod root structure so it can quickly attach itself into the soil and penetrate deep into the soil.

10.1.10 ANNUAL MAINTENANCE

It is anticipated that a successful native grass roadside project will take four to five years to become completely established, before routine maintenance can be implemented, starting in approximately the fifth year.

An important part of the annual maintenance is the timely and proper removal of weeds and non-native species. Newly planted native grasses will not grow quick enough and reseed themselves fast enough to establish themselves and out compete invasive weeds and non-native grasses. Therefore, weeding to control non-natives and overseeding with additional native grass seed is recommended in the first few years of maintenance to ensure that the native grass project will eventually be self sustaining.

The following is a typical recommended four-year maintenance program for a typical project based on the experience and research from this current Program.

Year One Maintenance Program. In year one, the following maintenance activities should be conducted:

- Annually remove all tumble weeds and thistle prior to these plants going to seed.
- Properly apply pre-emergent for weeds and non-native species control.

Years Two and Three Maintenance Program. In years two and three, the following maintenance activities should be conducted:

- Identify and evaluate successful and unsuccessful native grasses.
- Adjust the overseeding mix to incorporate additional native grass species if necessary.
- Prior to the first heavy seasonal rains, overseed the native grass mix in the entire project area, use 25 percent of the original amount of seed needed for the site to cover 100 percent of the area.
- Annually remove all tumble weeds and thistle prior to them going to seed.

Year Four Maintenance Program. In year four, the following maintenance activities should be conducted:

- Prior to the first heavy seasonal rains, reseed all thin and bare areas, as necessary.
- Properly apply pre-emergent to all areas and remove all tumble weeds and thistle before they go to seed.

10.2 FUTURE CONSIDERATIONS AND RECOMMENDATIONS

It is important to understand that this study found that the available research and development of native grasses for self sustaining projects is far behind perceived expectations. The concept of using native grasses as a sustainable roadside community is workable, but needs extensive research and development in testing many more native grasses in typical roadside conditions. Research and testing in controlled circumstances or in test areas not like roadside areas are not comparable and will produce incorrect information as was found during this test evaluation. The following are recommendations for continued research and testing necessary to develop this into a successful program:

- Research and test the direct relationship of soil compaction rates compared to weed growth and development of native grasses.
- Research pre-emergent and herbicide sprays that can be utilized for weed control that do not adversely affect native grasses.
- Research and test all native grasses available for growing characteristics, germination rates, seeding rates, survivability and ability to be grown in different mediums, such as plugs and sod.
- Research all available grasses for potential fire control. The research should include no supplemental water, summer supplemental water and permanently irrigated areas.
- Research and test the effectiveness of water polymers in increasing soil moisture in the development of plant material.
- Research and test to determine appropriate seed rates for drill seeding, hydroseeding and sod applications per individual grass species.

SECTION 11.0
REFERENCES

**SECTION 11.0
REFERENCES**

“Alternative Methods for Establishing Native Warm Season Grasses” in The Native Grass Manager (<http://prairiesource.com>) (December 26, 2000).

Anderson, Neil, “Coloring Outside the Lines: A Case Study of Nakae & Associates” in Land and Water (September/October 1999).

Bainbridge, David A. and Virginia, Ross A., “Restoration in the Sonoran Desert of California” in Restoration & Management Notes 8:1.

Bainbridge, David, “Soil shaping to improve native grass establishment” in Grasslands (Fall 2000).

“Basic Native Grass Physiology” in the Native Grass Manager (<http://prairiesource.com>) (December 26, 2000).

Bowler, Peter A., “Coastal Sage Scrub Restoration-I: The Challenge of Mitigation” in Restoration & Management Notes 8:2 (Winter 1990).

Brown, Cynthia S., Bugg, Robert L., “Effects of Established Perennial Grasses on Introduction of Native Forbs in California” in Restoration Ecology Vol. No.1, pp. 38-48 (March 2001).

Brown, Cynthia S. and Rice, Kevin J., “The Mark of Zorro: Effects of the Exotic Annual Grass *Vulpia myuros* on California Native Perennial Grasses in Restoration Ecology Vol. 8 No. 1 (March 2000).

Brown, Cynthia S., Rice, Kevin J. and Claassen, Victor, “The effects of soil amendments and mulches on establishment of California native perennial grasses: a summary of selected results” in Grasslands (Winter 2000).

