EROSION CONTROL IN REDWOOD NATIONAL PARK, NORTHERN CALIFORNIA, 1980

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Abstract. In Redwood National Park, erosion control treatments are aimed at reducing accelerated sediment yield from lands disturbed by timber harvest and road construction. Such practices address both active and potential sediment sources to streams. In 1980, detailed mapping of five rehabilitation units identified active gully systems, stream courses diverted from their natural channels, unstable road and skid trail stream crossings, and mass movement features. Approximately 1276 ha were examined in detail. Of this land, erosion control work was performed on 32 ha. Primary erosion control treatments utilize heavy equipment to perform earth moving tasks. These treatments, which result in the redirection of altered drainage networks and the removal of unnatural sediment sources, accounted for 58 percent of the total cost. Secondary erosion control treatments provide protection to areas freshly disturbed by primary treatments. These measures include bed and bank protection for excavated stream channels, and surface protection for bare soil areas. Secondary treatments, which utilize heavy equipment and manual labor crews, accounted for 34 percent of the total cost. The proper design of stream channel excavations can minimize secondary treatment costs. The proper application of heavy equipment can lower unit costs and increase the cost-effectiveness of erosion control treatments.

INTRODUCTION

In 1978 Redwood National Park was expanded by 19,400 ha in the lower Redwood reek basin. Of this land, 13,400 ha had been severely disturbed by timber arvest and road construction. Concurrent with park expansion, a multi-faceted, arge scale rehabilitation program began. Rehabilitation efforts focused on educing the amount of sediment delivered to tributary streams of Redwood Creek rom disturbed areas, and restoring a natural ecosystem. This paper summarizes e erosion control work supervised by Redwood National Park staff in 1980. e erosion control treatments used and their costs are discussed. Finally, xamples of unique erosion problems and treatments found on four rehabilitation its are described. The reader is referred to the paper written by Sonnevil, t. al. (1982) describing the evolution of erosion control in Redwood National ark, and by Teti (1982) which offers a detailed look at one of the rehabilitation units completed in 1980.

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Erosion control work proceeds in three phases. First, rehabilitation units are mapped in detail during the rainy season. Active and potential sediment sources are identified and an erosion control plan is developed. During the second phase, heavy equipment performs earth moving tasks. Equipment work is performed during the dry season, and is generally supervised by Redwood National Park staff. The third phase involves labor intensive work and is performed by park labor crews, labor contract, or voluntary youth organizations.

As identified by field mapping, timber harvest activities had caused severe and widespread disturbance to natural drainage networks and hillslope areas. Roughly 60 percent of the 1980 rehabilitation units had been logged since 1970, of which 80 percent had been tractor yarded. Tractors had commonly entered and crossed stream channels to obtain access to felled timber. In doing so, tractors would sidecast earth and woody debris into natural stream channels creating new sediment sources and potential stream diversions. Skid trail crossings each contained an estimated 70-230 m^3 of fill material. While these commonly eroded during large storm events, some remained intact and diverted streamflow down skid trails or across hillslopes causing severe gully erosion. Skid trail surfaces also concentrated storm runoff and their cutbanks often intercepted winter groundwater levels. Where waterbars had not been constructed, or were improperly placed, skid trails developed gullies and, in several instances, directed storm runoff onto unstable log landings.

Stream diversions, gully erosion, and mass wasting of fill material were also common along haul roads where culverts had been infrequently spaced, improperly sized, and/or poorly maintained. Some ephemeral and intermittent streams had been diverted by road construction because culverts had not been installed. During storm events, culvert capacities were often exceeded and culvert inlets frequently plugged with debris. As a result, streamflow either: 1) breached the road surface eroding massive volumes of fill from road crossings, 2) discharged onto broad hillslope areas causing gully erosion, or 3) was diverted into an adjacent stream channel causing accelerated bank and channel erosion as a result of increased streamflow.

