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STABILIZING ASH-COVERED TIMBERLANDS WITH EROSION CONTROL SEEDING AND FERTILIZATION

by

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In an earlier presentation, Mr. Stroh, with the Soil Conservation Service, discussed the development and implementation of a seeding and fertilization project to control surface erosion on the watersheds affected by the Mount St. Helens eruption. Most of us have heard or read statements that the project should or should not have been implemented. Other statements this past summer have expressed varying degrees of success or failure of the project. These statements are not questioned here, but most of us must be thoroughly confused at this point as no one has suggested guidelines for success or failure for all or part of the project.

The Soil Conservation Service asked me in spring 1981 to make an evaluation of the vegetation cover provided by the project. The general purpose of the study was to collect data from the Mount St. Helens erosion control project area in a form that could be scientifically compared with previous erosion-vegetation studies so that some quantitative measure of the project's effectiveness could be defined.

Soil or volcanic ash displaced by erosion in the presence or absence of vegetative cover on a Pacific Northwest forest watershed slope is most often not directly correlated with watershed sediment output. A complex sediment delivery factor involving many site factors along with vegetative cover must be used to compute potential sedimentation loading of stream channels in this region. Therefore, the sediment output from the ash-covered watersheds, particularly during the early period of vegetation development, cannot be used as a measure of success or failure for this erosion control project up to this time. Now that seeded and native vegetation stimulated by fertilization has had an opportunity for establishment, a judgment can be made regarding its ability to reduce erosion or ash displacement and to protect the watershed's soil resource.

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To gain perspective for the need and use of erosion control seeding and fertilization, we must relate the present Mount St. Helens activities to past experiences on forest watersheds in the Pacific Northwest. Fire has played an important role in the destruction and consequent development of most forested communities in the Pacific Northwest. The destruction of forests by fire frequently leaves the mineral soil surface covered with a nutrient-rich organic ash. The forest communities destroyed by the destructive forces of the eruption of Mount St. Helens in 1980, however, led to the burial of much of the surrounding forested area with a deep nutrient-poor volcanic ash. Although the forest community near Mount St. Helens was destroyed in a mode somewhat similar to that of wildfire, these differences in the subsequent forest floor could lead to marked differences in the development of the next forest community.

After a severe forest wildfire, it appears desirable to establish vegetal cover as soon as possible to reduce soil erosion and restore nutrient cycles. This same need appears relevant in forest areas severely affected by volcanic activity.

Most forest ecosystems are quite resilient to severe disturbance and will revegetate with native species. However, regrowth may be too slow or the density too sparse to provide immediate soil stability and to restore nutrient cycles. Thus, it has become an accepted practice to hasten the redevelopment of vegetative cover by the use of introduced grass and legume species and fertilization (Friedrich 1947, Lavin and Springfield 1955, Hafenrichter et al. 1968, Orr 1970, Perkins et al. 1971, Tiedemann and Klock 1973, 1976). Erosion studies[1/] indicate that at least 40 percent of the exposed mineral soil on the forest floor needs to be covered by vegetation to effectively control erosion on forest lands (fig. 1). The physical properties of the new volcanic ash near Mount St. Helens may make it more susceptible to erosion than the forest soils beneath the new ash. Thus, a 40-percent or greater vegetative cover is expected to be necessary to significantly reduce erosion on forest lands covered with the recent volcanic ash.

Volcanic ash is generally accepted as a good soil medium for the germination and growth of most plant species in the Cascade Range, particularly if soil moisture supplies are adequate. Although volcanic ash may be somewhat deficient in some plant nutrients (Klock et al. 1971, Geist 1977), its physical properties are favorable for seedling establishment. For example, seeding with introduced grass species was very successful on volcanic ash following forest wildfire in the Entiat Valley of eastern Washington (Tiedemann and Klock 1976). Physical and chemical properties of the 1980 Mount St. Helens volcanic ash, which includes fragments of rock or sand (tables 1 and 2), indicate that effective seeding will be much more

[1/] Klock, G. O. Data on file, Forestry Sciences Laboratory, Wenatchee, WA.

difficult on this material than on older volcanic ash. The coarse texture of the material may limit plant growth because of high bulk density and low water retention. Although properties of the ash make its nutrient retention capacity somewhat uncertain, the chemical data indicate that fertilization is essential for the quick redevelopment of both introduced and native species.

In fall 1980, the U.S. Soil Conservation Service requested and was permitted by the land managers to seed and fertilize 21,390 acres of forest land covered with volcanic ash by the Mount St. Helens 1980 eruption to control erosion. The objectives of the study reported here are to:

(1) Evaluate the vegetative cover provided by both the seeded and native vegetation during the June-July 1981 period.

(2) Estimate the quantity of volcanic ash eroded at each location where vegetative cover was evaluated.

Due to accessibility, size, range of conditions available to evaluate, and contract requirements, much of the study was conducted on forest land managed by the Washington Department of Natural Resources (DNR) and the Weyerhaeuser lands northwest of Mount St. Helens. The remainder of the study was on U.S.D.A. Forest Service land in the Clearwater Creek drainage east of the volcano.

The Study Area

Between September 15 and October 20, 1980, two different seeding mixtures and a common fertilizer application were applied by air to 12,153 acres of Washington Department of Natural Resources and Weyerhaeuser clearcut lands. Most of this land is in the Greenwater River valley and extends south to the ridge above the North Fork of the Toutle River in Township 10 N., Range 4 E. One seed mixture was used on lands between 1,800 and 2,800-foot elevation and the second mixture over 2,800 feet. A third seed mixture with the same fertilizer application rate was applied on 8,225 acres in the Clearwater and Bear Creek areas (T. 9 N., R. 6 E.) of the Gifford Pinchot National Forest. Here seeding was generally restricted to clearcut areas with less than 30-percent slopes below 4,000-foot elevation. Details of the seeding mixtures are included in table 3. On all areas seeded with the three mixtures, fertilizer was applied at a rate of 300 lbs/acre as 10-20-20 NPK. Actual application rates were 30 lbs/acre nitrogen, 60 lbs/acre phosphorus, and 60 lbs/acre potassium.

Study Method

To evaluate the vegetative cover provided by introduced and native species during the June 22-July 10, 1981, period, foliar cover of each species was measured on permanent belt transects. Transects were selected to provide vegetation information on a range of representative elevations, aspects, slope classes, and ash depths. On the Department of Natural Resources and Weyerhaeuser lands below 2,800 feet, four lines or series of permanent transects (two on seeded and two on unseeded areas) were established. A "line" consisted of 4 to 12 transects systematically selected from a random start at 100-m intervals along an elevation contour and varied in number, depending on size of the area to be sampled. Distance between transects occasionally varied as our sampling selection criteria excluded roads, former landings, or other severely disturbed areas. The four "lines" below the 2,800-foot elevation included 24 permanent transects. Above 2,800-foot elevation and within the area of highest priority for seeding as defined by the Soil Conservation Service, 18 lines (16 seeded and 2 unseeded) with a total of 116 transects were established. It was quite difficult to find unseeded areas representative of those areas that had been seeded at these elevations. The total of 104 transects within the seeded area represented a sampling density of nearly 1 transect per 117 acres.

In the Clearwater Creek drainage, three lines with 17 transects were established.