Brucker, Maury and Yang, Emiko, “Private Prairie and Woodland Restoration: Updating An Older Subdivision in Illinois in Land and Water (July/August 1999).

Bugg, Robert L. and Brown, Cynthia S., “Establishing Native Forbs within Existing Stands of Native Perennial Grasses from Transplants and Seed on Rural Roadsides in the Sacramento Valley of California in Sustainable Agriculture (<http://www.sarep.ucdavis.edu>) (Fall 1998).

Bugg, Robert L., Brown, Cynthia S. and Anderson, John H., “Restoring Native Perennial Grasses to Rural Roadsides in the Sacramento Valley of California: Establishment and Evaluation in Sustainable Agriculture (<http://www.sarep.ucdavis.edu>) (Winter/Spring 1998).

Bugg, Robert L., Brown, Cynthia S. and Anderson, John H., “Restoring Native Perennial Grasses to Rural Roadsides in the Sacramento Valley of California: Establishment and Evaluation” in Restoration Ecology Vol. 5 No.3 (September 1997).

“California Ecological Restoration Projects Inventory” (<http://endeavor.des.icdavis.edu>) (December 20, 2000).

Cairns, John, “Restoration and the Alternative: a Research Strategy” in Restoration & Management Notes 6:2 (Winter 1988).

Caltrans, “Native Grass Experiment on I-5 South of Willows Using California Department of Forestry & Fire Protection Seed” (April 21, 1999).

Carlsen, Tina M., Menke, John W. and Pavlik, Bruce M., “Reducing Competitive Suppression of a Rare Annual Forb by Restoring Native California Perennial Grasslands” in Restoration Ecology Vol. 8 No.1 (March 2000).

Costello, Michael, “Native Grass Species for use as Perennial Cover Crops in San Joaquin Valley Vineyards” (<http://danr010.ucdavis.edu/Grants/Reports/Costello/costello97-07.htm>) (December 20, 2000).

Dickens, Dr. Ray, “New Grasses & Herbicides for Roadsides in Land and Water (January/February 2000).

Dixon, Bob and Carr, Ann, The Imprinting Foundation, “Important Land Imprinting Specifications” in Land and Water (November/December 1999).

Dyer, A.R. and Rice, K. J., “Intraspecific and Diffuse Competition: The Response of *Nassella Pulchra* in California Grassland in Ecological Society of America (1997).

Eliason, Scott A. and Allen, Edith B., “Exotic Grass Competition in Suppressing Native Shrubland Re-establishment” in Restoration Ecology Vol. 5 No. 3 (September 1997).

“Establishing Permanent Grassland Habitat with California Native Perennial Grasses” in Valley Habitats.

Faessler, Fred and Apfelbaum, Steve, “Large-Scale Harvesting of Prairie Seed” in Restoration & Management Notes 6:2 (Winter 1988).

Gilpin, David, “Introduction to Using California Native Grasses.”

Gillham, Felicia, “Mycorrhizal Fungi Use for Trees Both Young and Old” in Land and Water (September/October 1999).

Hamilton, Jason G., Holzapfel, Claus and Mahall, Bruce E., “Coexistence and interference between a native perennial grass and non-native annual grasses in California” (November 12, 1998).

“Habitat restoration using the native grass *Elymus glaucus* (blue wildrye)” in California Native Grass Association.

Harper-Lore, Bonnie, “A Vegetation Manager’s Tour of Australian Roadsides in Land and Water (January/February 2000).

Harper-Lore, Bonnie, “A Vegetation Manager’s Vacation” in Land and Water (September/October 1999).

Harper-Lore, Bonnie, “Do Native Grasslands Have a Place on Roadsides?” in Land and Water (July/August 1998).

Henderson, Kirk, “Showdown At ISAC: IRVM vs. Safety?” in Land and Water (July/August 2000).

Henderson, Kirk, “Prairie Plantings on Roadsides” in Land and Water (March/April 1998).

Hier, Ross H., Merchant, Steven S. and Wolfe, Terrance J. with the Minnesota Department of Natural Resources, “Prairie Restoration in Minnesota: What’s Been Done and Plans for the Future” in Land and Water (November/December 1999).

Hodges, Jeff, “Beating Weeds in Native Grass Plantings” in Land and Water (March/April 2000).

Hodges, Jeff, “The Benefits of Prescribed Burning” in Land and Water (January/February 1999).

