A REVIEW OF THE REVEGETATION TREATMENTS USED IN REDWOOD NATIONAL PARK - 1977 TO PRESENT

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Abstract. The revegetation program in Redwood National Park treats freshly reshaped surfaces following physical erosion control work. Revegetation prescriptions are coordinated with physical site treatments to address surficial erosion control, slope stabilization and ecosystem restoration. The program has evolved from early use of wattles and unrooted stem cuttings to current use of nursery-grown cuttings, bare root and containerized seedlings. Grass seeding for immediate erosion control is being replaced by straw mulching. Experimentation continues for technique refinements and the wider use of native species. The most successful results are attributed to treatments which mimic natural vegetation patterns.

INTRODUCTION

Redwood National Park was established in 1968 to preserve significant examples of coastal redwood forests and the streams and seashores with which they are associated. Timber harvesting and related road construction in the Redwood Creek watershed outside the park combined with natural processes to pose iminent threats to downstream Park resources (Agee 1980). Naturally high erosion rates were greatly accelerated by intensive land use practices and unusually severe storms. Vegetation removal, alteration of hillslope drainages and development of an extensive logging road/skid trail network caused increased runoff, sediment yield, and accumulation of sediment deposits in major stream channels. Other problems included increased landsliding, filling, and widening of stream beds, erosion of stream banks, damage to streamside vegetation and overall degradation of natural aquatic ecosystems (Madej et al. 1980).

In 1978, Congress amended the Redwood National Park Establishment Act through Public Law 95-250 to enlarge the park by 48,000 acres of which 36,000 acres were recently logged. It directed that a watershed rehabilitation program be developed to minimize man-induced erosion and to encourage the return of a natural pattern of vegetation (see USDI 1981, Watershed Rehabilitation Plan).

In anticipation of congressional authorization to rehabilitate cutover timberlands, a pilot program was begun in 1977. The rehabilitation program

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has since moved from the developmental phase into full scale implementation in 1980, with continued monitoring for technique effectiveness and refinement.

Objectives of the Revegetation Program are: 1) accelerate the restoration of redwood forests and associated vegetation systems, 2) contribute to long-term slope stability through vegetation re-establishment, and 3) aid in reduction of surface erosion. This paper describes the revegetation portion of the Vegetation Management program and examines techniques of revegetation which were implemented in Redwood National Park from 1977 to present.

SEQUENCE OF REHABILITATION ACTIVITIES

The sites chosen for rehabilitation include former logging haul roads, skid trails and stream crossings, logging decks and landings, and prairie ranch roads. Park geologists and hydrologists assess the need for erosion control, selecting the most effective physical techniques to treat critical areas. In addition to erosion control, physical treatments are designed to promote the establishment of natural and planted vegetation by: 1) disaggregating rocked roads, 2) spreading excavated fill or soil over exposed bare rock, and 3) separating and returning buried topsoil to the surface.

Heavy equipment operations (stream crossing excavations, road outsloping and ripping, and water bars) result in freshly disturbed ground susceptible to surface erosion. In areas where stream crossings have the greatest potential for contributing material to creeks, grasses, shrubs, and mulches are used to reduce streamside sediment loss, with mulches providing immediate cover until vegetation can become established.

Vegetation is generally viewed as having a minor role in initial erosion control efforts, but over time becomes the primary defense against erosion on fully rehabilitated sites. Species with fibrous root systems secure surface soil and promote soil aggregation. Rhizomes bind larger blocks of surface soil. Large, deeply-penetrating roots give the subsoil greater shear strength. Low groundcover plants reduce raindrop impact, as do trees that produce abundant litter.

The vegetation staff develops site-specific vegetation prescriptions to promote long-term erosion control by rapid revegetation. Information for developing site-specific prescriptions is derived from an inventory of existing vegetation, site relief, and soil characteristics (soil color, texture, depth of groundwater or impermeable layers) of remnant and disturbed areas. Areas of high erosion and wildlife depredation potential are noted for special attention. Species and treatments are selected for each area to maximize survival and growth. Plant materials include seed and seedlings supplied by local nurseries and seed, transplants, and cuttings collected within the park. Mulches, seed, and fertilizer are applied after heavy equipment work. Wattles, cuttings, transplants, rooted cuttings, seedlings, and tree and shrub seeds are planted in winter. Documentation and monitoring programs are conducted throughout rehabilitation, and continue for several years. Results are used to evaluate the success of treatments and refine future prescriptions.

TREATMENTS AND EVALUATION

The development of the park revegetation program is reflected in both species and techniques employed. Prescription refinements have led to changes in quantities and types of treatments utilized (Table 1).