All transects extend along the elevation contour generally east or north from a 5-foot fiberglass post. The actual transect dimensions marked by wooden stakes are 2 feet by 44 feet (0.6 m by 13.4 m).

Vegetative cover was measured as a vertical projection of foliar material onto the ground surface within a 1-foot (0.3-m) belt along both sides of a measuring tape stretched between the stakes forming the transect. A 1.0-ft^2 (929-cm^2) frame divided into 0.50-, 0.25-, 0.15-, 0.10-, and 0.05-ft^2 sections (464, 232, 139, 93, and 47 cm^2, respectively) was used to reference cover measurements. The species of vegetation in each vertical projection of foliar material were identified, but each species contribution to total foliar cover was not estimated.

Frequency of an individual species was computed as a ratio of the number of times the species was observed in a vertical foliar projection to the total number of projections (88 X number of transects). Due to the varying stage of development and vigor levels, all ryegrass species were grouped as one type. No statistical tests of the data were performed.

The erosion on each transect was estimated by stretching a "sag" line between the two stakes forming the transect and measuring the distance between the "sag" line and the surface at 0.5-ft intervals. The original surface was estimated from computer graphics output, and the area between the two surfaces was used as an estimate of erosion. Random bulk density measurements were made across the study area.

Erosion measured by the transect method indicates soil or volcanic ash displacement, but not necessarily the quantity of material that will become sediment. Many factors besides vegetation influence whether ash material displaced by erosion becomes sediment in a stream channel.[2/]

Results and Discussion

Study results and interpretations are separated into three categories according to the criteria used for each of the three seeding mixtures (table 4).

Seed mixture 1 was used in the area evaluated in the Clearwater Creek drainage. Although the sample population is quite low (17 transects), the results appear representative of the area seeded on National Forest land east of Mount St. Helens. Our general observation is that our vegetative cover estimate may be slightly higher than an expected average for the entire 8,225 acres seeded with mixture 1. Vegetation cover estimates averaged 10.7 percent. Seeded species were the major component, occurring on 88.3 percent of the observation plots versus 1.6 percent for native species. Observations generally indicate a very high germination of ryegrass; despite limited growth, it dominated plant cover on all transects (table 5). No attempt was made to establish the effects of slope and aspect on seeding and fertilization effectiveness.

Observations generally indicated a very high germination and limited growth of the seeded ryegrass. Soil physical and chemical limitations greatly reduced the effectiveness in establishing an acceptable level of vegetative cover (40-percent) in this area. The typical surface and soil profile is characterized by a surface covering of coarse fragments of pumice or newly formed "dome" fragments on top of 5 to 15 cm of relatively fine volcanic ash. Beneath the fine ash lies 10 to 25 cm of coarse pumice fragments overlying 10 to 30 cm of sands of fragmented wall rock. Generally the seeded vegetation established roots in the fine ash surface material but not in the coarse underlying materials. Therefore, the new vegetation was quite small, often purple in color, showing evidence of moisture, temperature, and nutrient stresses which reduced growth and the maintenance of normal physiological processes. Thus, these plants were not effective for erosion control. These plants could benefit from the addition of more fertilizer. The residence time of fertilizer is uncertain, however; and extreme care would be needed in timing and type of fertilizer materials to successfully fertilize this plant material to stimulate growth and increase erosion control effectiveness.

[2/] Surface erosion, by Warrington, Gordon E., Kerry L. Knapp, Glen O. Klock, George R. Foster, and R. Scott Beasley. In: An approach to water resources evaluation of non-point silvicultural sources (A procedural handbook). U.S. Envir. Protection Agency EPA-600/8-80-012, Chapter IV. 1980.

In the absence of erosion, mechanical disturbance would probably be the most effective cultural treatment to increase vegetative cover in these areas. Where mechanical disturbance might be used, seeding the area to a quick developing species such as cereal ryegrass is suggested for erosion control. Use of this annual species can be coordinated with a conifer regeneration schedule to reduce unnecessary plant competition for soil water and nutrients.

Seed mixture 2 was used on the Washington Department of Natural Resources and Weyerhaeuser lands above 2,800 feet. This area was of most serious concern for erosion control because of steep slopes, increased levels of ash depth, and the harsher growing conditions occurring at higher elevations. On the 12 transects placed on unseeded lands, only about 0.6 percent of the surface area was estimated to be covered by foliar material. Nearly all this cover was provided by fireweed. It should be pointed out it was very difficult to find representative unseeded areas at these elevations since nearly all the critical areas had been seeded. These unseeded transects were all located on areas where the ash was at least 15 cm deep. The erosion was extensive enough on only four transects to expose mineral soil and allow the re-establishment of native species. It was generally observed that ash depths greater than 10 cm tended to suppress all growth of native species, most likely due to the depth and the high soil bulk density which averaged near 1.5 gm/cm^3.

The most extensive evaluation was made on the area seeded with mixture 2. On 96 transects, average foliar vegetative cover was 27.0 percent. Vegetative cover was more than twice as great on north slopes (49.5 percent) as compared with the three remaining aspects (18 to 28 percent). It was interesting to note that about 50 percent of the observations showed evidence of introduced species and 50 percent were native species. It was not unusual for these two types of species to be in different observations or both in the same observation on the same transect. Frequency of observations by species are listed in table 5. As were shown with cover estimates, the frequency values of either native or introduced species were greatest on north slopes with south slopes somewhat higher than east or west.

The 27-percent average vegetative cover in the seed mixture area is quite comparable to the 1st-year, 17- to 32-percent vegetation cover provided by rehabilitation seeding in volcanic ash following wildifire as reported by Tiedemann and Klock (1973).

Although our data are not in a form to make statistical analyses, the interaction between slope class and vegetative cover or frequency is evident. As shown in table 4, vegetation cover obviously increased with increasing slope class. That is, the steeper the slope, the greater the vegetative cover. The interaction is evident in that the north slopes tend to be steeper and show greater evidence of rill erosion than other aspects. In quantifying the erosion loss and graphing the relationship between soil surface conditions and vegetative cover (figs. 3-8), it is quite apparent that a significant portion of the vegetation is growing on the old buried mineral soil exposed by the rill erosion. This relationship can be somewhat masked by vegetation that developed in fall 1980 or spring 1981 in rills and has since trapped sediment, closing the rill. Excavation of the root system often shows that these plants germinated in mineral soil and their lower stems have since been covered by ash. These observations are reinforced by the 0- to 10-percent slope class having the least amount of vegetative cover. It is a unique paradox that the greater disturbance of the ash surface by erosion leads to the best vegetative cover. This is particularly true where the ash exceeds a depth of 5 cm.

In some locations the seeded species did germinate and attempt to grow on the ash surface much as in the Clearwater Creek drainage. Although the coarse pumice fragments were not present in the new surface materials profile, there was, in some locations, an ash layer overlying the sands or ash. Plants germinated in the surface ash but could not support their growth in the underlying sands, apparently because of a change in the ash density. Roots of excavated plants often extended between the finer ash and the coarse ash. A soil density of 1.4 gm/cm^3 might be considered near the upper limits of root extension for most monocotyledons. Thus, grass root extension appears to be restricted in the 1.5 gm/cm^3 of blast sands wall rock or ash covering this area.

