

REESTABLISHMENT OF NATIVE RIPARIAN SPECIES AT AN ALTERED HIGH ELEVATION SITE¹

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Abstract: The failure of a 22-foot-diameter pipe caused an estimated water flow of 40,000 cfs for approximately one hour, which scoured and removed 1.75 million cubic yards of soil and vegetation from Lost Canyon. Mitigation for the damage caused by the pipe failure included re-establishing the lost vegetation. This paper describes the process of re-establishment including the riparian component. Co-operative planning; perseverance in plant acquisition; use of local sources of plants; use of a qualified contractor; and applying ecological principles in planting techniques and maintenance practices contributed to successful re-establishment.

Lost Canyon is a part of the Helms Pumped Storage Project located 50 miles east of Fresno, California at elevations of 6300 to 7800 feet. This hydro facility adds more than a million kilowatts of electric generation capacity to the Pacific Gas and Electric Company (PG&E) system. During the testing phase of the construction of the power plant in 1982, a 22-foot-diameter pipe failed at the Lost Canyon Crossing. The high-energy flow of water (40,000 cfs for approximately 1 hour) destroyed various types of native vegetation, including mountain meadow, montane chaparral, Jeffrey Pine, Lodgepole Pine, Red Fir and deciduous riparian vegetation (PG&E 1983a). It also removed 1.75 million cubic yards of soil from the canyon. Shortly after the pipe failure, PG&E established a task force to mitigate the damage caused by the pipe failure. A series of workshops with regulatory agencies was set up to prepare a mitigation plan (PG&E 1983b). Necessary work and studies that would help prevent further damage to the environment were initiated. Studies included water quality, slope stability and sedimentation, wildlife and fisheries, visual impacts and revegetation.

This paper reports on portions of the revegetation mitigation including the test and operational plantings. Riparian and other vegetation types are included to compare their performance in re-establishing themselves.

Of the vegetation lost due to the pipe failure, 20 percent was riparian vegetation. The proposed revegetation projected an increase of riparian vegetation from 20 to 30 percent because of the increased width of the canyon floor caused by the scouring, the construction of two stream checks, and the high wildlife value of the riparian vegetation. It was essential to conduct trial

plantings at the earliest possible date to determine the feasibility and effectiveness of planting under the drastically altered conditions in Lost Canyon (PG&E 1984a). The test plantings were extremely valuable for formulating recommendations for the subsequent operational plantings. The operational planting consisted of planting 50,000 seedlings over a period of two years. The plant establishment rate required by the agencies was 400 to 500 woody plants per acre in plantable areas.

Test Planting

General Overview

A series of test plantings was conducted in 1983. The data covered the period of 1983 to 1985 after snowmelt. Because of the large volume of data, only selected material is presented. Test plantings were installed to evaluate species performance, range of environmental conditions, planting techniques and time of planting. Eleven planting areas/planting season combinations were evaluated. Two to eight species and two to four planting methods were planted in each planting area, resulting in the planting of 17 species in total (table 1).

Planting Methods

The planting methods used in the Species Trial represented 4 levels of planting intensity (see notes, table 1; Chan 1985) for a wide range of species in addition to 2 planting methods for establishing willows. The collar is a 5-inch diameter, 5 1/2-inch deep cylinder used to collect and concentrate precipitation into the root zone of the planted seedling. The collar is inserted into the planting hole, keeping the upper 1 1/2 inches above ground. The seedling is planted inside the collar at the natural grade. The screen is a 16-inch sheet of aluminum insect screen wrapped around the upper half of the collar and secured with tie wire to form a screen cylinder. The screen protects the seedling against deer, rodents and insects. It also provided shade to the seedling. The other two planting methods (Treatments V and VI) applied to a separate study regarding the establishment of willows and was tested in only one planting area. Treatment V was planting unrooted cuttings and Treatment VI was planting rooted cuttings.

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Table 1 – 1985 Lost Canyon revegetation project planting design.