Table 1. Vegetation treatments, 1977-1980.

				Containerized Seedlings and Rooted Cuttings					
	Wattles	Unrooted Stem Cuttings	Transplants	Redwood	Douglas-fir	Sitka Spruce	Alder	Coyote Brush	Whipplea
	1,820 ft	1,800	9	230	430	496	0	0	0
	27,155 ft	301,120 sq ft (est. 129,300)	64	2,270	2,650	0	0	0	0
	2,823 ft	22,000	1,919	3,400 (+67,850)*	8,900 (+58,680)*	0	800	7,471	5,066
	0	40	835	30,700 (2,000)*	26,320	0	59,000	23,200	13,800

*Seedlings planted for reforestation of cut-over lands.

WATTLING. Early erosion control and revegetation techniques, such as attling, were developed elsewhere and adapted for use in the Redwood National ark rehabilitation program. Wattles are bundles of woody branches partially ried in contour trenches and are intended to revegetate the site while oviding physical barriers to ravelling and rill development. Willows Salix, spp.) were the primary species used because they had been used lsewhere and were abundant. Willow readily sprouted, but did not survive e dry conditions found on most rehabilitation sites. Average initial rvival on 1978 sites ranged from 48 to 93 percent with vigor declining subsequent years on all but the wettest sites. Thimbleberry (Rubus rviflorus), salmonberry (Rubus spectabilis), blackberry (Rubus vitifolius), oyote brush (Baccharis pilularis var. consanguinea), and redwood (Sequoia mpervirens) were also tried with limited success. Alder (Alnus oregana), ueblossom (Ceanothus thrysiflorus), elderberry (Sambucus callicarpa), and ododendron (Rhododendron macrophyllum) wattles did not sprout. In general, ttles grew well on wet northern exposures with fine-textured soils. However, en on dry rehabilitation units, wattles placed close to springs or streams hibited high survival (Reed and Hektner 1981).

As a revegetation technique, results show that wattling can be effective en restricted to readily sprouting species and placed in areas of relatively gh summer moisture. The potential for successful use of wattling in Redwood tional Park is limited since most of the rehabilitation areas are very dry ring summer. Wattles were used extensively in 1977 and 1978, more selectively 1979 and deleted entirely from the program in 1980. Due to high cost and effectiveness, Weaver and Seltenrich (1981) recommended that the use of ttling as an erosion control technique also be discontinued. Other chniques have proven to be more effective and economical for both revegetation erosion control.

UNROOTED STEM CUTTINGS. Unrooted stem cuttings were used in early efforts to promote revegetation and root growth for slope stability. Thimbleberry, willow, salmonberry, blackberry, alder, blueblossom, coyote brush, rhododendron, elderberry, salal, big-leaf maple (Acer macrophyllum), evergreen huckleberry (Vaccinium ovatum), whipplea (Whipplea modesta), and bay (Umbellularia californica), were used as unrooted stem cuttings. Willow and coyote brush had the highest survival after one year on 1978 sites with ranges of 41 to 89 percent and 25 to 47 percent, respectively. All other species averaged less than 5 percent survival in the first year. Despite initially high survival rates for willow and coyote brush, vigor and survival are declining on all but immediate streamside sites. Willow stem cuttings are now used only along streams. Unrooted stem cuttings have not been used extensively since 1979. Other means of establishing these species are being developed.

ROOTED STEM CUTTINGS AND SEEDLINGS. Large-scaled propagation allows dense planting which is expected to establish vegetative cover more rapidly. Coyote brush seedlings and whipplea rooted stem cuttings are now the most frequently used shrub materials. Willow, thimbleberry, Sierra gooseberry (Ribes roezlii var. cruentum), ocean spray (Holodiscus discolor), and hazel (Corylus cornuta var. californica) cuttings are being experimentally rooted to broaden the spectrum of species available for site-specific prescriptions.

Nursery-grown alder seedlings were successfully established on 1980 rehabilitation sites and will be planted on 1981 sites. Alder enhances soil development and restoration due to the associations it forms with nitrogen-fixing Actinomycetes. Establishment of nodules on nursery stock prior to out-planting improved survival and initial growth of seedlings (Sugihara and Cromack 1981). Other hardwoods that may be nursery-grown include madrone, tanoak, big-leaf maple, and Oregon white oak (Quercus garryana).

