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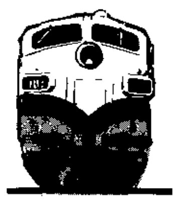
NATIONAL TRANSPORTATION SAFETY BOARD



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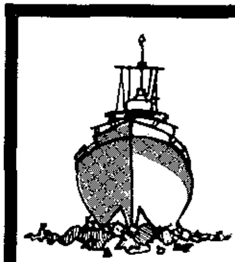
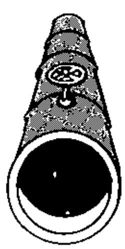


RAILROAD ACCIDENT REPORT

DERAILMENT OF AMTRAK TRAIN NO. 820 (THE CRESCENT) ON SOUTHERN RAILWAY SYSTEM TRACK ROCKFISH, VIRGINIA APRIL 3, 1983



NTSB/RAR-83/10

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/RAR-83/10	2. Government Accession No. PB83-916310	3. Recipient's Catalog No.
4. Title and Subtitle Railroad Accident Report— Derailment of Amtrak Train No. 820 (The Crescent), on Southern Railway System Track, Rockfish, Virginia, April 3, 1983		5. Report Date December 12, 1983
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No
9 Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594		10. Work Unit No. 3841
		11. Contract or Grant No.
12 Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		13. Type of Report and Period Covered Railroad Accident Report April 3, 1983
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract About 5:55 a.m. on April 3, 1983, Amtrak passenger train No. 820 (The Crescent), en route from New Orleans, Louisiana, to Washington, D.C., with 331 passengers and 18 crewmembers aboard, derailed when it struck a landslide near Rockfish, Virginia, about 23 miles south of Charlottesville, Virginia. Heavy rains in the area preceded the landslide. The track had been inspected 6 hours before the accident. The train was moving about 48 mph at the time of the accident. There was no train order in effect for reduced speed in the area of the derailment. Twenty-four persons were injured, and damage was estimated to be $232,000.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Southern Railway System to issue a train order to require the engineer of Amtrak passenger train No. 820, operating in an area known to have landslides, to operate the train at a speed from which he could stop in time if he saw a slide. Contributing to the accident was the failure of the Southern Railway System in the prevailing circumstances to have had the track patrolled nearer to the time the passenger train was to pass or to have slide detection devices.

17. Key Words landslide; slide detector; right-of-way maintenance		18. Distribution Statement This document is available to the public through the National Technical Information Service Springfield, Virginia 22161	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 32	22. Price

NTSB Form 1765.2 (Rev. 9/74)

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

Adopted: December 12, 1983

DERAILMENT OF AMTRAK TRAIN NO. 820 (THE CRESCENT) ON SOUTHERN RAILWAY SYSTEM TRACK ROCKFISH, VIRGINIA APRIL 3, 1983

SYNOPSIS

About 5:55 a.m. on April 3, 1983, Amtrak passenger train No. 820 (The Crescent), en route from New Orleans, Louisiana, to Washington, D.C., with 331 passengers and 18 crewmembers aboard, derailed when it struck a landslide near Rockfish, Virginia, about 23 miles south of Charlottesville, Virginia. Heavy rains in the area preceded the landslide. The track had been inspected 6 hours before the accident. The train was moving about 48 mph at the time of the accident. There was no train order in effect for reduced speed in the area of the derailment. Twenty-four persons were injured, and damage was estimated to be $232,000.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Southern Railway System to issue a train order to require the engineer of Amtrak passenger train No. 820, operating in an area known to have landslides, to operate the train at a speed from which he could stop in time if he saw a slide. Contributing to the accident was the failure of the Southern Railway System in the prevailing circumstances to have had the track patrolled nearer to the time the passenger train was to pass or to have slide detection devices.

INVESTIGATION

The Accident

On April 2, 1983, at 6:30 p.m., e.s t., 1/ National Railroad Passenger Corporation (Amtrak) southbound passenger train No. 819 (The Crescent) departed Washington, D.C., for New Orleans, Louisiana. The operating traincrew were employees of the Southern Railway System (SR), and the train was traveling on SR tracks. Before departing, the engineer and conductor received train order No. 587 that stated, "account heavy rain over division, run carefully, looking out for slides and washouts." As the train traveled south, there were heavy rain and rainstorms.

At Charlottesville, Virginia, the engineer received written train order No. 591 that restricted train No. 819 to a speed of 25 mph between milepost (MP) 152 and MP 153. 2/A small landslide had occurred at MP 152.4, but no debris covered the track. After leaving Charlottesville (MP 112.2), the engineer received by radio from the dispatcher

1/ All times herein are Eastern standard time.
2/ The mileposts are numbered from north to south.

oral instructions from the trainmaster to reduce speed to 25 mph at MP 127.9 and between MP 135 and MP 137. These instructions were based on the trainmaster's own judgment that these areas were susceptible to slides and washouts. The engineer complied with these train orders at these locations, and saw nothing unusual about the track conditions at either location. The engineer heard conversations on the train radio that indicated that track patrols were inspecting the trackage. The engineer again reduced speed to 25 mph at MP 152 in compliance with train order No. 591.

Train No. 819 arrived at Monroe, Virginia, at 10:10 p.m., and the SR crewmembers went off duty, slept in an SR dormitory at Monroe, and returned to duty at 4:50 a.m. They departed Monroe on northbound Amtrak passenger train No. 820 (The Crescent), en route from New Orleans to Washington with 331 passengers aboard, at 5:20 a.m. Leaving Monroe, the engineer received the same two written train orders he had received the day before--train order No. 591 that required him to reduce speed to 25 mph between MP 152 and MP 153 and train order No. 587 that stated, "account heavy rain over division, run carefully, looking out for slides and washouts." The engineer complied with train order No. 591 and then operated the train in accordance with timetable instructions and authorized speed, which was 79 mph. He did not receive any oral instructions by radio, as he had on April 2, concerning speed reductions at MP 127.9 and between MP 135 and MP 137.

The rain that the crewmembers had encountered the evening before had stopped, and daylight was just breaking as the train approached the Rockfish, Virginia, area, about 23 miles south of Charlottesville. As the train entered a left-hand curve at 48 mph, 2 mph below the 50-mph authorized speed for the curve, at MP 135.2, the locomotive headlight illuminated the east slope of a cut section through which the track was laid. The engineer saw "a shadow" on the track about 200 feet in front of the train and immediately applied the train brakes in emergency. At the same time, he realized that the "shadow" was a large landslide. The fireman simultaneously called an alarm to the engineer. A few seconds later, at 5:55 a.m., before the train brakes could slow the train, the train struck the landslide.