The erosional processes described above were common to all 1980 rehabilitation units. However, the combination of underlying geology, hydrologic events, severity of ground disturbance, and natural erosional processes caused the development of unique or complex erosion problems. Newly created surficial processes and the redistribution of mass on unstable hillslopes, re-activated pre-logging mass movement features, and, in some cases, initiated new ones. It should also be noted that most of the erosion observed on the cutover units appeared to stem from the major storm events in 1972, and 1975.

EROSION CONTROL TREATMENTS

Erosion control treatments consisted of primary and secondary treatments. Primary treatments are earth moving functions performed by heavy equipment to: 1) redirect drainage networks altered by haul road and skid trail construction, and 2) remove both active and potential sediment sources to streams. Secondary treatments encouraged the stabilization of areas freshly disturbed by primary treatments. These treatments included the placement of check dams and rock armor in excavated stream channels, and the application of straw mulch and revegetation treatments to bare soil areas. Both heavy equipment and manual labor crews performed secondary treatments. In 1980, five rehabilitation units were completed under the supervision of Redwood National Park staff. Approximately 1276 ha were mapped in detail. Of this land, erosion control work was performed on 32 ha which includes 23.5 km of haul roads. The total cost of erosion control work was $587,320, of which, primary and secondary treatments accounted for 58 percent and 34 percent respectively. Figure 1 provides a breakdown of all costs.

Drainage networks were redirected by removing haul roads, excavating road and skid trail crossings, treating log landings, and constructing waterbars. The degree of road removal considered road bench stability, proximity to stream channels, and road location (prairie or forest). Road removal utilized combinations of dragline cranes, hydraulic excavators, crawler tractors, backhoes and/or dump trucks. Typically, road surfaces were decompacted (ripped) to a depth of 50 cm using chisel teeth mounted to a D-8 (or equivalent) crawler tractor at an average cost of $427/km. Road benches were then either: 1) cross-road drained (closely spaced, deep troughs cut across the road bench to decrease concentrated inboard ditch runoff), 2) partially outsloped, or 3) completely outsloped. In 1980, 23.5 km of haul roads were removed. Of this total, backhoe-tractor teams cross-road drained 14.6 km of forest roads at an average cost of $1515/km. Partial outsloping was performed on 5.8 km of forest roads by hydraulic excavator-backhoe-tractor teams at an average cost of $1750/km. In the prairies, where aesthetics were also considered, excavator-tractor teams completely outsloped 3.1 km of roads at a cost of $4297/km (fig. 2).

Like haul roads, log landing surfaces are compacted and concentrate storm runoff. To improve infiltration rates and disperse surface runoff, tractors ripped and partially outsloped landing surfaces. A total of 26 landings (.2 - .3 ha each) were treated at an average cost of $1200/landing.

Waterbars direct concentrated runoff from compacted, bare soil areas onto more stable, vegetated ground. Properly constructed and placed, waterbars can de-water active gully systems and prevent further gullying. Tractors and/or backhoes constructed waterbars on skid trails ($9 - $30 each) at an average cost of $19 each. Labor crews also constructed waterbars, but only in areas where equipment access was impractical ($19 - $48 each).

Primary erosion control treatments also included the removal of active and potential sediment sources to stream channels. Such sediment sources included haul road and skid trail crossings, unstable or oversteepened fillslopes along roads, and unstable log landings. In 1980, an estimated