One-year old containerized redwood and Douglas-fir seedlings purchased from local nurseries have been used extensively in the revegetation program. Sitka spruce (Picea sitchensis) has been used in limited amounts. In general, initial survival has been less than 50 percent, however by the third year, those seedlings surviving have become well established. Predation by black-tailed deer and Roosevelt elk is high on conifers and shrubs, but does not always cause mortality. Fertilizer pellets, mycorrhizal inoculation, mulching, vexar tubes and Big Game repellant are being examined as methods for increasing survival and establishment. Preliminary investigations indicate that survival of two-year old bareroot Douglas-fir and redwood seedlings is much higher under the harsh conditions typical of the park rehabilitation sites.

FIELD TRANSPLANTS. Field transplanting permits the establishment of larger plants with well-developed root systems on sites where rapid vegetative cover and root expansion are desirable. Transplanting also allows greater use of species where seed collection, propagation or rooting techniques have not been successfully developed. Most transplants are obtained on-site and are already adapted to the local environment. Transplants have been successfully used since 1977 and include: alder, redwood, coyote brush, whipplea, salal, evergreen huckleberry, rush (Juncus, spp.), sedge (Carex, spp.), madrone (Arbutus menziesii), 'Alta' fescue (Festuca arundinacea), cattail (Typha latifolia), coltsfoot (Petasites palmatus), iris (Iris, spp.), deer fern (Blechnum spicant), bracken fern (Pterdium aquilinum var. pubescens), and sword fern (Polystichum munitum). Moderate sized transplants have done well

and survival of whipplea and coyote brush increased with top-pruning. Cost and survival comparisons for transplants, rooted cuttings, and seedlings are planned for this year.

SEEDING. Establishment of early successional vegetation can be accelerated by artificially seeding native tree, shrub, and ruderal species. Localized dense stands of coyote brush, alder, sedge, and rush have been successfully established by direct seeding. Small quantities of maple, tanoak, blueblossom, cattail, dock (Rumex crispus) and chinquapin (Castanopsis chrysolepis) were seeded with little success. Continued technique development may allow these and other species to be utilized more extensively in the revegetation program.

Grass seeding is widely used for erosion control on disturbed areas. Annual ryegrass (Lolium multiflorum), 'Blando' brome (Bromus mollis), creeping red fescue (Festuca rubra), and vetch (Vicia, spp.) were used on 1977 sites. Ryegrass dominated, with cover over 70 percent the first year. Grass coverage has decreased each successive year, to presently less than 10 percent. Quail are thought to have eaten most of the vetch seed.

Annual and perennial ryegrass, 'Potomac' orchard grass (Dactylis glomerata 'Potomac'), velvet grass (Holcus lanatus), barley (Hordeum vulgare), fawn tall fescue (Festuca arundinacea), and crimson clover (Trifolium incarnatum), were used alone or in combination in 1978. Only ryegrass persisted past the first year in any amount. Initial coverage was spotty, varying from less than 1 up to 40 percent.

The 1979 seed mix included perennial ryegrass, orchard grass, creeping red fescue, and 'Highland' colonial bentgrass (Agrostis tenuis 'Highland'). Ryegrass dominated the first year but was replaced the following year by bentgrass with little change in overall cover. In general, cover was less than 10 percent on unfertilized areas and greater than 50 percent on fertilized areas. On one unit, spring cover averaged 50 to 75 percent with 250 lbs/acre and 75 to 90 percent with 500 lbs/acre ammonium phosphate / sulfate (16-20-1-13S) fertilizer. Fertilizer also stimulated ruderal species; cover averaged 35 to 50 percent with 250 lbs/acre fertilization compared to 2 to 4 percent on control plots (Popenoe 1981).

Bentgrass, creeping red fescue, fawn tall fescue, 'Blando' brome, 'Durar' hard fescue (F. ovina var. duriscula), Zorro fescue (F. megalura), 'Mt. Barker' subclover (Trifolium subterraneum), 'Lana' woolypad vetch (Vicia dasycarpa), and common vetch (Vicia, spp.), were used on 1980 sites. Grass cover increased with fertilization, with brome the most successful. In the first season, however, even without fertilization, the legumes dominated, averaging 50 to 75 percent cover, with only vetch doing well on poorly-drained blue clay sites.

It has been noted that timing of fertilization significantly affects relative species composition. Fall applications of fertilizer improve stand cover of seeded grasses while late winter applications favor woody invader species such as coyote brush.