The locomotive lurched to the right and then turned onto its left side. (See figure 1.) Both the engineer and fireman were thrown from their seats and onto the floor of the locomotive cab. The second locomotive unit and the first six cars also derailed. (See figure 2.) The conductor immediately instructed the flagman and baggageman to go through the train and check for injured passengers. The conductor left the train and directed passengers who had detrained to remain at the train until emergency response personnel arrived. The passengers eventually boarded the train's seven rear cars, which had not derailed, and a locomotive sent from Monroe pulled the cars back to Shipman, Virginia. From Shipman, ambulances took some of the 24 injured passengers and crewmembers to a hospital in Charlottesville.

Injuries to Persons

Injuries	Passengers	Amtrak employees	SR operating employees	Total
Fatal	0	0	0	0
Nonfatal	15	9	0	24
None	316	4	5	325
Total	331	13	5	349

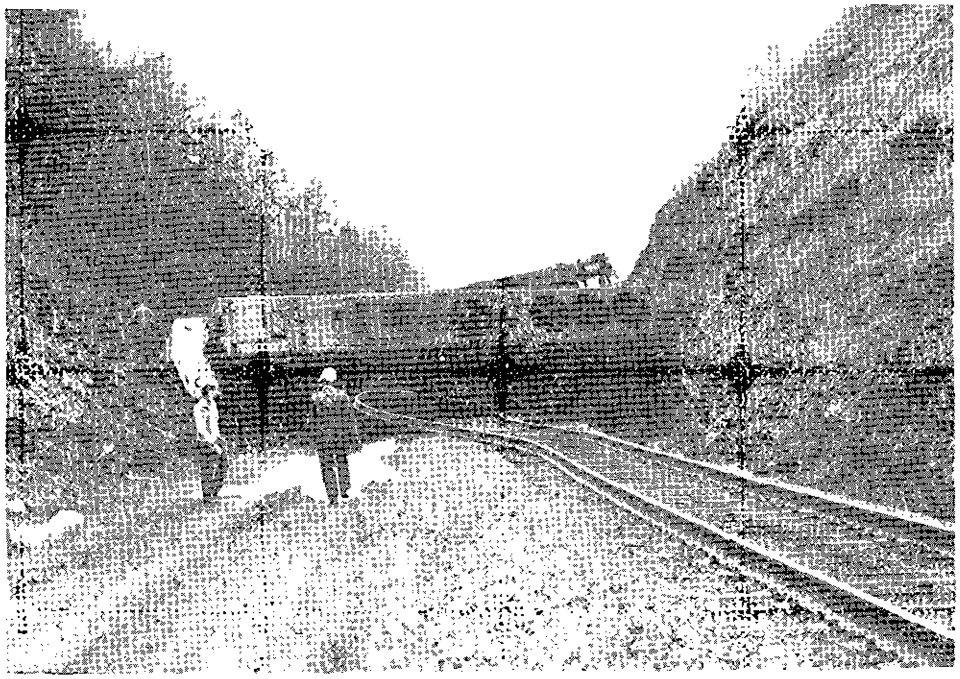


Figure 1.--Lead locomotive unit of train No. 820.

Damage

The trucks were torn from under the first locomotive unit. The unit's fuel tanks and much of the equipment under the floor were damaged extensively. The trucks also were torn from under the second locomotive unit, and the unit's fuel tanks were damaged. The baggage car, the first car behind the locomotive, was damaged moderately. The damage to the derailed passenger cars was minimal.

Damage, including the cost of cleanup, was estimated to be as follows:

Equipment	$222,000
Track	10,000
Total	$232,000

Personnel Information

The SR traincrew included a conductor, engineer, fireman, baggageman, and trainman. Each crewmember was qualified by the SR in its operating rules and timetable instructions. They had received current physical examinations and were approved without restrictions. Each was an SR employee regularly assigned to duty on board The Crescent. There are two Crescent crews who work every other day; their normal schedule is about 4 hours on duty, about 7 hours off duty, about 4 hours on duty, and then about 32 hours off duty before the next assignment.

The SR crewmembers went on duty in Washington at 5:45 p.m. on April 2, 1983, after about 32 hours off duty, for the southbound trip that departed at 6:30 p.m. They arrived in Monroe at 10:10 p.m. and went off duty. They went on duty at 4:30 a.m. for the northbound trip that departed at 5:20 a.m. They had been on duty 1 hour 25 minutes when the accident occurred.

Also on board were 13 Amtrak employees involved in passenger service duties.

Train Information

The SR operated The Crescent for Amtrak as train No. 819 southbound and train No. 820 northbound. Train No. 820 originated in New Orleans at 7:30 a.m. on April 2, 1983, and arrived in Monroe on time at 5:20 a.m. on April 3, 1983. The train consisted of 2 locomotive units, 1 baggage car, and 12 coaches and sleepers. The passenger cars were equipped with emergency window exits.

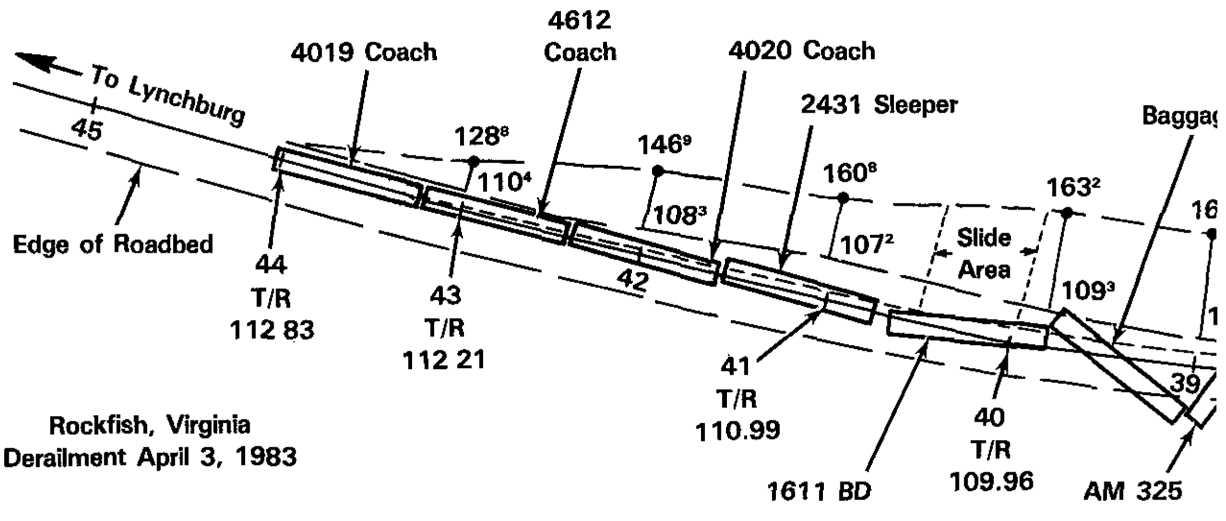
The locomotive units were General Motors model F40PH. The lead unit was equipped with 26L-type brake equipment, a speed indicator, a speed recorder, a radio with SR frequency, twin sealed-beam headlights, alerting light system, and an alerter. Neither locomotive unit had an event recorder.