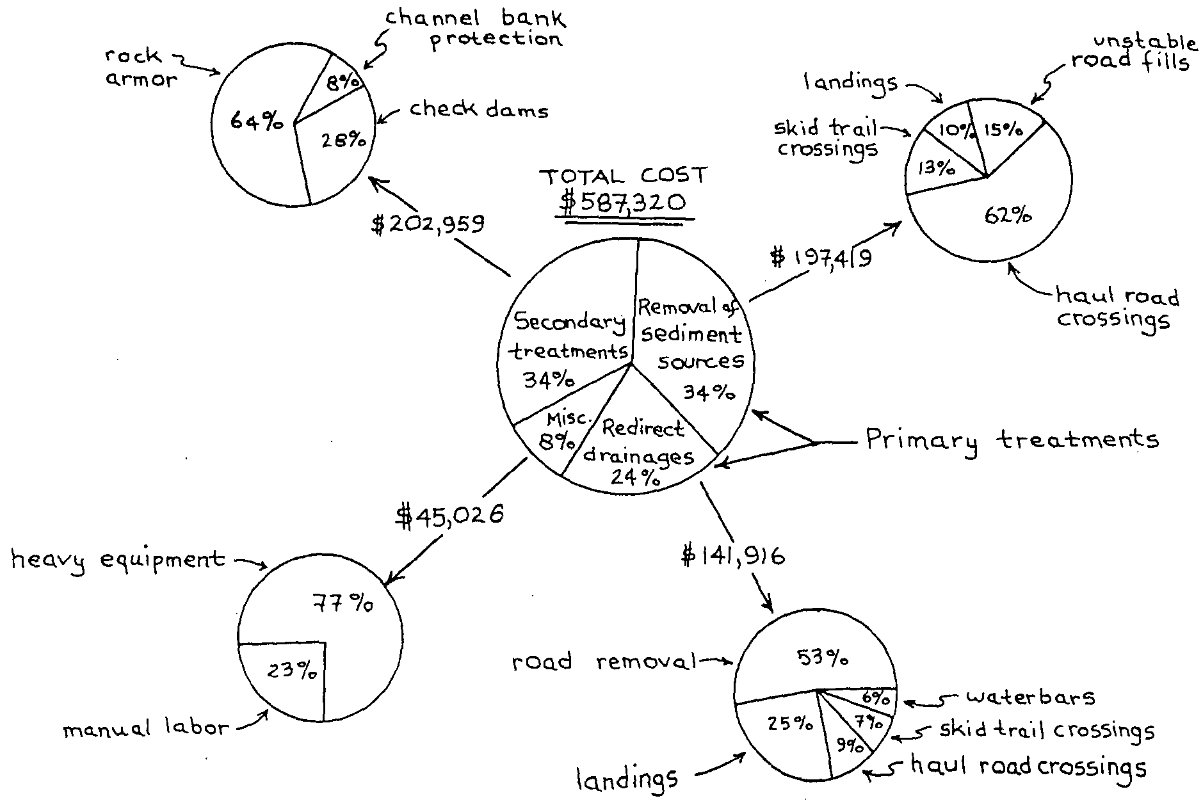
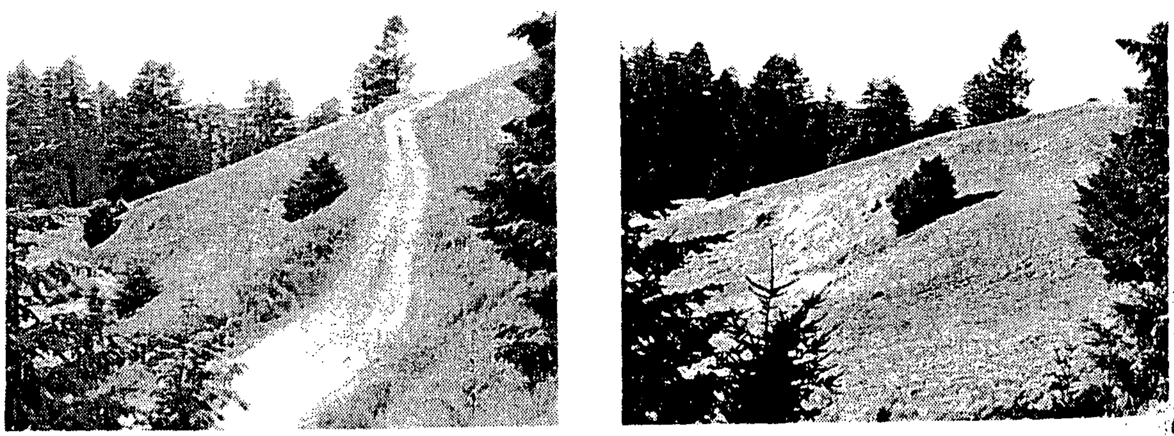


FIGURE 1. Cost breakdown to perform 1980 erosion control work.