Planting Area	Planting Season	Number of Species	Treatment Types*	Replications Per Species/Treatment	Total Plants
1	Spring	7	I-IV	10	280
1	Fall	7	I-IV	10	280
2	Fall	8	I-IV	10	320
3	Fall	6	I-IV	10	240
4	Fall	5	I-IV	10	200
5	Spring	8	I-IV	10	320
5	Summer	8	I-IV	10	320
5	Fall	8	I-IV	10	320
6	Spring	5	I-IV	10	200
7	Fall	6	I-IV	10	240
8	Fall	2	V-VI	50	200

*Treatments:

I = No collar, initial watering only

II = Collar, initial watering only

III = Collar, screen, initial watering only

IV = Collar, screen, scheduled watering

Results

Data were collected at the end of the first growing season and again after the second growing season after snow melt in 1985. Because there are too many results to present each separately, results will be presented graphically. An explanation of the graphic presentation is given in the example below for the comparison of survival for the seven species at planting area 2 (table 2).

The eight species are ranked from the highest survival rate to the lowest survival rate. The number of plants that survived is directly below the species letter. The total number of plants tested for each species (40) is identical and is shown to the right of the slash. Thus, 31 out of 40 plants of species H plants survived. In order of survival rate, from highest to lowest, the ranking was highest for species H, lowest for species G. The underlining of a group implies that there is no significant difference at the .05 level between members of that group. More than one group may be underlined in each analysis to show significant differences between groups and individuals. Thus, HCEDBF implies that species H, C, E, D, B and F statistically have about the same survival rate. However, if two species are not underlined, then these two species are significantly different at the .05 level. So, the survival rates for species C, E, D, B, F and A are statistically superior to species G.

The analyses for height and stem diameter are presented in a similar manner. The mean height or stem diameter growth is substituted for survival rates. The

results of comparing stem diameter growth for the seven species at planting area 1 were tabulated (table 3).

Height and caliper width comparisons between species are made using all plants (dead and surviving). The mean height and caliper width given below the comparisons are only for those plants that survived.

Table 2 – Analysis 1: Most Successful Species - Planting Area 2

Survival Rank (Species) ¹	Best						Worst	
	H	C	E	D	B	F	A	G
Number Surviving	31	28	28	27	22	22	21	7 /40 ²

¹ The letter symbol for species in the results of the test plantings are:

A - *Salix*, LPM

B - *Salix*, HC

C - *Populus tremuloides*

D - *Populus trichocarpa*

E - *Pinus c. murrayana*

F - *Pinus jeffreyi*

G - *Chrysolepis sempervirens*

H - *Sambucus caerulea*

I - *Alnus incana*

J - *Pinus monticola*

K - *Sorbus scopulina*

L - *Abies concolor*

M - *Abies magnifica*

² Total number of plants for each species.

Table 3 – Analysis 1: Most Successful Specie Planting Area 1.

Stem diameter Rank (Species)	Best						Worst	
	E	C	F	A	D	B	G	
Mean (diameter)	6.4	4.5	4.5	4.6	3.8	5.1	3.8	

Results were affected not only by site conditions, but by construction activities in the canyon including building stream flow checks, diversion channels, debris removal and hazardous tree removals. In spite of these disturbances, the results generally reflected the effectiveness of the plant species, plant methods and cultural practices tested.

As expected, survival was consistently higher the first year compared to the second year. What was not expected was the high overall survival in the first year. In six of the eight planting areas, all species tested in those areas had over 53 percent survival. In 32 of the 44 species/area cases, survival was over 80 percent. In 40 of the 44 cases, survival was over 70 percent. Disregarding planting areas, 13 of 17 species had over 70 percent survival (PG&E 1984b). In the other two planting areas, low survival was associated with the planting of unrooted cuttings of willows.

Good results in the first year were attributed to using adapted species for the various planting areas. Also contributing to the results were the performance of the revegetation contractor, initial watering of all plants, occurrence of some summer rain in August, and the relatively short time plants had been in the ground. However, some plants had grown at the site during most of the growing season and had withstood poor soil conditions and rather hot and dry conditions during the first year.

Mean height and caliper growth were determined for surviving plants regardless of planting areas (table 4). These data in the first year had limited significance but they were valuable for future evaluation of the test plantings.

In the second year regardless of the level of difficulty of the various planting areas, riparian species performed satisfactorily (tables 3 - 8).

In Lost Canyon, 50 percent or higher survival under the difficult conditions was considered good. In all five planting areas (tables 5 - 9), where riparian species were planted with other vegetation types, the majority of species that performed best were riparian species. In particular, *Populus tremuloides* was in the best performance group in all of the five planting areas, as well as the top performer in the streambank planting area which had only riparian species (table 10). Area 7 did not have any riparian species.