Holland, Steve, “Interstate 35 Prairie Revegetation” in Land and Water (March/April 1999).

Houseal, Greg and Smith, Daryl, “Source-Identified Seed: The Iowa Roadside Experience in Ecological Restoration 18:3 (Fall 2000).

Jackson, Laura L., McAuliffe, Joseph R. and Roundy, Bruce A., “Desert Restoration: Revegetation Trials on Abandoned Farmland in the Sonoran Desert Lowlands” in Restoration & Management Notes 9:2.

Kurtz, Carl, “Seventeenth Biennial North American Prairie Conference” in Ecological Restoration 18:4 (Winter 2000).

“Levee Revegetation with Native Grasses” in Grasslands (Winter 1998).

Mahler, David, “New Device Speeds Seed Harvest” in Restoration & Management Notes 6:1 (Summer 1998).

“Managing Herbicide Resistant Weeds in California” (<http://www.weedsearch.com>) (January 22, 2001).

Marquez, Viviane J. and Allen, Edith B., "Ineffectiveness of Two Annual Legumes as Nurse Plants for Establishment of *Artemisia californica* in Coastal Sage Scrub in Restoration Ecology Vol. 4 No. 1 (March 1996).

"Mycorrhizae on the Job: the Experience of the Experts" in Land and Water (September/October 2000).

Nelson, Laura L., Allen, Edith B., "Restoration of *Stipa pulchra* Grasslands: Effects of Mycorrhizae and Competition from *Avena barbata*" in Restoration Ecology (March 1993).

"Native Plants for Roadsides – Grade One – Introduction to the Innovative Use of Local Native Plants for Roadsides and Mitigation Sites" in (<http://www.batnet.com>) (December 27, 2000).

"Native Grass Restoration Helps Control Erosion, Weeds" in (<http://danr011.ucdavis.edu>) (December 20, 2000).

Pacific Coast Seed Inc., "Planning, Seeding and Maintaining Native Perennial Grasses."

Packard, Steve, "Just a Few Oddball Species: Restoration and the Rediscovery of the Tallgrass Savanna" in Restoration & Management Notes 6:1 (Summer 1988).

Pickart, Andrea, "Dune Restoration in California: A Beginning" in Restoration & Management Notes 6:1 (Summer 1988).

"Planting and Maintaining Prairiegrasses" in Land and Water (July/August 1999).

Rana Creek Habitat Restoration, "California Native Seed Description."

Rana Creek Habitat Restoration, "Planting and Establishing Native Perennial Bunch Grasses."

Rice, Peter M., Toney, Christopher J., Bedunah, Donald J. and Carlson, Clinton E., "Plant Community diversity and growth form responses to herbicide applications for control of *Centaurea macuosa*" in Journal of Applied Ecology (1997).

"Roadside Use of Native Plants" in Land and Water (January/February 2000).

"Roadside Native Grasses Might Curb Herbicide Use" in Sustainable Agriculture Research and Education Program (May 1998).

Rogers, Dennis, "Notes on Planting and Maintenance of Bunchgrasses."

Schulhof, Richard, "Public Perceptions of Native Vegetation" in Restoration Management Notes 7:2 (Winter 1989).

Schultz, Gillian Polly, University of California Riverside, "Seedling Establishment and Competition in Coastal Sage Scrub and Annual Grassland" (August 1996).

“Solution for Tough Seeding: Ideal for interseeding waterways, filter strips, and CRP acres” in *Land and Water* (September/October 1999).

St. John, Ted, Dixon, Robert and St. John, Mick, “Restoration at Discovery Park” in *Land and Water* (March/April 1998).

Storms, Nancy, University of California Riverside, “Restoration of a Native Shrubland in an Area of Frequent Disturbance and High Nitrogen Deposition” (December 1999).

Vincent, David, “Roots (That was Then)” in *Land and Water* (September/October 1999).

Wester, Lyndon, Department of Geography, University of Hawaii, “Composition of Native Grasslands in the San Joaquin Valley, California” (December 1981).

Wirka, Jeanne, “The state of the art: prescribed burning in California grasslands” in *Grasslands* (Fall 1999).

Wirka, Jeanne, “The Nature Conservancy pioneers new seeding technique at Dye Creek Preserve” in *California Native Grass Association* (Summer 2000).