Track Information

At 7:32 p.m. on April 2, on instructions from the trainmaster, who was located in Lovingston, Virginia, 10 miles south of Rockfish, an SR track supervisor began inspecting the SR track for slides and washouts that might have occurred because of the heavy rains. The track supervisor began the southward inspection in Charlottesville at MP 112.2 and found large rocks on the No. 1 track at MP 116. Track No. 1 was taken out of service at this location. The track supervisor was at MP 132 through MP 143 between 11:31 p.m. and 12:03 a.m. (April 3) and passed through the area of MP 135 and MP 136 without taking exception to the track conditions at that time. The track supervisor stopped his inspection at MP 161 about 1:10 a.m. and returned to Charlottesville by highway. No other trains traveled over the track after the inspection and before train No. 820 went through the area.

The track at the accident site was laid in a cut made in 1860 along the 500-foot contour line (above sea level) south of a railroad bridge over the Rockfish River. The right-of-way was 50 feet wide on each side of the track. The west slope, where the landslide occurred, had not been disturbed since its construction, according to SR records. The east slope was disturbed in 1919 when the roadbed was widened to accommodate another track. In 1960, when centralized traffic control (CTC) was installed, the northbound (east) track was retired, and only a single track was left between MP 132.0 and MP 143.4. The abandoned track was removed later.

The west slope of the cut rises from zero feet near the end of the railroad bridge near MP 135 to 56 feet (measured from the top of the rail) over a distance of 200 feet. (See figure 3.) The highest point of the slope is 61 feet. In the slide area, the slope rose about 55 feet with a 1 1/2 to 1 slope at the north end of the slide area. About 10 feet of the slope was displaced in the landslide. The amount of earth movement was estimated to be about 150 to 200 tons, or 100 cubic yards. (See figure 4.) The earth covered the west rail to a depth of about 6 feet and covered the east rail to a depth of about 2 feet.



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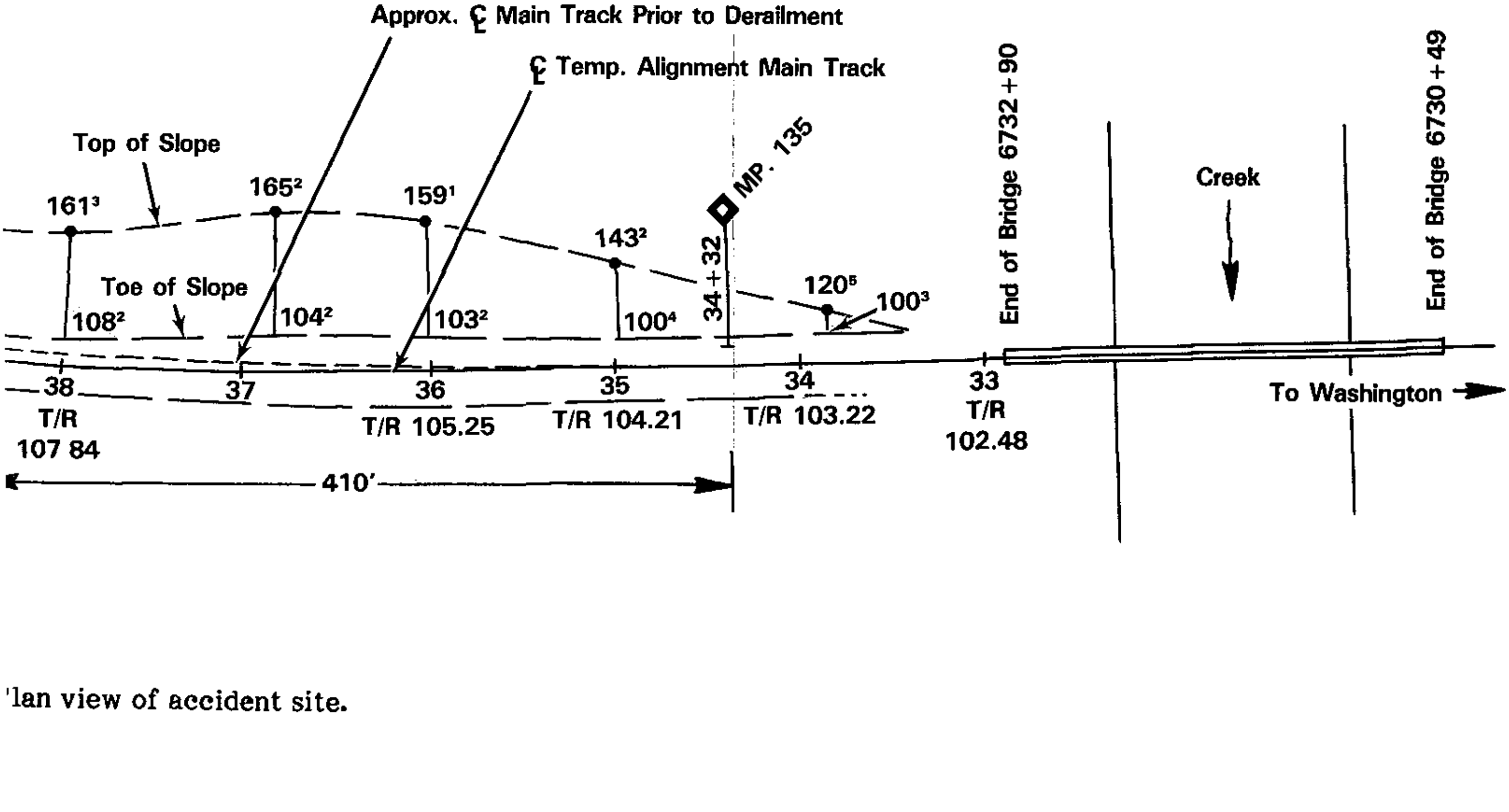

'lan view of accident site.