Much of the vegetation cover, particularly by the native species, appears to have been stimulated by the application of fertilizer. The dark green color and vigor of the native species rooted in the mineral soil beneath the ash indicate an apparent significant boost in growth by the addition of fertilizer. It appears that due to the physical and chemical properties of the ash, the applied fertilizer was quickly leached and trapped by the underlying mineral soil, thus remaining available to support new vegetative growth.

The area below 2,800-foot elevation was planted with seed mixture 3. In this area the seeding and fertilization were effective in providing vegetative cover. A good opportunity was available to compare seeded versus unseeded areas with equal number of transects. Total plant cover in the unseeded areas averaged 12.6 percent and 73.4 percent in the seeded area. In these areas, seeding and fertilization must be considered effective for future erosion control as the vegetation cover was significantly above the desired 40-percent acceptance level. In fact, the seeding may be too successful. As forest lands, these areas will, or have already been, planted to conifers. Competition for moisture and nutrients could be critical for several years between the seeded species, stimulated natives, and the planted conifers. The 24 permanent transects in this area will provide excellent reference points from which to evaluate this future competition.

One factor that must be kept in mind is that the volcanic sands (ash) in this portion of the study area were less than 10 cm deep and often less than 5 cm. Much of the surface area was disturbed by early rill erosion, exposing a considerable portion of the mineral soil. Thus, the soil conditions for re-establishment of vegetation were much better in this area than those planted with mixtures 1 and 2.

An effort was made to document the extent of rill erosion and quantify the amount of erosion. Soil surface profiles were measured at each transect with a "sag" line. Sample characteristics of these profiles are shown in figures 3-8. We were unsuccessful in quantifying the amount of surface and rill erosion before the time of our measurements. On some profiles the original surface can be defined; however, this was not possible for enough transects to make an effective evaluation of erosion. An evaluation of this type at this time does not lead to any relationship with the present vegetative cover. Most of this vegetation has developed since the period of maximum erosion.

These transect measurements of surface profile will, however, be extremely valuable in evaluating the effectiveness of the present vegetation cover in controlling erosion. Remeasuring the same surface transect profiles in summer 1982 will show the soil loss under the present vegetation management condition. It may also be possible to use this information for refinement of future erosion predictions.

Summary

Vegetative cover on the seeded and fertilized ash-covered timber lands severely affected by the 1980 eruption of Mount St. Helens has been measured on permanent transects that were randomly selected. Vegetative cover measured on these transects is representative of the entire selection of aspects, slopes, and elevations in the study area.

For effective surface erosion control, we have suggested 40-percent total foliar or vegetative cover as the threshold value for determining successful establishment of vegetation after seeding. Vegetative cover greater than 40 percent does not guarantee there will be no future surface erosion, but the probability of significant surface erosion will be reduced. For less than 40-percent cover, the probability of surface erosion is increased but does not always occur as other site factors may be more important in controlling surface erosion.

The success as of July 10, 1981, of the Mount St. Helens erosion control seeding and fertilization project carried out by the USDA Soil Conservation Service was judged on the 40-percent vegetation cover guideline. Success ranged from highly successful to failure depending on the site as well as the physical and chemical characteristics of the recent volcanic ash within the area seeded and fertilized.

The seeding project appears to be very successful in that portion of the project within the Greenwater River valley below 850-meter (2,800-foot) elevation where the land is managed by the Washington Department of Natural Resources and the Weyerhaeuser Company. Total vegetative cover was estimated at 73.4 percent in the treatment area and 12.6 percent in the nearby unseeded area. This area, however, had the greatest opportunity for success because of climate and surface conditions for re-establishment of vegetation. The vigorous erosion control vegetation may be quite competitive with newly planted conifer seedlings for water and nutrients over the next few years.

The project was marginally successful in providing vegetation in the same area of the Greenwater River valley over 850-meter elevation also managed by the Washington Department of Natural Resources and the Weyerhaeuser Company. Total vegetative cover was estimated at 27.0 percent in the seeded area and 0.6 percent in two nearby unseeded areas. Differences between seeded and unseeded lands within this area were difficult to define because of the limited availability of unseeded areas with comparable environments. Those areas used for comparison were at upper elevations with harsher conditions for vegetation establishment and growth. Vegetation cover on steep north slopes was nearly twice that observed on other aspects. Within the treatment area, seeded and native species were observed in nearly equal numbers. Thus, fertilization was most likely a key contributor in establishing vegetation. Although the 40-percent revegetation guideline was not met on all slopes in this area, there appears to be a good balance between providing surface cover and limited competitive vegetation for newly planted conifers.

Seeding on the Gifford Pinchot National Forest lands in the Clearwater River valley east of Mount St. Helens appeared adequate to provide the necessary vegetation. Because of the physical and chemical characteristics of the new volcanic ash, however, growth of the germinated seedlings was inadequate. Thus, this portion of the project must be considered a failure as the vegetative cover is only 11 percent. Although fertilization could be used to stimulate vegetative growth in this area, cost most likely would be prohibitive in all but the most critical areas. Land scarification on a limited basis will probably be the most cost effective treatment to re-establish erosion control vegetation as well as early conifer production in this area.

Of the species planted, ryegrass provided the most effective cover in the 1st year after planting.

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Table 1. Physical properties of the 1980 Mount St. Helens volcanic ash[1/]

Sample region	n	Bulk density	Moisture retention (-bars) 0.1	0.3	15	Avail. water	Particle size
		gm/cm^3		%		cm/cm	mm
0-30 km							
blast fragments	8	1.49	4.5	3.5	2.3	0.03	0.562
tephra	14	1.51	19.9	16.0	4.2	0.23	0.056[2/]
(Mt. Margaret)							
blast fragments	2	1.72	4.4	3.9	2.1	0.04	0.355
tephra	2	1.50	24.1	19.0	3.5	0.31	0.032
30-180 km							
blast fragments	13	1.37	15.3	10.7	4.1	0.15	0.355
tephra	33	1.47	28.8	21.4	4.2	0.36	0.035
180-609 km	20	1.21	38.6	26.9	4.1	0.42	0.022

[1/]Unpublished data by G. O. Klock on file, Forestry Sciences Laboratory, Wenatchee, Washington.

[2/]Data excludes local deposits of "popcorn" pumice in the immediate area east of the volcano.

Table 2. Chemical properties of the 1980 Mount St. Helens volcanic ash[1/]

Sample region	n	N	S	P	CEC	pH
		%	%	ppm	me/100 g	
0-30 km						
blast fragments	10	0.029	0.078	4.86	2.13	8.2
tephra	14	0.018	0.111	4.81	2.86	6.7
(Mt. Margaret)						
blast fragments	2	0.034	0.152	4.09	2.17	7.6
tephra	2	0.030	0.143	4.28	3.52	7.2
30-180 km						
blast fragments	13	0.022	0.044	6.92	2.49	7.2
tephra	33	0.027	0.187	14.31	3.39	6.2
180-609 km	20	0.025	0.032	6.82	1.84	6.7

[1/]Unpublished data by G. O. Klock on file, Forestry Sciences Laboratory, Wenatchee, Washington.