Comparing the four planting treatments tested, best results were related to the level of planting intensity. Overall, the more effort expended, the better the results (table 11). Under specific conditions, the most intensive method may not be the most cost-effective method because conditions may not warrant the additional effort or cost. For example, in favorable moist sites watering

may not be necessary, or depredation may not be a problem. However, if the site is difficult, the most intensive method will likely provide the best chance of success.

Operational Planting

Overview

Operational plantings were initiated one year after the test plantings. Selection and propagation of plants were initiated during the same year as the trial planting. Because of the magnitude of the Lost Canyon revegetation planting, PG&E proposed that the planting be performed in two phases. The reason for this was to concentrate on planting stabilized areas first and to allow time for steeper slopes to stabilize. Extending the planting installation also helped relieve the plant acquisition difficulties associated with the short time frame.

The planting design for Lost Canyon was developed by physically marking 200 foot sections from the head of the canyon down to the end of the canyon at Wishon Lake. This sectioning was effective in designating species for specific conditions in a section and facilitating distribution of plants throughout the canyon. It also facilitated communications in reporting special problems and applying specific treatments to the correct areas. Because the canyon was 200 to 300 feet wide, sections were approximately one acre in size in most cases. Ninety sections were established.

Records were kept on plants in each section in regards to what was planted (PG&E 1987a; PG&E 1988) and what maintenance was provided. Much effort was made to establish a balance of vegetation types throughout the canyon and to match the species to conditions where they were best adapted. Color-coded flags were used to mark actual planting locations of individual plants. A qualified person was selected to mark locations in advance of the planting crew. The person not only had to be able to identify most favorable or promising locations for each species, but had to develop natural patterns and densities that were compatible with the surrounding area.

Planting Procedures

Specifications and drawings were prepared and the job was bid. Circuit Rider Productions of Windsor, California was the successful bidder. Different planting methods and cultural practices were specified for different planting conditions in order to achieve the most cost-effective results. Of the 50,000 seedlings planted, 22,093 were riparian species.

Table 4 - Total Mean Height Caliper and Survival of each Species regardless of Planting Area, Species Trial - Lost Canyon, Helms Project, first year.

Species	Mean Height (cm)	Mean Caliper (mm)	Pct of Survival (No. Plants)
<i>Salix sp.</i> (LPM) unrooted	0	0	0
<i>Abies concolor</i>	3.5	2.2	75.0 (90)
<i>Pinus monticola</i>	3.8	2.0	75.0 (90)
<i>Abies magnifica</i>	3.9	2.1	76.9 (123)
<i>Pinus jeffreyi</i>	8.9	3.3	92.5 (259)
<i>Salix sp.</i> (HC) rooted	9.7	2.4	88.6 (186)
<i>Arctostaphylos patula</i>	9.7	2.4	97.5 (39)
<i>Sambucus caerulea</i>	10.0	2.6	91.3 (73)
<i>Sorbus scopulina</i>	14.2	4.2	85.8 (103)
<i>Ceanothus cordulatus</i>	15.5	2.5	62.5 (25)
<i>Populus trichocarpa</i>	15.8	2.9	87.5 (210)
<i>Salix sp.</i> (LPM) rooted	17.2	2.8	83.2 (341)
<i>Salix sp.</i> (HC) unrooted	17.8	2.8	9.2 (12)
<i>Alnus tenuifolia</i>	20.4	4.6	55.0 (22)
<i>Chrysolepis sempervirens</i>	22.7	2.6	81.3 (130)
<i>Populus tremuloides</i>	26.6	3.4	99.2 (357)
<i>Pinus C. murrayana</i>	33.3	5.9	99.4 (358)

Table 5 - Statistical Analysis Lost Canyon Revegetation - 1985 Analysis 1: Most Successful Species - Planting Area 1 (Wildlife Area). Site conditions: Moderate but disturbance from construction activities.

Survival	Best					Worst	
Rank (Species)	C	E	F	D	A	B	G
Number Surviving	37	36	29	27	26	16	15 /80
Height (cm)	Best					Worst	
Rank	C	E	A	D	F	B	G
Mean	34.9	32.8	27.8	24.4	13.4	20.6	22.1
Stem diameter (mm)	Best					Worst	
Rank	E	C	F	A	D	B	G
Mean	6.4	4.5	4.5	4.6	3.8	5.1	3.8

See key to species symbols in Table 2.