(a) (b)

FIGURE 2. Before (2-a) and after (2-b) sequence of prairie road removal (complete outsloping). A hydraulic excavator and crawler tractor retrieved sidecast material from below the outer edge of the road and piled the material against the road cutbank. The crawler tractor then spread the piled material to blend with the surrounding slope morphologies.

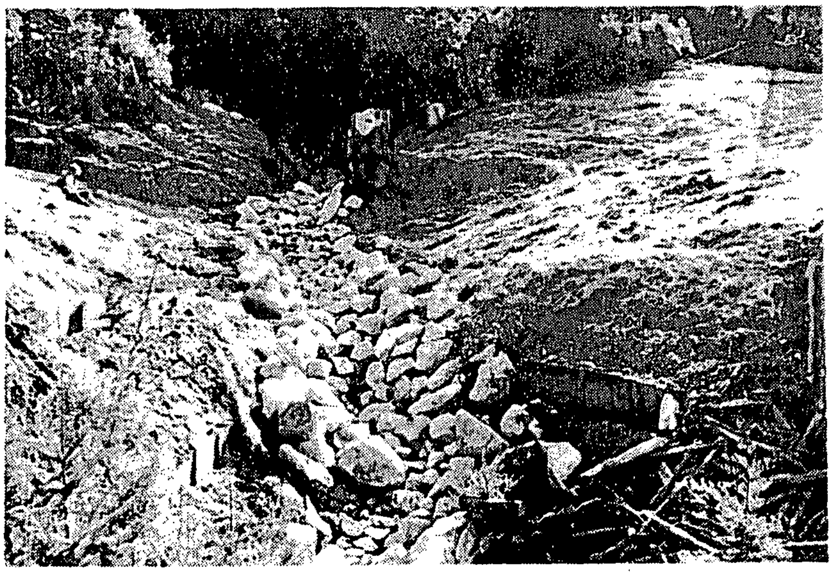
35,400 m^3 of fill was excavated from stream channel crossings at an average cost of $4.90/$m^3$. Stream channels were excavated to approximate pre-logging sideslope geometries and channel gradients (fig. 3). Skid trail crossings accounted for 8700 m^3 ($2 - $9/$m^3$), and haul road crossings accounted for 26,700 m^3 ($2 - $15/$m^3$). Typically hydraulic excavators, dragline cranes, or backhoes, and crawler tractors or loaders removed fill from road crossings and stored the removed fill within 60 m from the excavation site. At some stream channels, the adjacent road cutbanks intercepted groundwater and this prevented the immediate area from being used as storage. Excavated fill from such road crossings was loaded into dump trucks to be transported (end-hauled) and stored at a dry, stable location ($6.50 - $11/$m^3$). A similar approach was prescribed to treat unstable road segments located above stream channels where suitable storage space was not available. Approximately 1500 m^3 of unstable road fill was retrieved and endhauled ($5 - $9/$m^3$).

Secondary treatments were designed to minimize channel erosion in newly excavated stream channels, and to eliminate rill and gully erosion on freshly disturbed ground. Channel protection consisted of rock armor and check dams while adjacent banks were protected by combinations of straw, seed mixes, jute netting (loosely woven hemp), Curlex (shredded aspen in a monofilament netting), and seedlings.

Crawler tractors, dump trucks, and track-mounted loaders were used to quarry and transport rock to excavated stream channels. A total of 6300 m^3 of rock was delivered to rehabilitation units at an average cost of $12/$m^3$ ($9 - $22/$m^3$). Stream channels required 26-325 m^3 of rock ranging from 15-90 cm in diameter. Any combination of crane, excavator, or backhoe, and tractor or loader placed rock in stream channels at costs ranging from $1.50 - $21/$m^3$. Using heavy equipment, the average cost for rock placement was $7.25/$m^3$. Labor crews performed the final adjustment of rock placed by heavy equipment, and placed rock in smaller channels where large boulders were not essential. In these smaller channels, labor costs for rock placement ranged from $19 - $57/$m^3$ and averaged $42/$m^3$. Rock armor adjusts slightly in response to the first runoff events, and requires little or no maintenance.