Table 3. Introduced seed mixtures used for erosion control

Mixture 1: (8,225 acres Gifford Pinchot National Forest lands)

Species	Seeding rate
	--lbs/acre--
Perennial ryegrass (*Lolium perenne* L.)	10
Annual ryegrass (*Lolium multiflorum* Lam)	15
Hairy vetch (*Vicia villosa* Roth)	4
Subterranean clover (*Trifolium subterraneum* L.)	4

Mixture 2: (Dept. of Natural Resources and Weyerhaeuser lands above 2,800 feet)

Species	Seeding rate
Perennial ryegrass (*Lolium perenne* L)	5
Annual ryegrass (*Lolium multiflorum* Lam)	15
Creeping red fescue (*Festuca rubra* L.)	10
Timothy (*Phleum pratense* L.)	2
White clover (*Trifolium repens* L.)	2
Birdsfoot trefoil (*Lotus corniculatus* L.)	2

Table 3. (Continued)

Mixture 3: (Dept. of Natural Resources and Weyerhaeuser lands below 2,800 feet)

Perennial ryegrass (*Lolium perenne* L.)	5
Annual ryegrass (*Lolium multiflorum* Lam)	15
Creeping red fescue (*Festuca rubra* L.)	10
Orchardgrass (*Dactylis glomerata* L.)	4
White clover (*Trifolium repens* L.)	2
Birdsfoot trefoil (*Lotus corniculatus* L.)	2

Table 4. Estimated foliar cover and plant species frequency.

	Seed mixture treatment areas				
	1	2		3	
	Seeded	No seed	Seeded	No seed	Seeded
	Percent				
Number of transects	17	12	104	12	12
Estimated total cover	10.7	0.6	27	12.6	73.4
Cover by aspect					
North			49.5 (14)[1]		
East			18.3 (35)		
South			27.8 (12)		
West			27.6 (43)		
Cover by slope class					
0-10 percent			16.0 (10)		
10-30 percent			26.1 (53)		
30-50 percent			26.7 (30)		
> 50 percent			44.9 (11)		

Table 4 (Continued)

Seeded species frequency (total area)	88.3	0.4	50.2	3.3	87.0
By aspect					
North			69.8 (14)		
East			44.4 (35)		
South			64.9 (12)		
West			43.6 (43)		
Native species frequency (total area)	1.6	3.0	50.3	44.0	58.1
By aspect					
North			66.6 (14)		
East			36.5 (35)		
South			72.0 (12)		
West			51.1 (43)		

1/ Numbers in parentheses indicate number of transects in each category.

Table 5. Observed species frequency.

	Treatment areas				
	1	2		3	
	Seeded	No seed	Seeded	No seed	Seeded
	Percent				
Introduced					
Ryegrass[1/]	89.1	T[2/]	49.8	0.5	85.9
Creeping red fescue	0.2	0	12.8	0	3.9
Orchard grass	0	0	1.4	0.2	0.8
White clover	0	0	2.4	0	21.2
Birdsfoot trefoil	0	0	T	0	0.5
Hairy vetch	T	0	T	0	0
Subterranean clover	0	0	0	0	0
Planted conifer				1.9	1.3

Table 5 (Continued)

Native					
Fireweed (Epilobium angustifolium)	T	1.7	35.7	2.3	18.9
Pearly everlasting (Anaphalis margaritacea)	0	0.2	7.4	0.2	9.6
Willow (Salix spp.)	0	0	0.4	0.2	T
Trillium (Trillium ovatum)	0	0	1.4	0.1	T
Canadian thistle (Cirsium arvensis)	0	0	8.5	4.7	32.4
Blackberry (Rubus vitifolius)	0.3	0	2.9	6.6	13.3
Thimbleberry (Rubus parviflorus)	0	0	0.3	0.1	4.5
Swordfern (Polystichum munitum)	0	0	0.2	3.2	6.3
Bracken fern (Pteridium aquilinum pubescens)	0.6	0	0.8	0	4.2
Tansy (Tanacetum spp.)	0	0	1.2	11.7	5.0
Elderberry (Sambucus spp.)	0	0	0.2	0	1.8
Wood-sorrel (Oxalis spp.)	0	0	2.2	0	0.6
Oregon grape (Berberis spp.)	T	0.8	5.6	8.0	2.4
Dandelion (Taraxacum spp.)	0	0	1.8	1.8	1.9
Other	0	0	6.6	5.2	4.0

[1] All ryegrass species were grouped together.

[2] T-Trace

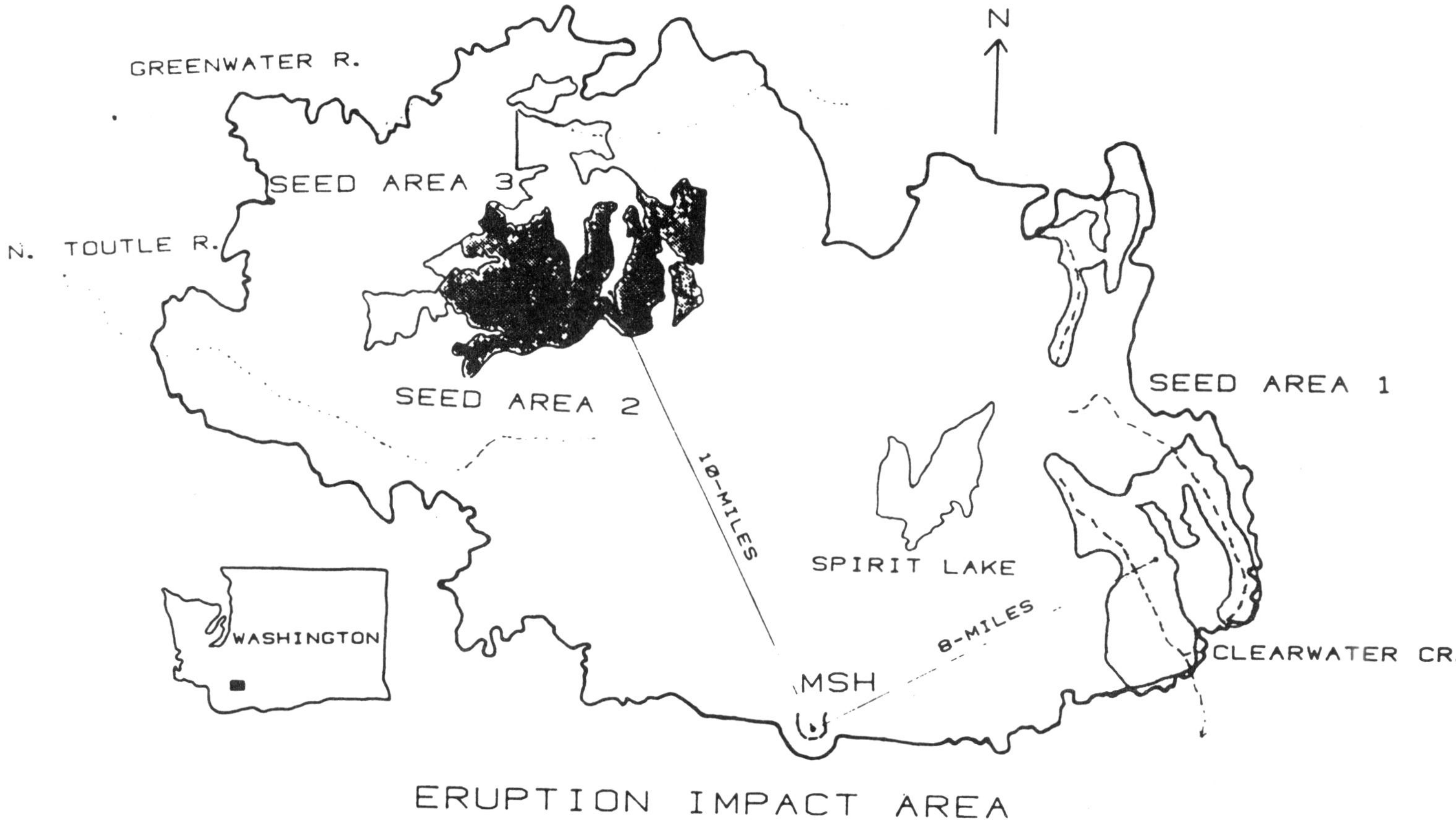

Figure 1. Location of the three areas seeded with different specie mixtures in the Mount St. Helens eruption impact area.