SECTION 12.0
PHOTOGRAPHS

**SECTION 12.0
PHOTOGRAPHS**

Native Grass Sample Photos

The following are sample photos of the various test plots, nurseries, sod, grass plugs, and planting and seeding techniques used during the program.

Sample Photos

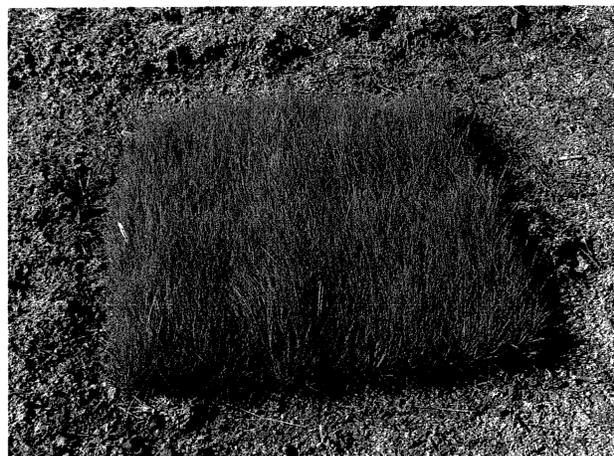
Speedling Nursery:

Speedling is one of the nurseries that assisted in the research and development of native grass plugs and sod. This company produced outstanding quality native grass plugs and sod.



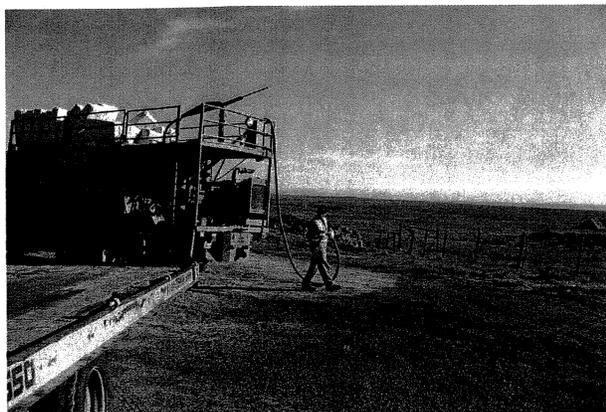
GreenHart Nursery:

GreenHart assisted in growing native grass plugs for this program.



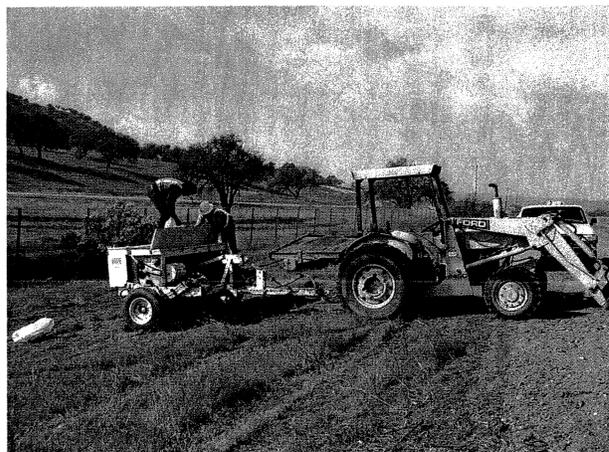
Hydroseeding Technique:

One of the various seeding techniques tested during this program.



Drill Seeding:

One of the various seeding techniques tested during this program.



Imprinting Seeding:

One of the various seeding techniques tested during this program.



Native Grass Plugs

Numerous native grass plugs were developed and tested for this program. Grass plugs were developed and installed for each of the individual native grass species tested at every site.

242 Cell Grass Plug



72 Cell Grass Plug



Native Grass Sod

Native grass sod was developed and tested at each of the test site locations. Each of the individual grass species at each site had monoculture sod mats developed and installed. Also during year two additional sod mats were developed using a blended mixture of native grasses to develop more natural denser mat and that could out compete weeds.

Year One Sod Tests

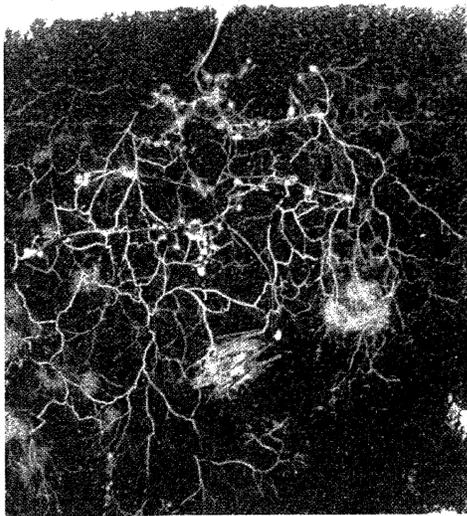


Year Two Sod Tests



Mycorrhiza Soil Inoculum

Mycorrhiza inoculum was a soil additive that was added to portions of each test site. This soil additive produced drastic results increasing root structure approximately 40% and improved plant growth and survivability.