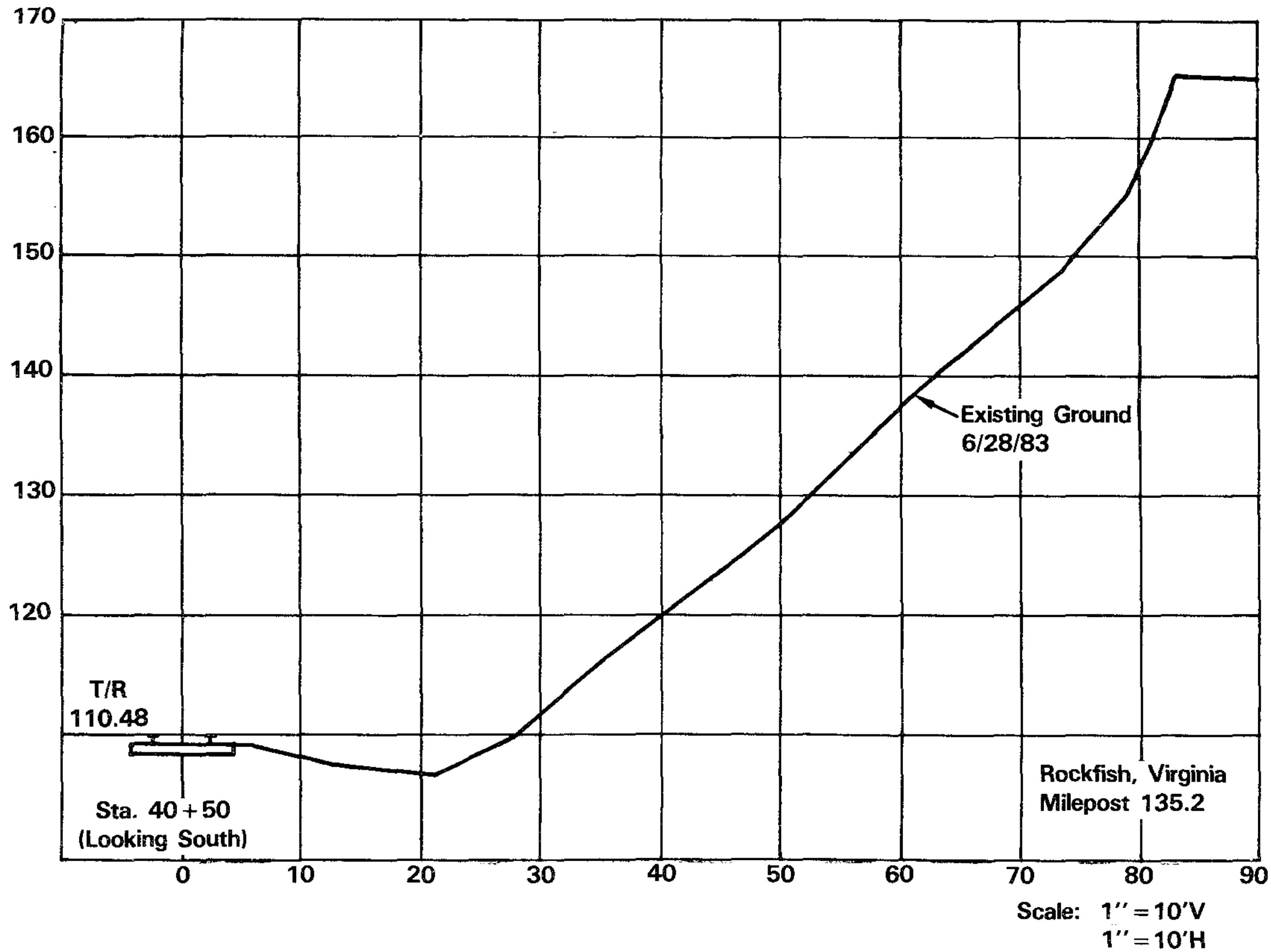

Figure 3.--Height of slope.

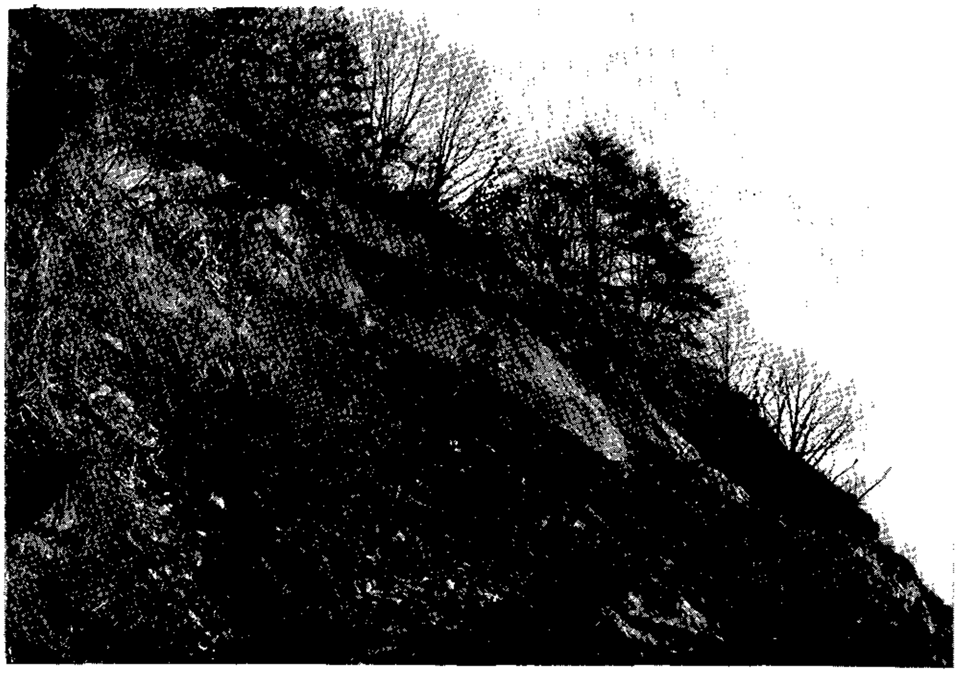

Figure 4.--Slide at accident site.

The surface structure at the slope and adjacent to the slide area consisted of sandy soil and rock outcroppings of bedrock and saprolite. The soil was classified as 50 percent sandy loam and 50 percent silt loam, based upon the classification system used by the U.S. Department of Agriculture. The grain size distribution was found to be 0.2 percent gravel, 50.4 percent sand, and 49.4 percent fines. (See figure 5.) Natural moisture content was equal to 18.0 percent. The slope generally rose about 1 foot for every foot of horizontal depth--about 59 feet in 60 feet of horizontal depth. Near the top of the scarp, the slope increased to about a 2-foot rise in 1 foot of depth for a distance of about 10 feet.

The vegetation had been burned and cut from the west slope by the SR. (See figure 6.) Tree stumps about 8 inches in diameter were in the slide debris. Similar stumps were also on the west slope at other stable areas. The east slope had vegetation. (See figure 7.)

After the accident, the SR relocated the track eastward, away from the slide slope, at the old location of the northbound track. The west slope was smoothed to conform to the new contour. The SR planted vegetation on critical slope areas. Long-term corrective measures under consideration include the reduction of the slope gradient from its present steep configuration. Acquisition of right-of-way is anticipated, permitting the reduction of the slope to bring the area into conformance with current industry design standards of 2 to 1 slope.

There were no slide detection devices—fence-like barriers erected near the track and connected to the signal system which actuate a stop signal if displaced—in the accident area. Train No. 820 passed a signal about 1/2 mile before the accident site.