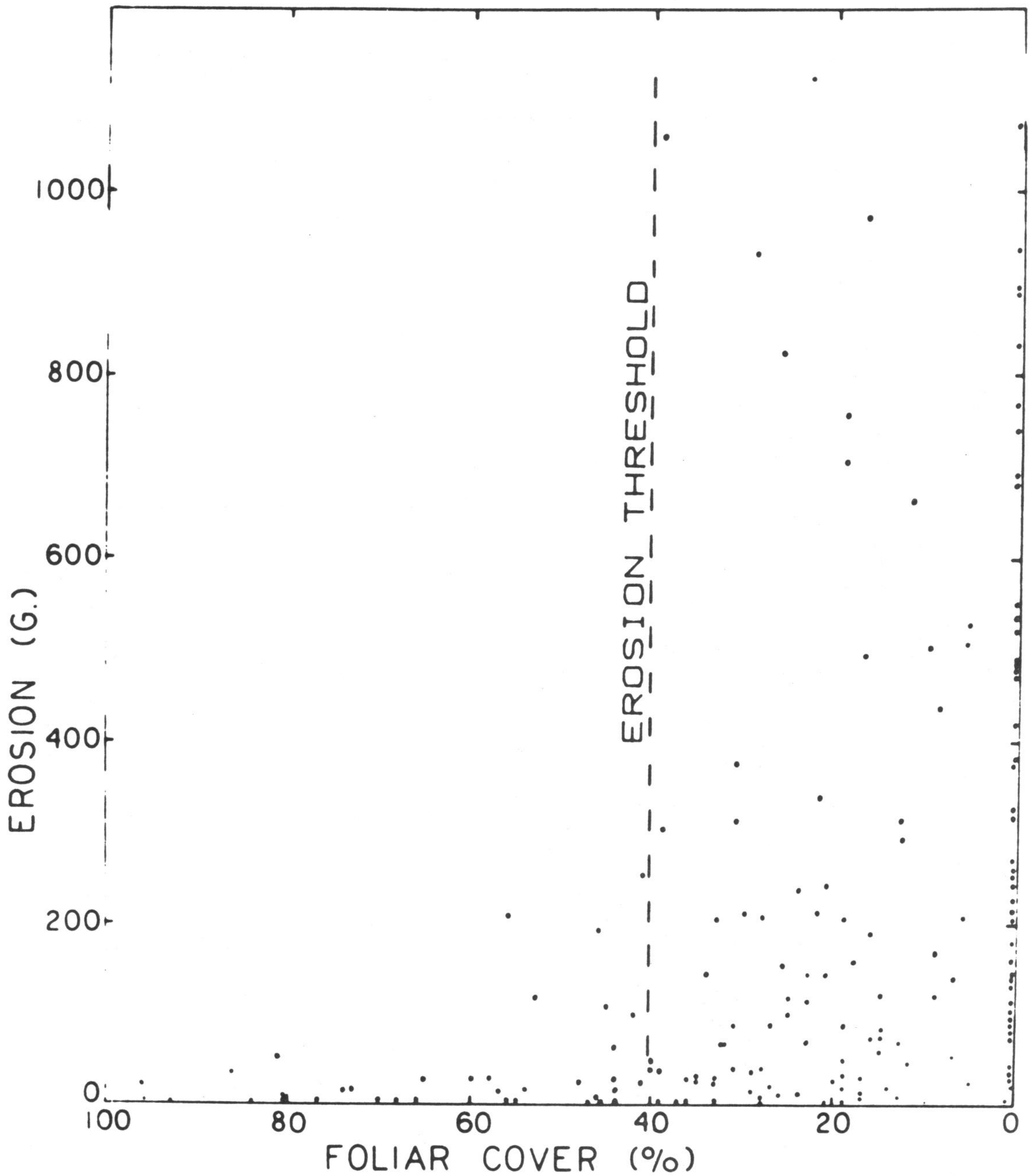

Figure 2. Field test plot data determined with simulated rainfall showing relationship between vegetation (foliar) cover and surface erosion. Note the 40-percent estimated threshold value.