Monterey Site



Monterey site was the most successful site. Grass plugs, drill seeding, hydroseeding did extremely well and soil compaction rates were optimal and suppressed weed growth.

Placer County Site



Placer site had good success for grass plugs, hydroseeding, and drill seeding, but had problems with invasive weeds from adjacent site. Grass plugs could not out-compete invasive non-native grasses.

San Luis Obispo Site



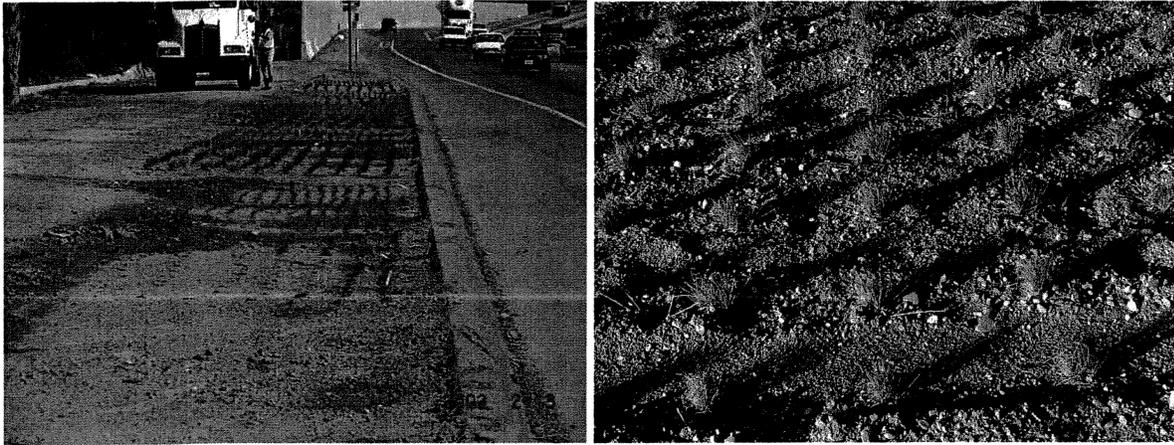
San Luis Obispo site had good success for grass plugs, sod, hydroseeding and imprinting but had problems with invasive weeds from adjacent site. Grass plugs could not out-compete invasive non-native grasses.

Fresno County Site



Fresno site had harsh soil and climate conditions that drastically impacted the survivability of the grass plugs, sod, drill seeding and hydroseeding.

Riverside County Site



Riverside site had harsh soil and climate conditions that drastically impacted the survivability of the grass plugs, sod, drill seeding and hydroseeding.

SECTION 13.0
LIST OF PREPARERS

**SECTION 13.0
LIST OF PREPARERS**

13.1 CALIFORNIA DEPARTMENT OF TRANSPORTATION

Jack Broadbent, Landscape Architect, Caltrans

13.2 P&D CONSULTANTS, INC.

Harry Clarke, Landscape Architect
Michael Benner, Principal-in-Charge
Christine Huard-Spencer, Quality Control
Shelly Feeney, Sr. Biologist
Guy Whitney, Horticulture
Daryl Fisher, Word Processing

13.3 SUB-CONSULTANTS

Acacia Landscapes, Dominique Colbert.....	(808) 643-0687
Soil & Plant Laboratories, Jack Damonte.....	(714) 282-8777
Plant Success, Kelly Green.....	(714) 990-8172
Redwood Seed Company, Craig Dremann	(650) 325-7333
Speedling Nursery, Graham Wright	(800) 557-8500
GreenHeart Nursery, Paul Hertel.....	(805) 680-5918
S&S Seed Company, Victor Schaff.....	(805) 684-0436
Ted St. John	
North Tree & Fire Company, Kevin Fisher.....	(916) 783-2800
ConservaSeed Seed Company, Scott Stewert.....	(916) 776-1200