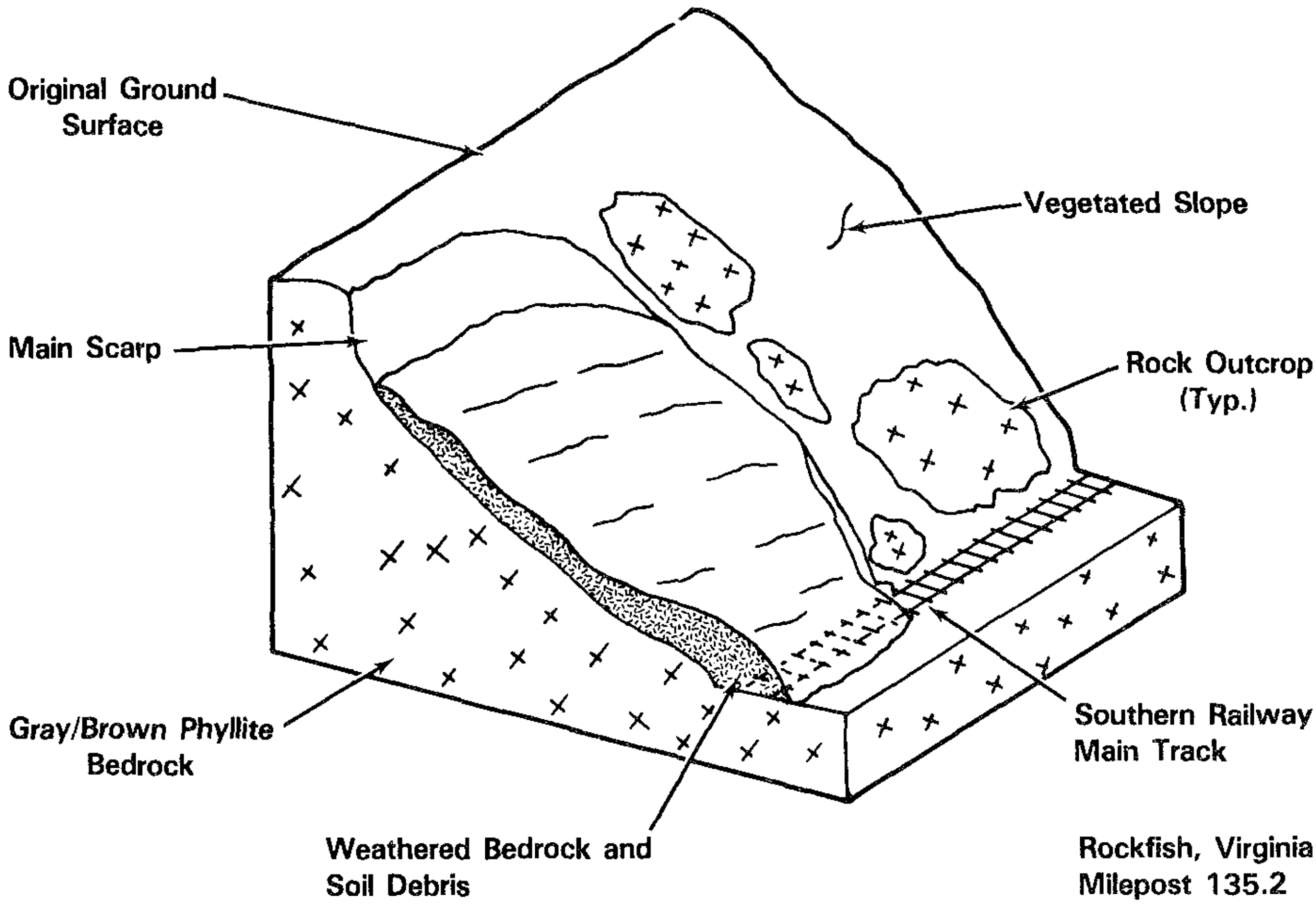

Figure 5.--Structure of slope.

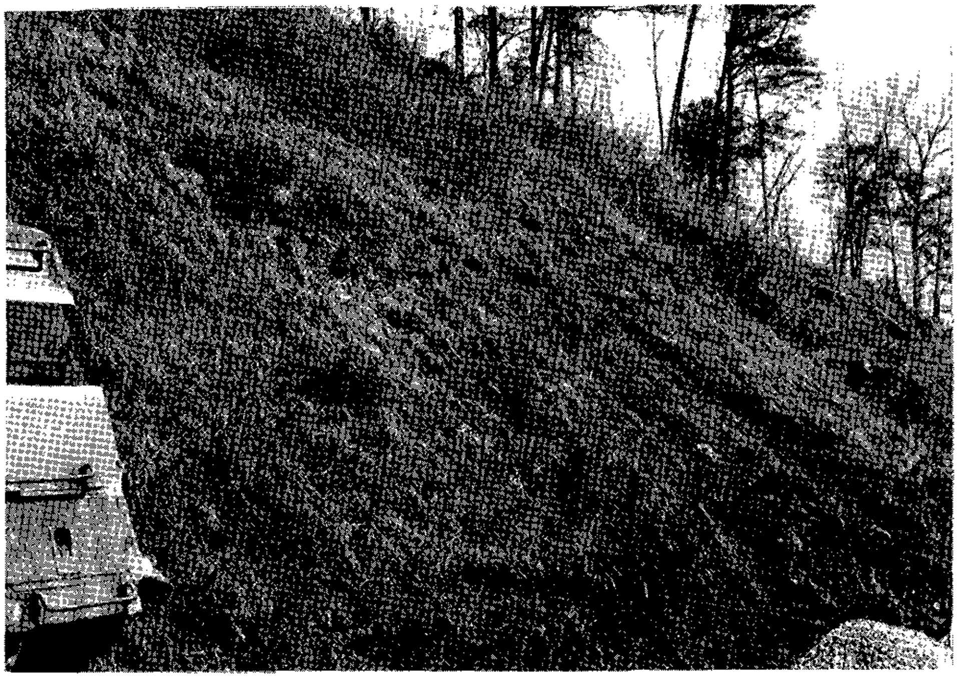

Figure 6.—West slope.

Figure 7.—East slope.

Method of Operation

The daily scheduled train operations along the track where the accident occurred are two passenger trains and nine freight trains southbound and two passenger trains and nine freight trains northbound.

Trains in the area of this derailment are controlled by signal indications of automatic wayside signals of a centralized traffic control system (CTC), by a timetable, and by train orders. Train crewmembers are directed in their duties by radio-transmitted instructions from the dispatcher in Greensboro, North Carolina.

When the crewmembers of train No. 820 went on duty at Monroe, the engineer and conductor received train order No. 587, dated April 2, 1983, and addressed to conductors and engineers of northbound trains that stated, "account heavy rain over division, run carefully, looking out for slides and washouts." The engineer and conductor told Safety Board investigators that they interpreted the train order as placing no restrictions on train speed.