Conclusion - Species C, *Populus tremuloides*, and E, *Pinus c. murrayana*, are clearly the best in survival, height and stem diameter.

Table 6 - Statistical Analysis Lost Canyon Revegetation- 1985. Analysis 1: Most Successful Species - Planting Area 2 (wildlife area). Site conditions: moderate.

Survival	Best				Worst			
Rank (Species)	H	C	E	D	B	F	A	G
Number Surviving	31	28	28	27	22	22	21	7 /40
Height (cm)	Best				Worst			
Rank	E	C	D	B	A	H	F	G
Mean	34.	28.4	26.4	22.0	23.0	7.1	12.0	14.3
Stem diameter (mm)	Best				Worst			
Rank	E	C	D	F	H	B	A	G
Mean	7.0	4.6	3.9	4.9	3.1	3.7	3.4	3.3

See key to species symbols in Table 2.

Conclusion - Species E, *Pinus c. murrayana*, is clearly superior in survival, height and stem diameter.

Table 7 - Statistical Analysis Lost Canyon Revegetation- 1985.
Analysis 1: Most Successful Species - Planting Area 3 (wildlife area).
Site conditions: moderate.

Survival	Best						Worst
Rank (Species)	E	C	D	A	B	F	
Number Surviving	31	29	25	19	15	13	/40
Height (cm)	Best						Worst
Rank	E	C	D	A	B	F	
Mean	38.6	37.0	24.1	32.1	23.1	11.5	
Stem diameter (mm)	Best						Worst
Rank	E	C	D	A	B	F	
Mean	7.5	5.3	3.8	4.0	3.8	3.7	

See key to species symbols in Table 2.

Conclusion- Species E, Pinus c. murrayana, is superior for survival, height and stem diameter.

Table 8 - Statistical Analysis Lost Canyon Revegetation- 1985.
Analysis 1: Most Successful Species Planting Area 4 (high bluffs).
Site conditions: difficult.

Survival	Best					Worst
Rank (Species)	E	A	B	C	D	
Number Surviving		11	9	9	4	/40
Height (cm)	Best					Worst
Rank	E	A	C	B	D	
Mean	35.7	23.9	37.9	22.3	19.3	
Stem diameter (mm)						Worst
Rank	E	A	C	B	D	
Mean	7.8	3.9	5.1	3.7	3.7	

See key to species symbols in Table 2.

Conclusion - Species E, Pinus c. murrayana; A Salix, LPM; and C, Populus tremuloides, are superior for survival, height and stem diameter.

Table 9 - Statistical Analysis - Lost Canyon Revegetation - 1985. Analysis 1:
Most successful species - planting area 5 (spoil area). Site conditions: difficult.

Survival	Best								Worst
Rank (Species)	C	A	F	E	M	K	J	L	
Number Surviving	60	49	47	38	29	27	26	21	/120
Height (cm)	Best								Worst
Rank	C	E	A	F	A	K	J	L	
Mean	28.9	35.9	22.0	9.8	13.8	6.2	5.3	5.9	
Stem diameter (mm)	Best								Worst
Rank	C	E	F	A	K	M	J	L	
Mean	4.2	7.0	4.1	3.8	4.7	2.0	2.5	2.1	

See key to species symbols in Table 2.

The heights for species E and F are similar statistically.

Conclusion - Species C, Populus tremuloides, is the best.

Table 10 - Statistical Analysis Lost Canyon Revegetation - 1985. Analysis 1: Most successful species - planting area 6 (streambank areas). Site conditions: favorable.

Survival	Best				Worst	
	C	D	A	I	B	
Rank (Species)						
Number Surviving	38	29	28	21	6	/40
Height (cm)	Best				Worst	
	C	D	A	I	B	
Rank						
Mean	34.3	35.0	33.4	32.9	21.8	
Stem diameter (mm)	Best				Worst	
	C	A	I	D	B	
Rank						
Mean	5.4	5.8	8.0	5.7	5.7	

See key to species symbols in Table 2.

Conclusion - Species C, *Populus tremuloides*, is the best.