Like rock armor, check dams can minimize channel erosion in newly excavated stream channels. Check dams are constructed from milled redwood boards and have an estimated useful life of 10 years. Prior to 1980, check dams were commonly constructed in small streams, and were capable of containing an estimated peak discharge of less than .2 cms. In 1980, experimental check dams were constructed with the largest group capable of containing an estimated 1.4 cms peak discharge. A total of 424 check dams were constructed at an average cost of $109/dam ($25 - $1400/dam). Single board check dams, averaging 1 m high and 2 m long, cost from $25 - $84/dam and averaged $37/dam. The average cost to construct multiple board check dams (1.3 m high, 4.6 m long) was $156/dam and ranged from $117 - $1400/dam. Check dams must be periodically inspected and maintained to prevent plugging and washing-out of the entire structure.

(a)



(b)

FIGURE 3. Before (3-a) and after (3-b) sequence of a haul road crossing excavation from an intermittent stream channel. As a primary treatment, a crawler tractor and track mounted backhoe-loader excavated approximately 769 m^3 of fill from the stream channel. Rock armor was prescribed as a secondary treatment and was placed by the same equipment. The excavation required a combined total of 18 equipment hours, and rock placement required 5 hours. The total treatment cost $1530.

Secondary treatments were also designed to prevent sheet, rill and gully erosion from bare soil areas, to preserve open soil structure and high infiltration rates, and to aid in subsequent revegetation. Straw mulch was applied to bare soil areas at rates of 4500 - 6700 kg/ha; average cost of application was $1800/ha. On steep channel banks (>25°) jute netting was applied over a straw layer and anchored to the ground with redwood stakes. This technique prevented the straw from being blown off the channel banks and added further protection against surface erosion and soil compaction. The average cost to apply straw and jute netting was $1.55/m^2 ($15,000/ha).

SITE SPECIFIC EROSION CONTROL TREATMENTS

The erosion control treatments described in the preceding section were typical of most work performed in 1980. However, unique erosion control treatments were prescribed to treat unusual or complex erosional processes identified on each of the rehabilitation units.

Bridge Creek, M-6-2 Road and Slope Unit

An erosion control treatment unique to the Bridge Creek, M-6-2 rehabilitation unit was the attempted stabilization of a .80 ha landslide. Constructed in the early 1970's, the M-6-2 road crossed 20°-27° hillslopes approximately 100 m above the main channel of Bridge Creek. Underlain by highly sheared schist, areas on the hillslope had an accelerated soil creep/landslide history. On one such area, an estimated 4200 m^3 of fill had been sidecast onto the crown of an old landslide during road construction. A small log landing had also been constructed there. Three tractor skid trails, constructed immediately above and leading down to this landing, created further ground disturbance in this naturally unstable area. The disturbance caused by road and skid trail construction altered surface and groundwater drainage characteristics and loaded the crown of the slide. In all probability, groundwater levels were also increased by the clearcutting of upslope areas. As a result, an 80 m wide, approximately 100 m long hillslope region, including the road prism, failed in response to 1972 storm events. Portions of the slide mass continued to show recent, intermittent movement and a significant volume of material remained perched above Bridge Creek. Fresh, vertical displacements up to 1 m were observed along the crown and margin scarps, and discontinuous drainages maintained saturated soil conditions throughout several locations on the upper slide mass.