SR operating rule 1013 states, "Engineers must take necessary precautions for safe movement during or after heavy rain or storms." The SR's procedures for issuing train orders do not prescribe conditions under which weather-related train orders should be issued. Track inspections and patrols are ordered when the division superintendent, trainmaster, or dispatcher considers them to be necessary, based on their judgment of the effect that weather or other conditions might have on the track.

Meteorological Information

At 5:48 a.m., on April 3, 1983, the weather at Charlottesville, about 23 miles northeast of Rockfish, was reported to be skies partly cloudy, visibility 7 miles, temperature 49° F, and the winds southerly at 6 knots.

Rain was observed at Rockfish on April 2, 1983, from 1 p.m. to 9:30 p.m. No precipitation was observed from 9:30 p.m. on April 2 to 6 a.m. on April 3. From 7 a.m. on April 2, to 7 a.m. on April 3, 2.21 inches of rain were recorded by the cooperative observer 3/ at Rockfish. For the 7-day period from 7 a.m. on March 27 to 7 a.m. on April 3, 3.56 inches of rain were recorded. For the 30-day period from 7 a.m. on March 4 to 7 a.m. on April 3, 7.75 inches of rain were recorded. The normal precipitation for Rockfish in March is 4.24 inches; in March 1983, total precipitation measured 5.52 inches. The normal precipitation for April is 4.24 inches.

The following National Weather Service Forecasts were made:

> Zone Forecasts for Virginia National Weather Service Washington
> 4:30 p.m. est Sat. April 2, 1983
>
> Tonight--Rain heavy at times possible thunderstorms.
>
> Sunday--Variable cloudiness with showers likely.
>
> Zone Forecasts for Virginia National Weather Service Washington
> 9:30 p.m. est Sat. April 2, 1983

3/ The observer receives equipment, training, and supervision from the National Weather Service.

Tonight--Rain heavy at times with a few thunderstorms possibly accompanied by strong gusty winds.

Sunday--Variable cloudiness with showers likely especially during the afternoon.

The following special weather statements were issued by the National Weather Service at 8:10 p.m. and 10 p.m. on April 2:

Special Weather Statement
National Weather Service, Richmond, Va.
8:10 p.m est Sat. April 2, 1983

At 8 p.m. weather radar indicated a line of heavy showers and thunderstorms moving into central Virginia from the mountains. The line reached south from Northern Virginia through Charlottesville to Lynchburg to Danville and into North Carolina. The line was moving northeast at around 40 mph and will cross through central Virginia within the next two hours.

Some of the thunderstorms will be associated with heavy downpours--gusty winds—dangerous lightning and possibly some small hail. Rainfall reports in excess of two inches were reported in the mountain areas from these storms earlier this evening with some minor lowland and street flooding occurring in the Waynesboro area.

Special Weather Statement---correction
National Weather Service, Richmond, Va.
10 p.m. est Sat. April 2, 1983.

At 9:45 p.m. weather radar indicated an area of heavy showers and thunderstorms continuing to move through central Virginia. The area was from Northern Virginia southward through the counties of Albemarle--Buckingham--Prince Edward and Mecklenberg.

Heavy downpours—gusty winds—dangerous lightning and the possibility of small hail will accompany this area as it moves to east-northeast at around 30 mph. There is also the possibility of some urban, street and lowland flooding from the heavier rains.

The trainmaster and dispatcher were aware of bad weather reports.

Medical and Pathological Information

Fifteen passengers and 9 Amtrak employees were injured. The injuries included minor strains, bruises, and contusions. All of the injured persons were treated at the scene, in Shipman, or at a local hospital and released.

No toxicological tests of the crewmembers were made.

Survival Aspects

The derailed passenger cars came to rest at a slight angle. Passengers were able to detrain through the normal exits. None of the emergency window exits was used. The conductor immediately took charge of the emergency situation, and all crewmembers carried out their emergency duties according to their training and instructions.

Because of the inaccessibility of the area, injured passengers were transported on the passenger cars that did not derail to a point where ambulances and emergency medical treatment could be obtained. No significant problems were encountered by rescue personnel. The rescue operation lasted about 3 hours.

Tests and Research

The locomotive speed tape revealed that the train was moving at 48 mph when it derailed.

Other Information

Right-of-Way Maintenance.--Railroads operating in Virginia are required by section 56-426 of the Virginia Code to keep their rights-of-way "clear and free from weeds, grass, and decayed timber, which from their nature and condition are combustible material, liable to take and communicate fire from passing trains to abutting or adjacent property." The SR periodically burns all vegetation and any other combustibles along its rights-of-way in Virginia to comply with this law, which dates to 1919. The Virginia Division of Forestry stated that compliance with the law does not require burning and that no vegetation is required to be cut. However, the SR believes that burning is the most economical and practical way to meet the law's requirements.

A review of the maintenance of the west slope at MP 135 indicated that the SR had last cleared the slope in December 1982. However, the entire slope had not been burned, just the area at the top of the slide. While no record of slope movement before this accident was indicated in the railroad's records, it was apparent that movement had occurred before this landslide on both the east and west slopes at MP 135.2 because of the manner in which the trees on the slopes tilted.

The Virginia Division of Forestry stated that train operations cause 9 to 15 percent of all forest fires. The Division provided the following table:

Railroad-Caused Forest Fires in Virginia

Year	Number of fires	Acres burned
1977	187	752
1978	192	1,322
1979	145	533
1980	116	294
1981	140	562
1982	103	241

The Virginia Division of Forestry believes that the right-of-way clearing law is necessary to reduce the risk of fire and is environmentally sound because it protects public and private property adjacent to the railroads from fire damage. The Virginia General Assembly has not supported requests to rescind the law, and the State courts have upheld the law. Other States have similar laws. The Virginia Division of Forestry points out that because of certain local conditions, right-of-way clearance is required only along 50 percent, or 1,500 miles, of the State's railroad rights-of-way.

The American Railway Engineering Association (AREA) has published recommended practices for the construction and maintenance of slopes along railroad rights-of-way. 4/ (See appendix B.) These practices provide information on soil considerations, methods for stabilizing slopes, and planning for stabilization. The AREA manual states, "Landslides occur most frequently at times of high groundwater or heavy rainfall. They seldom occur without advance cracking of the ground or other signs." Other literature is available concerning slope stability and the methods of prevention and control of slides. 5/ The SR does not have a stabilization program that incorporates the AREA recommended practices.

The Federal Highway Administration (FHWA) advises that most strategies employed to insure soil stabilization on embankments on the Federal highway system are site-specific; however, the establishment of vegetation is a key ingredient in stabilization strategy. The FHWA does not recommend practices that hinder foliation.