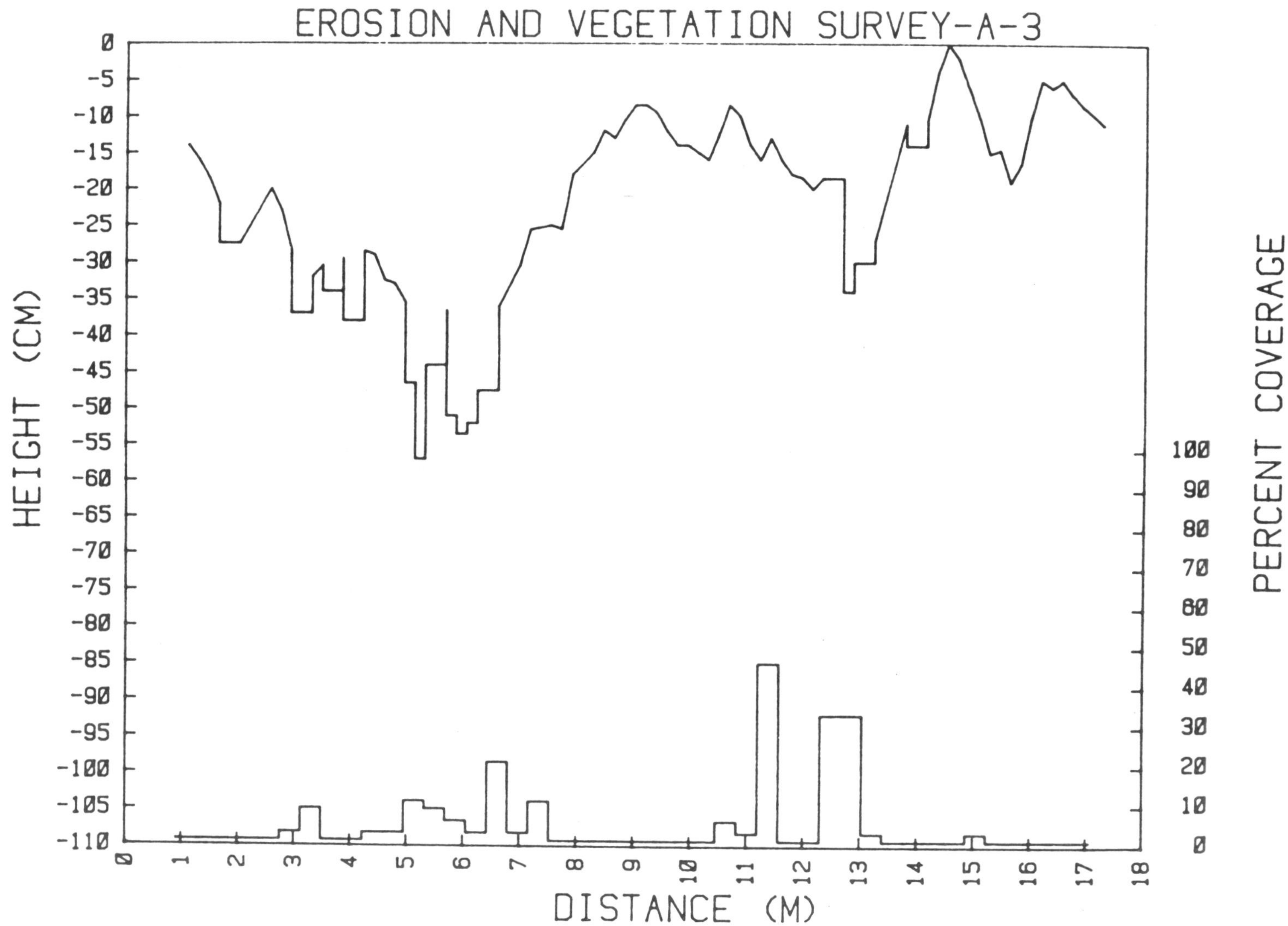

Figure 3. Soil surface profile and vegetation foliar cover (average 4.3 percent) for transece A-3 on an unseeded, 43-percetn sout slope at the 565 meter (1850) elevation.

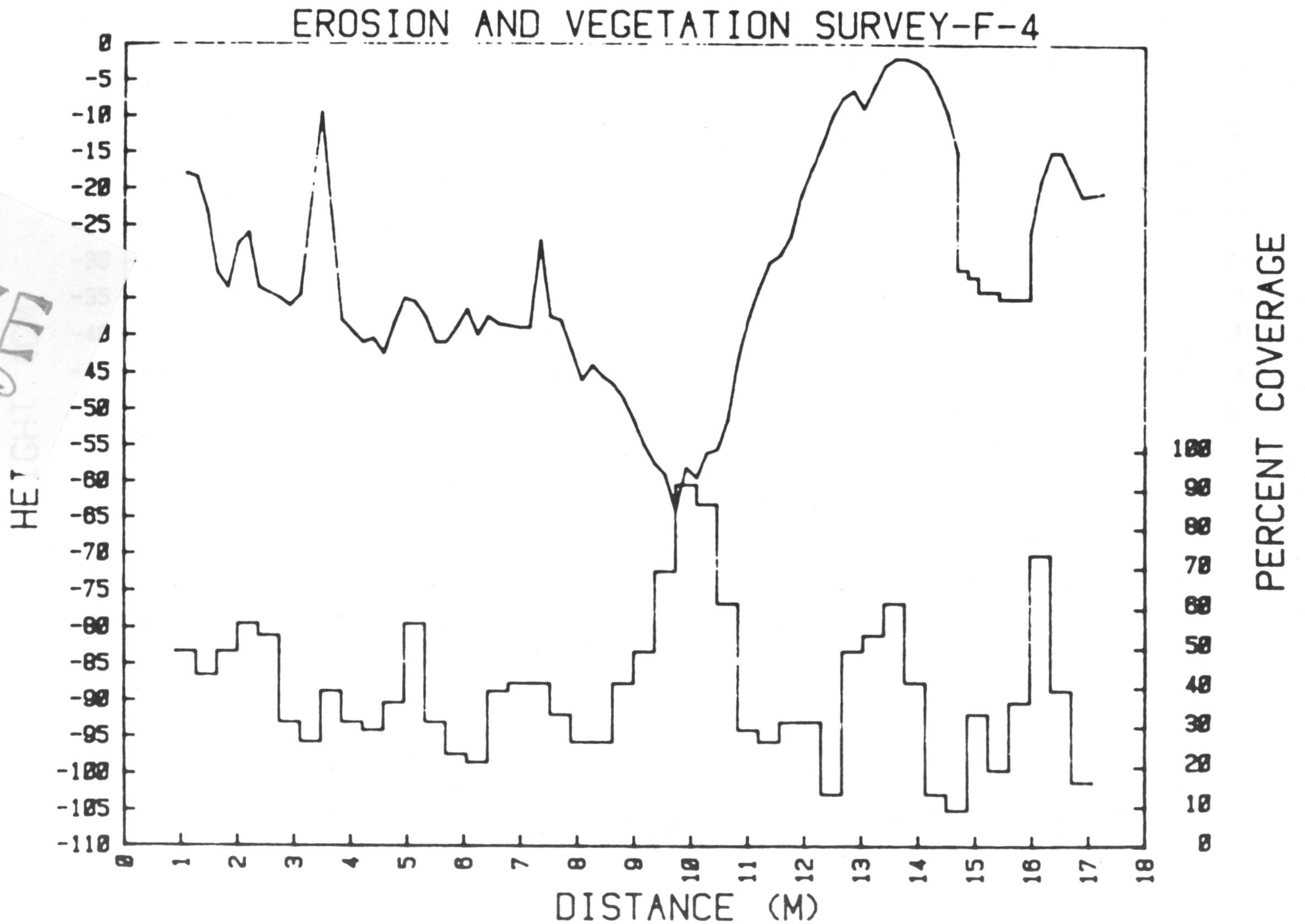

Figure 4. Soil surface profile and vegetation foliar cover (average 39.0 percent) for transect F-4 on a 26-percent east slope at the 870 meter (2850-foot) elevation seeded with mixture 2.