Stabilization efforts were directed towards unloading weight from the slide, and improving surface and subsurface drainage. During the wet season, springs and groundwater discharge areas created by skid trail cuts were located and mapped. During the dry season, a dragline crane and crawler tractor excavated an estimated 3076 m^3 of fill from the upper .30 ha of the slide, and dump trucks endhauled the material to a dry, stable storage location. The combined costs to excavate and endhaul the fill material averaged $6.91/m^3. Upon completion of the fill removal, groundwater discharge areas were relocated and combined with surface drainages to form an artificially constructed drainage network. A backhoe then excavated drainage channels throughout the treated portion of the slide to collect water and speed drainage across this sensitive area. To prevent bank and channel erosion, labor crews constructed 115 check dams in the drainage channels at a unit cost of $25.00 per check dam. Check dams averaged 1 m high and 1.3 m long. As a final treatment labor crews spread grass and red alder (Alnus oregona) seed and straw mulch, and planted red alder seedlings.

1920 Road and Slope Unit

Erosion control work unique to the 1920 rehabilitation unit included the extensive excavation of skid trail crossings and drainage ditches to improve drainage above a large, incipient hillslope instability. Located on the east side of Redwood Creek, the lower portion of this unit is underlain by highly sheared Franciscan sandstones and siltstones associated with the Grogan Fault. Active earthflows occur throughout this lower hillslope region and evidence of previous mass movement exists across the entire unit as "tread and riser" topography, old scarp traces, and a topographically inverted stream reach (i.e., flows along a ridge crest). The logging history of this unit dates back to the 1950's, but accelerated timber harvest did not occur until 1973-1975. Approximately 75 percent of this unit was tractor yarded, and in portions of this unit, disturbance to natural drainage networks was extensive.

Winter field mapping identified a large, incipient hillslope instability near the southern unit boundary which appeared to be reactivated by altered, post-logging soil and groundwater conditions. Evidence of this slope instability was a small (3000 m^2) earthflow surrounded by discontinuous scarps and tension cracks which extended approximately 100 m to either side and 200 m above. Farther above the slope instability, the headwater regions of intermittent streams were extensively damaged by tractor activity. Stream channels were filled with sidecast material and crossed by numerous skid trails. In concert with several large perenneial springs which drained onto this area, surface drainage networks were discontinuous, poorly defined, and encouraged saturated conditions in the structurally sensitive hillslope area. These factors, when combined with the existence of inherently weak bedrock lithology, decreased evapotranspiration, and increased ground saturation, were accelerating slope instability.

Large, active earthflows occur along this hillslope and contribute large volumes of sediment to Redwood Creek. Erosion control prescriptions focused on reducing the earthflow potential of this hillslope instability. These measures were an attempt to prevent saturated soil conditions by collecting, directing, and speeding surface drainage. Two backhoes and a crawler tractor excavated skid trail crossings from stream channels, and constructed drainage ditches to direct spring flow into more stable watercourses. A total of 2200 m^3 was excavated from 21 skid trail crossings at an average cost of $625/crossing ($6.00/m^3). Three drainage ditches and 53 waterbars were constructed at average unit costs of $660 and $9.30 respectively. Finally, labor crews spread straw and grass seed on 1.7 ha of newly disturbed ground, and constructed 49 check dams to control surface erosion.

Maneze Creek Unit

On the Maneze Creek Unit, gully erosion was treated on hillslopes that had been extensively disturbed by skid trail construction during tractor logging in the early 1970's. Skid trails were not waterbarred following timber harvest, and storm runoff and intercepted groundwater concentrated on skid trails causing severe gully erosion. A particularly active gully system averaging 6.2 m wide and 2.5 m deep, had downcut through highly erosive Atwell soils and was delivering sediment directly to Maneze Creek, a perennial tributary to Redwood Creek. Furthermore, the gully system appeared to be accelerating the development of a large hillslope failure (estimated 20,000 m^3) by feeding a portion of its flow into the headscarp region of the hillslope failure. Below the headscarp, the gully was continuing to downcut and enlarge for the remaining 250 m of its length to Maneze Creek.