Virginia's Department of Highways and Transportation stated, in regard to its design standards:

> You will note that the only burning we do is controlled burning to get rid of trash that has accumulated by virtue of the reconstruction of the highway. Under no situation do we burn the right of way simply to get rid of combustibles. 6/

Landslide Accident Data.--The Federal Railroad Administration (FRA) receives reports on approximately 100 accidents per year involving weather-related right-of-way encroachments. Most of the accidents reported relate to floods and washouts; it is estimated that only about 10 accidents reported are related to landslides. It is not possible to determine precisely how many reported accidents involve landslides because landslide damage to track is reported to the FRA under the same blanket category as washout, rain, flood, snow, and ice damage.

The Safety Board has some limited data on moisture-related earth slides based on seven accidents investigated since 1967. The SR does not have accident data specifically categorized as slide-related.

Earlier Derailment.--On February 18, 1982, Amtrak passenger train No. 820, The Crescent, struck a rock and mud slide at MP 135.9. The lead locomotive unit and the first car, a mail car, derailed. The second locomotive unit was damaged but did not derail. Damage was estimated to be $71,850. The slope from which this slide originated was similar in terrain and geologic structure to the slope at MP 135.2. The slope also

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4/ American Railway Engineering Association, Manual for Railway Engineering (Fixed Properties), 1982.

5/ For example, Hay, William W., Railroad Engineering, New York: John Wiley & Sons, 1982, pp. 338-347.

6/ Letter dated July 6, 1983, to the Safety Board.

had been cleared and burned at some time. The weather observation station in Rockfish had recorded 3.39 inches of precipitation in the 17 days before the accident, and 0.69 inch of precipitation in the preceding 24 hours. It was not raining at the time of the derailment and had not been raining for several hours.

ANALYSIS

The Accident

The route of The Crescent through central Virginia is through mountainous terrain where the SR track is laid through many cuts. The trainmaster's concern that the heavy rains in the area on April 2 might affect train operations prompted the issuance of train order No. 587 instructing SR crews to "run carefully, looking out for slides and washouts." However, the train order did not restrict train speed, and the engineer of train No. 820 did not interpret the order as requiring reduced speed. The dispatcher issued only one written slow order—for a section of track 17 miles north of the derailment site--which was in effect on April 2 and April 3 for both northbound and southbound trains. However, the trainmaster apparently was concerned enough about two other areas, including the area where the accident occurred, that he had issued the dispatcher oral instructions for southbound train No. 819 on April 2 to reduce speed. These instructions apparently were not to continue in effect on April 3 and were not given to northbound train No. 820, which went through the area about 9 hours later. The trainmaster's concern over the weather also led to special track inspections. However, the derailment area was last inspected about 6 hours before train No. 820 collided with the landslide.

The heavy rains in the derailment area stopped about 9:30 p.m. on April 2. The weather forecasts on April 2 stated that the line of heavy showers and thunderstorms would be moving out of the area. The discontinuance of track inspections in the derailment area and the failure either to continue in effect the oral instruction to reduce speed in the derailment area on April 3 or to issue a written train order apparently were the result of the trainmaster's reduced concern over the effect of the weather on train operations once the rain ceased.

From the beginning, the SR's initial response to the weather situation was not effective. Train order No. 587's instruction to "run carefully" was ambiguous and did not require operating practices that would allow the engineer to perceive an obstruction and avoid a serious accident. Since operating rule 1013 that requires engineers to "take necessary precautions . . . during or after heavy rain . . ." is only a general precautionary rule, it must be supplemented by train orders or special instructions to make the rule meaningful. Under the SR rules, unless he encounters actually hazardous conditions, the engineer is not permitted to reduce timetable speed except by specific train order or special instruction; accordingly, the engineer of train No. 820 was operating the train as authorized at the time of the accident.

Even if the train had been moving at 25 mph, the speed required in the area by the trainmaster's oral instruction on the day before, the accident might not have been prevented because of the limited sight distance at the curve. Because of the curve, the engineer did not see the landslide until the train was within 200 feet of it. In order for the train to have been stopped in that distance, its speed would have to have been no more than 10 mph. The end of the rain, the termination of the special track inspections, and the absence of special track instructions, all of which the engineer had encountered the night before, may have given the engineer of train No. 820 a false assurance that the track ahead was clear for normal operations.

The SR had more than adequate time to conduct a track inspection ahead of train No. 820, which was carrying 331 passengers. The last inspection should have been made closer to the time that train No. 820 would pass through the area to make likely the detection of a slide. The SR management should have been aware that the threat of landslides is not eliminated when heavy rain ceases. Landslides can occur hours or days later as a result of heavy rain, as happened in this case. Moreover, the landslide that occurred nearby in 1982 occurred after a lesser amount of rainfall than in this case and also occurred after the rain had stopped.

The SR should review its procedures concerning train orders related to weather conditions. The SR should specify, in unambiguous terms, conditions under which the train orders will be issued and the specific actions which are to be taken by a train's crewmembers to comply with the train orders. The SR also should review its practices regarding track inspections and patrols to ensure that they are timely and effective in reducing the risk of a train encountering operating hazards.

The Safety Board recognizes that many railroads have general precautionary operating rules similar to SR rule 1013. Rule 1013 will not be effective in adverse weather situations unless it is supplemented by specific instructions or train orders. All railroads should review and supplement as necessary their operating rules and practices to make them more effective in predictable albeit abnormal operating situations.

Landslide Prediction and Detection

Land stabilization along railroad rights-of-way is a universal problem. There are many areas where track was laid decades ago in cuts and other areas that do not meet current construction standards. Some of these areas, especially in mountainous terrain, cannot be modified to eliminate the landslide hazard. Thousands of slides that occur in the United States each year are detected before a train strikes them. Railroads have used many methods, such as slide detection fences and track inspections, to deal with unstable areas. Many railroads operating in the same area and on the same terrain as the SR use slide detection fences. If the track at the accident site had been equipped with a slide detection fence, the landslide would have been detected, and the signal that train No. 820 passed about 1/2 mile before the accident site would have changed to red. Unless the landslide had happened only minutes before train No. 820 approached, a slide detection fence probably would have prevented this accident.

The best methods of reducing the hazard of landslides, however, are methods that both predict and attempt to prevent landslides. The stability of a slope can be determined by the measurement of the displacement of earth or rocks. Stakes driven into the ground in slide areas and instrumentation such as tilt meters (inclinometers) can be used to determine movement. Although SR records show that the slope at MP 135.2 had remained stable since 1860, the leaning of the trees on the slope should have alerted someone to the possibility that some earth movement had occurred before this landslide. A slide causing a derailment had occurred 13 months before at a similar slope 0.7 mile south of the accident site. The Rockfish area had received 7.75 inches of rain in the 30 days preceding the April 3 slide. The trainmaster's oral instruction to southbound train No. 819 showed that he was concerned about the possibility of a slide or washout in the accident area. Consideration of all these circumstances should have caused the SR to be more cautious about train movements in the area on April 3 even though the heavy rains had stopped, and should have prompted the SR to examine closely the slope stability in the area of heavy rain.