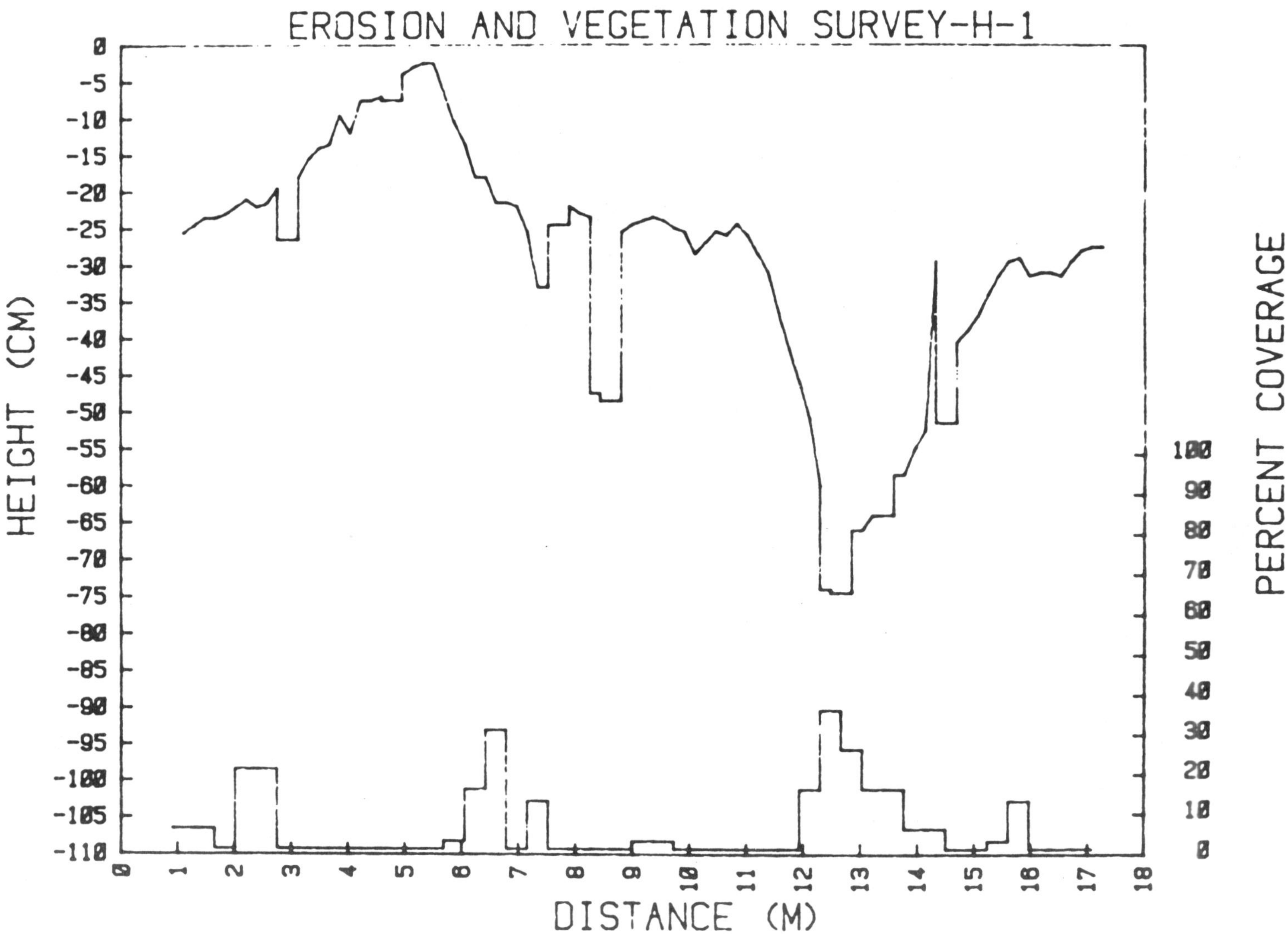

Figure 5. Soil surface profile and vegetation foliar cover (average 6.9 percent) for transect H-1 on a 20-percent east slope at the 1006-meter (3300-foot) elevation seeded with mixture 2.

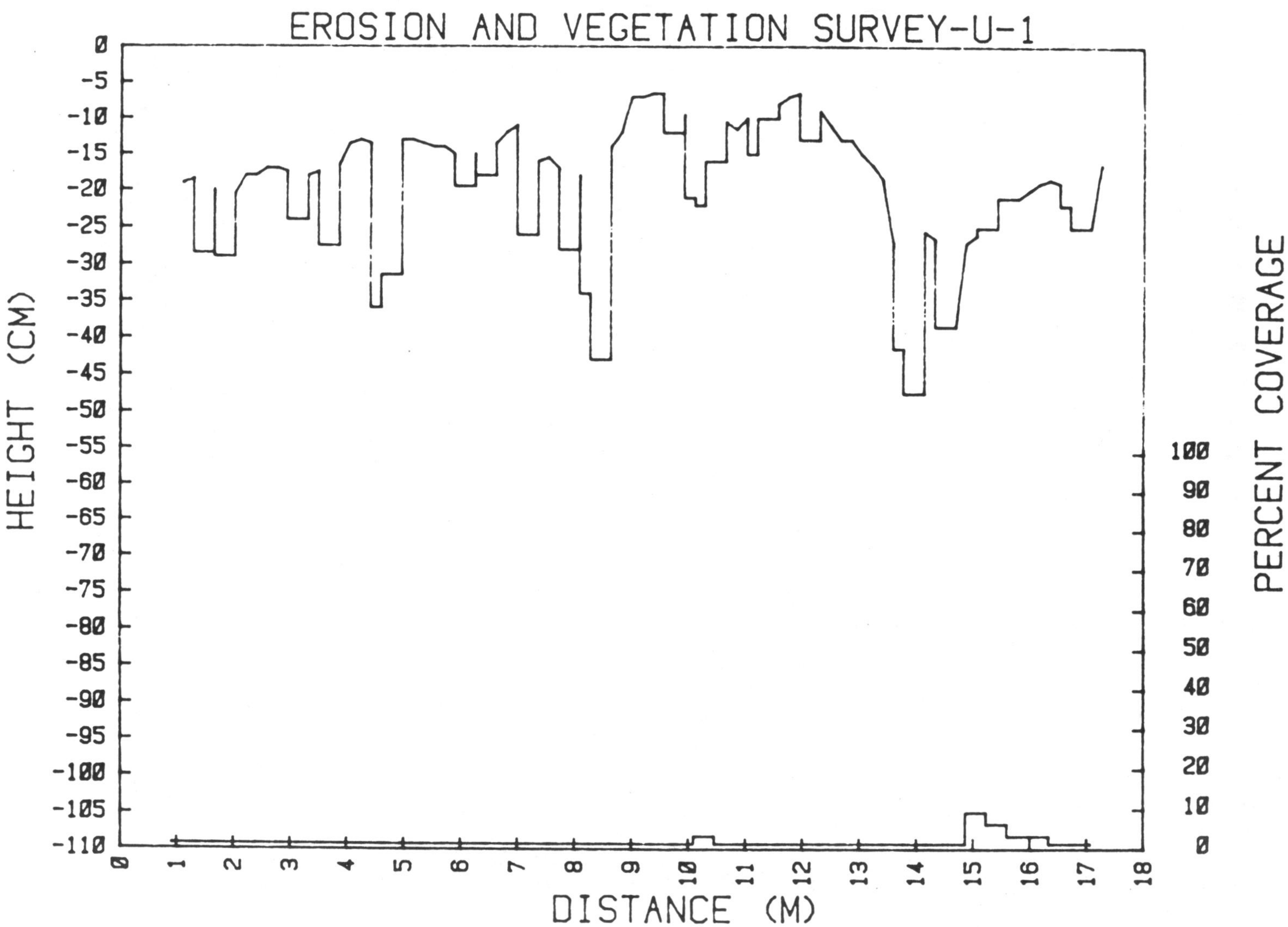

Figure 6. Soil surface profile and vegetation foliar cover (average 1.6 percent) for transect U-1 on an unseeded, 52-percent south slope at the 1160-meter (3800-foot) elevation.