Grass has been locally effective for controlling frost heaving, as well as rainsplash, sheet, and rill erosion but not until late in the season. Except in wet areas, dense grass cover has not been established prior to the first rains. In 1981, limited trials of fall hydroseeding of grasses with fertilizer

and mulch produced a rapid ground cover of greater than 80 percent. Water availability and vehicle access limit the potential of this technique in the park. Hydroseeding is being done on roadcuts through prairies where conventional methods cannot be used. Grass is a vigorous competitor with native woody vegetation and greatly reduces natural invasion, an objective along prairie roads in Redwood National Park. This same competition with native woody species has led to more restricted use of grass seeding in forested units. Some of the effects of grasses on invading and planted species are being investigated on 1980 rehabilitation units.

MULCHES. Mulches, when spread immediately after heavy equipment work and prior to the first rains, are used to minimize surficial erosion. Mulches also reduce and disperse runoff (promoting infiltration) and reduce evaporation. On environmentally harsh sites, these factors favor re-establishment of vegetation. Straw mulches at 2,000 and 4,000 lbs/acre were found to reduce total herbaceous cover while increasing initial invading coyote brush seedling density. In addition to straw, redwood chips, hardwood bark, whole chipped Douglas-fir and Monterey Pine (Pinus radiata) mulches were used in 1979. Excessive handling costs and poor revegetation led to the elimination of all but straw mulch for 1980. Weedy contaminants from the straw have been found but have not persisted into the second year.

COSTS

In 1978, $87,000 was spent for vegetation materials and installation. Of this, 74% ($64,353) was for wattles, 19% ($16,742) for unrooted stem cuttings and the remaining 7% ($6,305) for all other revegetation.

By 1980, a changing emphasis in treatments and techniques enabled revegetation of larger areas for similar costs. Of approximately $77,000 spent in 1980, less than 1% ($40) was spent for unrooted stem cuttings, 2% for transplants ($1,420), 26% ($20,200) for seeding and fertilizing and 72% ($55,500) for seedlings and rooted cuttings.

Table 2 shows the unit cost of major revegetation techniques used for 1978-1980, including materials and labor. Costs varied widely by site and by year

TABLE 2. Unit cost comparison of major revegetation techniques including materials and labor, 1978 - 1980.*

				Containerized Seedlings and Rooted Cuttings			
Year	Wattles	Unrooted Stem Cuttings	Transplants	Conifers	Alder	Coyote Brush	Whipple
1978	avg. $2.47/ft ($1.00 - $2.93)	avg. $0.38 ea ($0.10 - $0.39)	$0.60 ea	$0.08 ea plus $0.12 ea labor	-	-	-
1979	avg. $1.16/ft ($1.02 - $1.79)	avg. $0.26 ea ($0.19 - $0.85)	avg. $1.48 ea ($0.49 - $2.21)	$0.10 ea (. . . . . plus undocumented labor costs	$0.10 ea	$0.35 ea	$0.35 ea)
1980	-	$1.00 ea	$1.70 ea ($1.39 - $3.00)	$0.10 ea (plus $0.137 - $0.216 ea for labor and overhead	$0.125 ea	$0.107 ea	$0.125

* 1977 itemized treatment costs not available.

depending upon labor source and site conditions. Revegetation work was performed by request for bid contracts, cost reimbursable contracts, in-house labor and contract labor. Site accessibility, source of plant materials (obtained on-site vs. carried in) and difficulty of planting influenced total labor costs.

DISCUSSION

The revegetation program in Redwood National Park treats freshly recontoured surfaces following physical site treatment. In most cases the surfaces are nutrient deficient subsoils lacking native seed and micro-organisms. Environmental stresses due to summer drought and winter cold are intensified by the lack of canopy cover. Early rehabilitation projects relied upon species and techniques developed elsewhere for other conditions. Prescriptions such as willow wattling and grass seeding had been intended for immediate surficial erosion control and revegetation. These techniques often proved unsatisfactory in the environment of rehabilitation sites. Mulches have now been substituted for immediate surface protection while vegetative prescriptions address long-term erosion control through native vegetation re-establishment.

Current work concentrates on improving survival and establishment of planted vegetation and there is new emphasis on managing the seedbed environment to promote natural revegetation. Bulk native seed collection, processing, propagation, and planting techniques are being refined. Two-year old bare root conifer seedlings will be used more extensively, particularly on the harsher sites. Field trials examining the value of slow-release fertilizer pellets and treatments to minimize wildlife depredation are being conducted. Broadcast fertilization will be timed to favor establishment of native species. Experimental use of compost will begin next year and hydroseeding of native shrub species will be tested.

Vegetation treatments and techniques are most successful when they mimic the natural vegetation patterns adjacent to rehabilitation sites. Utilization of colonizing species improves prospects for successful plant establishment on harsh sites. Well-established native vegetation will assist in long-term slope stability and erosion control.

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