A diversion channel was prescribed to de-water the gully system. The diversion was designed to intercept hillslope runoff and gully flow from the stable headwaters of the gully and deliver the runoff directly to Maneze Creek. Heavy equipment excavated a low gradient, 200 m long diversion channel nearly along contour. Approximately 3800 m^3 of material was excavated at an average cost of \$3.50/m^3. Following the excavation, equipment placed 285 m^3 of rock averaging 60 cm in diameter to prevent channel enlargement and downcutting. Equipment cost to armor the channel averaged \$12/m^3.

W-Line Road and Slope Unit

Prairie restoration was the theme on the W-Line rehabilitation unit. This unit encompassed 81 ha of natural grasslands of Dolason Prairie across which 3.1 km of logging haul road had been constructed in the late 1950's. The lower 1 km was later upgraded to gain access to two timber units completed in 1977. The earlier haul road crossed emphemeral streams in 16 locations, and the crossings were either log/fill ("Humboldt") or fill constructions. Twelve crossings had either washed out or plugged and diverted flow down the inboard ditch of the road. Extensive gully erosion and channel erosion had occurred. Prairie soils are highly erodible, lack deep root structures which can inhibit the rate of downcutting, and have low infiltration rates and shallow groundwater levels. These factors make them especially sensitive to altered hydrologic conditions.

The high visibility and easy access to prairie land implies a greater potential for future visitor use and places a higher value on the aesthetic appearance of prairies than on logged forest lands. Therefore, erosion control prescriptions considered the aesthetic value of the prairies as well as the erosional processes. The haul road was completely outsloped allowing runoff to remain dispersed. Slope morphologies above and below the road were blended together so virtually no trace of the road was visible (fig. 2). Sixteen road crossings were removed by a hydraulic excavator and crawler tractor at a cost of \$4731 (\$295/each). The prairie road was completely outsloped by a hydraulic excavator and crawler tractor with a 6-way blade. Total cost to outslope 3.1 km of road was \$13,321 (\$4297/km). Secondary treatments included seed and straw application on recontoured slopes, and rock or small check dam placement in stream channels.

As for the success of erosion control treatments, we must assume a "wait and see" or "time will tell" position. All rehabilitation units are being closely monitored to evaluate the effectiveness of erosion control treatments.

DISCUSSION

Erosion control treatments are divisible into primary and secondary treatments. Primary treatments result in the physical removal of potentially erodible fill and woody debris, and the alignment and/or improvement of drainage networks. Secondary treatments provide protection to areas freshly disturbed by primary treatments, and can also be performed in areas inaccessible to heavy equipment.

Unit costs to perform primary treatments with heavy equipment vary between work sites and rehabilitation units. The reasons for such variations include: 1) location and accessibility of work sites, 2) size of road or stream excavation, 3) the amount of debris encountered during fill excavations, and 4) types of equipment used. Perhaps the most important factor is the latter. Unit costs are affected by equipment application simply by having the right equipment for the job. Based on the past three years of experience, hydraulic excavators and crawler tractors appear to be the most cost-effective equipment combinations for most earth moving tasks.

In 1980, secondary treatment costs accounted for 34 percent of the total cost for erosion control. Of this cost, check dams and rock armor account for 92 percent. Check dams and rock armor minimize bank and channel erosion in excavated streams. However, the amount of sediment saved by check dams and rock armor can be one to two orders of magnitude less than the amount of sediment removed by primary treatments. Notwithstanding the effectiveness of check dams and rock armor, most stream channel excavations can be designed to accommodate runoff events having 20-year return intervals, thereby minimizing bank and channel erosion and reducing the need for costly secondary treatments.

In contrast to 1980, "erosion potentials" are now being performed to predict the cost-effectiveness of treatments proposed at all work sites. The sediment to be saved by performing a treatment is weighed against the cost to perform that treatment. Secondary treatment costs may be reduced by perhaps 80 percent by eliminating excessive rock and check dam treatments. Supervisory geologists and hydrologists are more experienced with heavy equipment and are utilizing equipment more cost-effectively. Finally through extensive peer review, prescriptions are being closely scrutinized to insure a more uniform, cost-effective statement of purpose, and application of techniques.

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