Table 11 - Statistical Analysis Lost - Canyon Revegetation - 1985 . Analysis 6: Comparisons of treatments I, II, III, and IV. (all planting areas, except 8).

Survival	Best				Worst	
	IV	III	II	I		
Rank (Treatment)						
Number Surviving						/680
Height (cm)	Best				Worst	
	IV	III	II	I		
Rank						
Mean	24.4	24.1	22.9	24.3		
Stem diameter (mm)	Best				Worst	
	IV	III	II	I		
Rank						
Mean	4.6	4.6	4.6	4.8		

Conclusion - Collar, screen and supplemental watering (Treatment IV) always ranks among the best treatments for survival, height and stem diameter.

Table 12 - Statistical Analysis - Lost Canyon Revegetation - 1985. Analysis 5: Benefits of planting rooted cuttings (planting area 8).

	Species A			Species B	
	Best	Worst		Best	Worst
Survival					
Rank (Treatment)	VI	V		VI	V
Number Surviving	12	2	/50	34	26
					/50
Height (cm)	Best			Best	
	VI	V		VI	V
Rank					
Mean	21.8	11.0		51.7	26.6
Stem diameter (mm)	Best			Best	
	VI	V		VI	V
Rank					
Mean	3.8	2.3		5.2	3.7

Conclusion - Planting rooted cuttings of Species A (Treatment VI) is vastly superior to planting unrooted cuttings (Treatment V). Planting rooted cuttings (Treatment VI) of Species B offers no significant benefits over unrooted cuttings (Treatment V) of Species B.

Table 13 - Representative age, class, growth, and survival of species planted in sample sections.

Species	Section No.	Age Class	Aver. Height (cm)	Aver. Caliper (mm)	Percent Survival of Sample
<i>Alnus incana</i>	32	3	52.0	13.0	70.0 (10)
	37	3	91.0	19.0	48.2 (56)
	44	3	59.0	17.0	75.8 (33)
	77	3	107.0	21.0	86.1 (36)
<i>Corpus stolonifera</i>	37	3	1	5.6	5.0 (20)
	37	1	7	4.1	30.0 (10)
	44	2	2	5.3	57.1 (14)
	48	3	3	6.4	38.5 (26)
<i>Populus tremuloides</i>	32	3	62.0	8.4	23.4 (64)
	44	3&2	55.0	8.6	69.5 (105)
	48	3	35.0	6.9	88.6 (44)
	77	3	67.0	10.0	66.7 (45)
<i>Populus trichocarpa</i>	37	4	49.0	10.0	NK (22)
	44	2	43.0	11.0	NK (19)
<i>Salix spp.</i>	32	3	53.0	11.0	53.7 (54)
	44	1	19.0	5.4	23.6 (110)
	48	1	12.0	3.6	32.5 (40)
	48	3	71.0	9.9	64.0 (50)

Results

Because of the vast and difficult terrain and the exceptionally high number of plants planted, it was not feasible to count every seedling in the canyon. A sampling method (PG&E 1987b) was used to determine the number of seedlings established. Of three statistical estimating procedures used, survival estimates ranged from 47,017 to 48,441 after three years from the initial operational planting. This figure included all sources of plants PG&E had planted including the test plantings and a supplemental planting of 5,270 plants.

The source of the plants inventoried were categorized by the type planting, year planted and whether the plant was derived from natural regeneration or aerial seeding (Lodgepole and Jeffrey Pines). It was sometimes difficult to pinpoint the source of a plant because of various reasons. However, for most species, it was fairly easy to distinguish planted individuals from those of natural regeneration. Many of the identifying flags and planting collars were still in place. Most of the plants inventoried were attributed to the revegetation effort (PG&E 1988). The total number of living plants regardless of origin was accurate and was used to fairly assess the fulfillment of the regulatory agencies' requirement for plant establishment.

Some results of the riparian vegetation plantings are provided (table 13). These results in many cases were comparable to the test planting.

Discussion

Selecting Adapted Species

For typical riparian conditions, it is efficient to plant willows or black cottonwood as soon as conditions are favorable in the Fall using cuttings planted directly at the site. Selecting local sources of cuttings and planting as soon as the source plants become senescent is recommended. If the site is marginal, i.e. the seasonal weather conditions predicted to be dry or time of planting is delayed into spring, rooted cuttings of local sources of species is recommended. Supplemental watering should be used if needed.