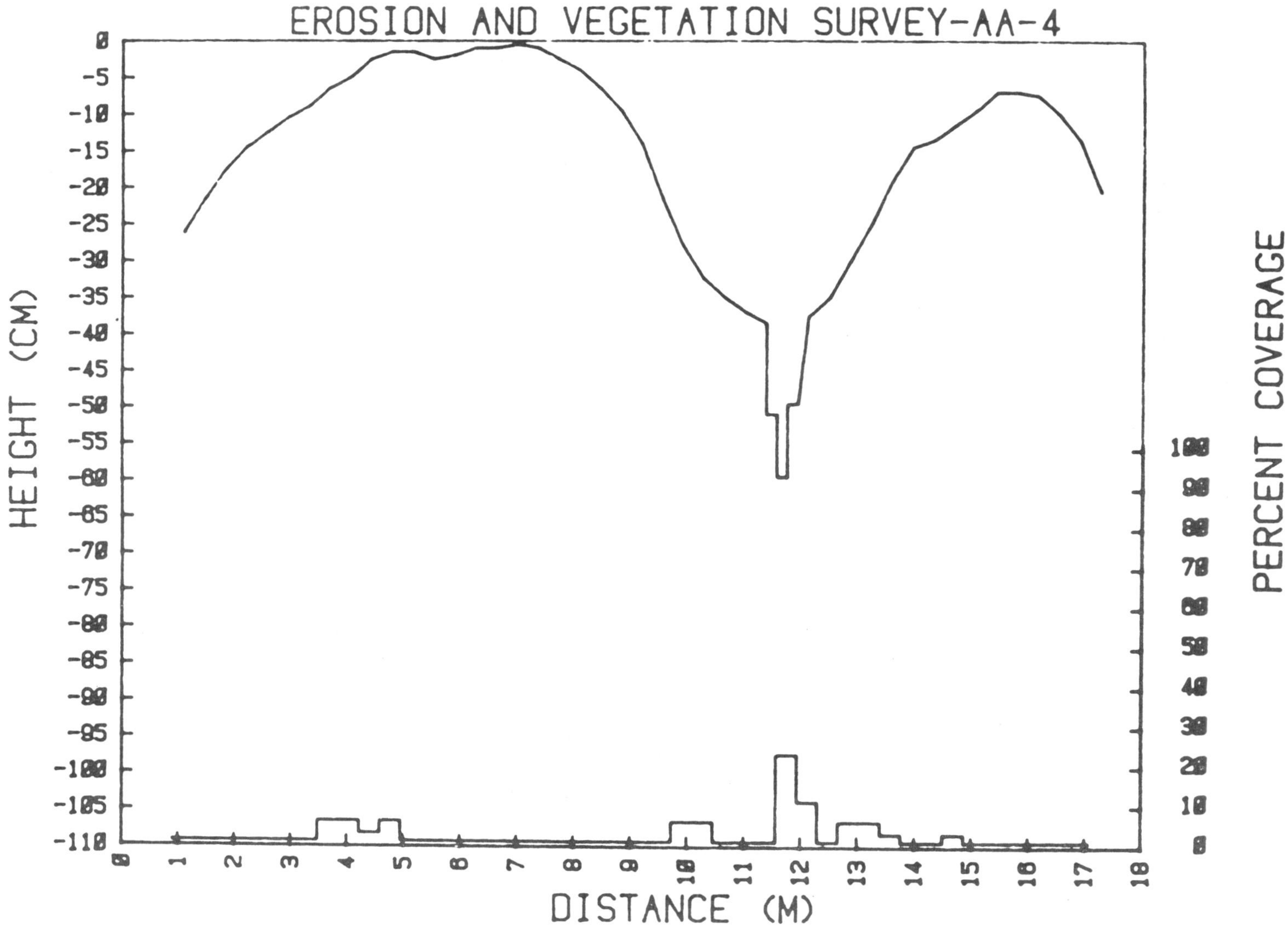

Figure 7. Soil surface profile and vegetation foliar cover (average 3.8 percent) for transect AA-4 on a 28-percent southwest slope at the 808-meter (2650-foot) elevation seeded with mixture 1.

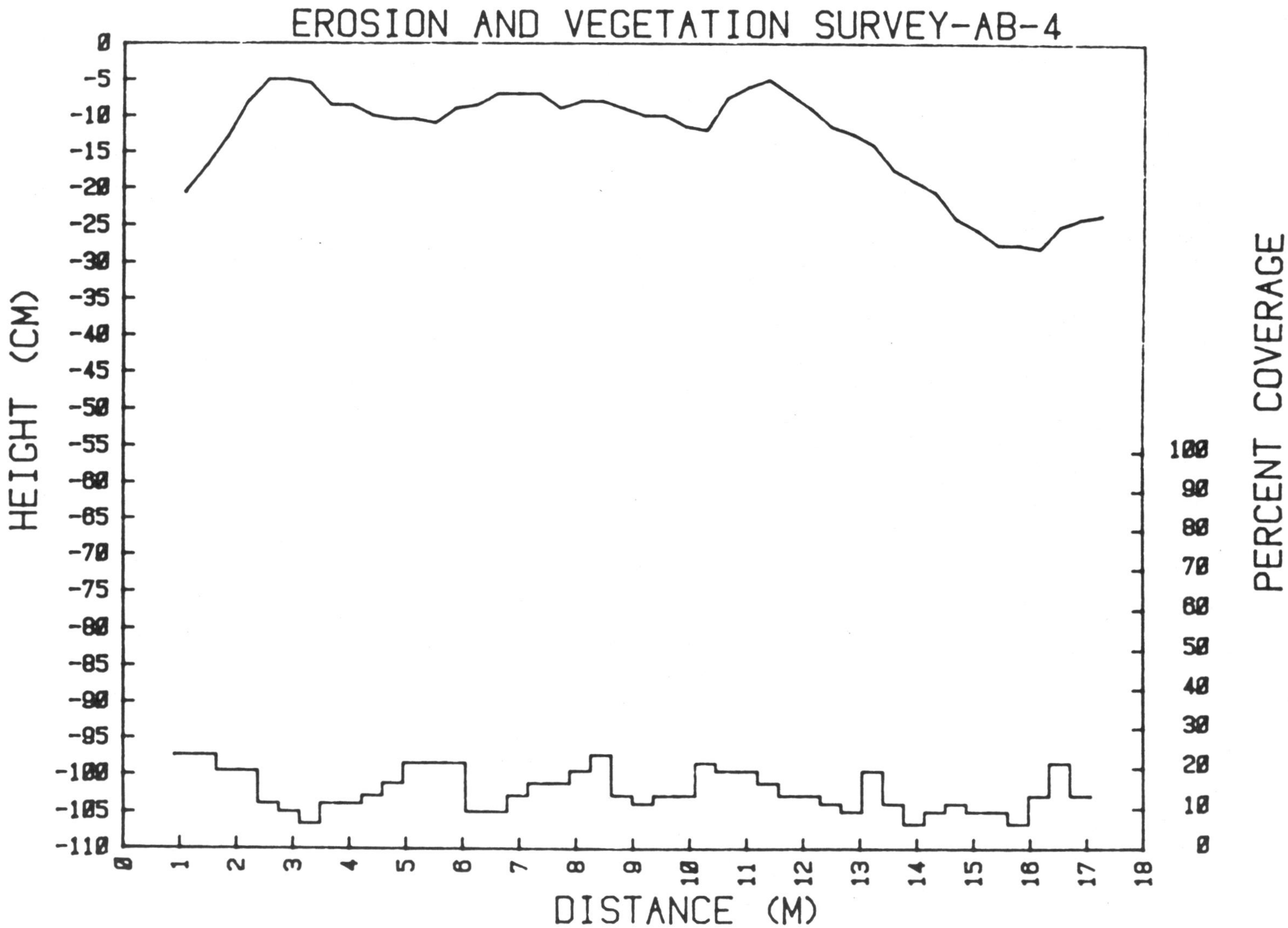

Figure 8. Soil surface profile and vegetation foliar cover (average 13-percent) for transect AB-4 on an 8-percent southwest slope at the 790-meter (2600-foot) elevation seeded with mixture 1.