For difficult sites where it is desirable to establish riparian vegetation more considerations need to be given to the planting. Identifying site conditions in which the various types of riparian species are able to become established is best accomplished by establishing trial plantings early in the planting program or by installing limited size pilot planting. Testing a wide range of species in a wide range of conditions is desirable in large projects. Significant results should be evident in one year.

Even without understanding the internal mechanism of the plant's ability to become established, one can utilize the plant's response to acquire an indication of its future performance at disturbed sites. Indicators such as vigor, color of foliage, survival and growth rate at the site have more direct value than laboratory studies or studies performed at other sites. In addition, site conditions change with time as nature creates more favorable conditions for plants to develop. These subtle changes may take place over relatively longer periods of time but are difficult to study because of the lack of research continuity and the funding difficulty.

Quaking aspen, scouler's willow and to a lesser extent, red-stem dogwood have a wide range of adaptation. It seems these species are capable of becoming established in quite dry and rocky conditions at high elevations. Their peak performance may not be at these kind of sites, but growth is quite adequate. Reproduction by natural seeding may not be likely under these conditions but vegetative perpetuation is possible.

Plant Acquisition and Timing of Plant Propagation

In addition to selecting adapted plant species and using proper planting methods for specific site conditions, plant acquisition is also important, including plant propagation and timing. Planning and co-ordination is essential. Because of the 6 to 12 month lead time to acquire

plants it may not be feasible to include plant acquisition as part of the planting contract nor may it even be desirable to do so. Plant acquisition is a specialized process requiring rigid guidelines but enough flexibility to acquire sufficient supplies of species. A planting contractor may have limitations. Specialized knowledge of plant propagation may be required. Plant acquisition is also time consuming; knowing current market conditions is necessary.

Maintenance

Minimal or no maintenance is desirable as the most effective means of establishing riparian vegetation. Plants that grow in balance with the natural existing environmental conditions are better able to survive and to continue perpetuating on their own. One is not able to determine the adaptiveness of the species used for the existing site conditions without applying this approach. The response of the species should be evident in the first growing season. If watering is used, it should be only enough to supplement the natural rainfall during periods of drought or if plantings are installed late in the season. However, it may be more cost-effective to install supplemental plants than to perform excessive maintenance. The results of the initial planting will allow one to make a determination as to the necessity of making a supplemental planting. If exceptional vigor is observed with certain individual plants or species compared to plants that failed or performed poorly, these plants should be propagated to expand the planting. It is also advisable to identify specific site conditions where positive results were consistent and emphasize planting such areas in later stages.

Conclusions

As a group, the riparian vegetation in Lost Canyon was versatile. Some species were most adapted to typical riparian conditions in which deep sandy soil was saturated in late winter-early spring and perennially moist at lower depth in the latter part of the growing season. Other species were able to extend their environment to drier conditions but still probably utilize moisture at lower depths, particularly in rocky soil. Some species were established in nearly solid rock with few fissures but had constant moisture from seepage.

The revegetation effort significantly accelerated and aided the healing process in Lost Canyon. However, the need for improvements in the state-of-the-art was evident. A better understanding of plant establishment in regards to nature's response to a catastrophic event is needed. Areas of research include inoculation of disturbed soil with mycorrhizae and other micro-organisms.

According to one scientific investigator, replanting a native ecosystem cannot be realized if a component as critical as mycorrhizal symbiosis is not included in the replanting process (St. John, 1984). This did not appear to be true from the data collected at Lost Canyon as well as some other revegetation projects. Artificial inoculation of a severely disturbed soil may not be obligatory although it is likely to be beneficial to establish native woody plants. Also, fertilization seems to aid rather than inhibit plant establishment. The optimal amount appears to vary with species. The lowest levels that can achieve a healthy growth response is recommended.

An understanding of natural processes needs to be more clearly defined, including re-establishment of soil organisms in relation to host plants, assimilation of minerals and organic matter and how to apply new technological information into practical horticultural procedures. We need to be able to better identify a plant's range of adaptation and to understand how to establish a balance between the plant and the existing environmental conditions. Riparian vegetation appears to be established in Lost Canyon and normal continual development appears promising five years after the initial planting.

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