The SR should examine periodically its rights-of-way to determine where unstable slopes exist and eliminate the hazards they pose for railroad operations. The AREA has issued recommended practices for the maintenance of earth and rock slopes on railroad rights-of-way. Many of these practices concerning stabilization, protection, and warning methods apparently were not used by the SR at this accident site. The SR should adopt the recommended practices of the AREA, and should undertake planning for a stabilization program promptly.

Currently, it is not possible to determine precisely how many reported railroad accidents involve landslides because landslide damage to track is reported to the FRA under the same blanket category as washout, rain, flood, snow, and ice damage. The SR, like most railroads, does not keep data on the numbers and locations of landslides along its track. Because landslide conditions are more predictable than weather conditions, it might be more revealing and useful if landslide accident data were to be reported in a category separate from other weather-related accident data. The FRA should consider changing its reporting requirements to accomplish this.

Right-of-Way Maintenance

The events that cause or contribute to a landslide are related to geological and meteorological factors. The lack of vegetation on an earth slope generally is considered to be a contributing factor to erosion, which can lead to landslides and other problems which damage the environment. FHWA-recommended practices do not discourage use of vegetation on slopes on highway rights-of-way. The AREA lists the planting of vegetation as one method of stabilizing earth slopes on railroad rights-of-way. On the other hand, it is possible that excessive vegetation on certain types of soil could lead to a landslide. Determination of the precise cause of the slide that caused this accident would require analysis far beyond the needs of the Safety Board to determine the cause of the accident and to recommend remedial measures. However, the Safety Board believes there can be no question but that the clearing of vegetation on the slope at MP 135.2 by burning and the unusually heavy rainfall in the area were factors in this landslide.

The Safety Board recognizes that the SR conducts clearing operations to comply with the State of Virginia's law regarding removal of combustibles from railroad rights-of-way and that the SR believes that such a law is unnecessary. The law dates back to 1919, when it was believed that many forest fires were caused by sparks from coal-fired steam locomotives, brake shoe sparks, and burned off or overheated wheels or journals. Many changes have been made in railroad equipment and operations over the years to reduce the risk of fire. Steam locomotives are no longer in regular rail service, locomotives now have spark arresters, locomotives now use dynamic braking assisted by only light brake applications except in emergencies, and brake shoes have been redesigned to reduce sparks. Communications on the railroad also have been improved, so early detection and reporting of fires along the rights-of-way are possible. Although the data from the Virginia Division of Forestry indicate a continuing prevalence of fires along railroad rights-of-way, the data do not indicate the exact causes of the fires. It is possible that the fires which continue to occur on railroad rights-of-way are caused by railroad operations.

The Virginia Division of Forestry holds a meeting each year attended by representatives of all railroads operating in the State to discuss the State's right-of-way clearing law and the railroads' responsibilities under the law. The Safety Board believes that the SR should continue to raise its concerns regarding the right-of-way clearing law in this forum with a view to prompting a current examination of the situation.

Although the FHWA-recommended practices pertain to highway right-of-way construction and maintenance, the information in some of the guidelines can be applied to railroad right-of-way maintenance. The FRA should review this information and disseminate to railroads pertinent information to use in railroad right-of-way stabilization programs.

CONCLUSIONS

Findings

1. The engineer was operating the train at 2 mph below the authorized timetable speed for the curve at the accident site. Train order No. 587 regarding the weather did not require a reduction in timetable speed.

2. The track was last inspected 6 hours before train No. 820 moved through the area. The area should have been inspected closer to the scheduled passage of train No. 820.

3. The instruction to reduce speed in the derailment area given to southbound train No. 819 on April 2 was not given by the trainmaster to northbound train No. 820 on April 3, even though the threat of landslides still warranted the action.

4. The actions instituted by the Southern Railway System as a result of the weather did not detect the landslide at MP 135.2 in time to prevent the derailment.

5. The Southern Railway System does not have procedures for issuing train orders to prescribe with particularity conditions under which weather-related train orders should be issued.

6. The Southern Railway System should have been aware of unstable earth movement on the slope at MP 135.2 because of the leaning trees, a condition recognized in the AREA practices as an indicator of potential earth movement.

7. The conditions that existed on the west slope at MP 135.2 were not in accordance with the recommended practices of the American Railway Engineering Association regarding maintenance of earth and rock slopes.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the Southern Railway System to issue a train order to require the engineer of Amtrak passenger train No. 820, operating in an area known to have landslides, to operate the train at a speed from which he could stop in time if he saw a slide. Contributing to the accident was the failure of the Southern Railway System in the prevailing circumstances to have had the track patrolled nearer to the time the passenger train was to pass or to have slide detection devices.

RECOMMENDATIONS

As a result of this investigation, the National Transportation Safety Board made the following recommendations:

---to the Southern Railway System:

> Revise procedures for train orders related to weather conditions to prescribe conditions under which the train orders should be issued, and specific actions to be taken by crewmembers so that the risk of operating hazards caused by weather will be minimized. (Class II, Priority Action) (R-83-103)
>
> Examine periodically its rights-of-way for unstable slope conditions, and eliminate these conditions where possible. Install slide detection devices or adopt other appropriate measures to detect landslides where unstable slope conditions cannot be eliminated. (Class II, Priority Action) (R-83-104)
>
> Adopt the recommended practices of the American Railway Engineering Association regarding maintenance of earth and rock slopes. (Class II, Priority Action) (R-83-105)

---to the Federal Railroad Administration:

> Require that landslides on railroad rights-of-way be reported separately from other weather-related accident data. (Class II, Priority Action) (R-83-106)
>
> Review information available from the Federal Highway Administration regarding highway right-of-way construction and maintenance, and disseminate to railroads information pertinent to railroad right-of-way stabilization programs. (Class II, Priority Action) (R-83-107)

---to the Association of American Railroads:

> Inform its members of the circumstances of the Amtrak derailment at Rockfish, Virginia, on April 3, 1983, and encourage them to review and revise as necessary their procedures for train orders related to weather conditions to prescribe conditions under which the train orders should be issued, and specific actions to be taken by crewmembers so that the risk of operating hazards caused by weather will be minimized. (Class II, Priority Action) (R-83-108)
>
> Encourage its members to review and revise as necessary their operating rules and practices to make them more effective in predictable abnormal operating situations. (Class II, Priority Action) (R-83-109)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G. H. PATRICK BURSLEY
Member

/s/ DONALD D. ENGEN
Member

JIM BURNETT, Chairman, did not participate.

December 12, 1983

APPENDIXES

APPENDIX A

INVESTIGATION

The National Transportation Safety Board was informed of this accident at 7 a.m. on April 3, 1983, and immediately dispatched an investigator to the site. The Safety Board was assisted in the investigation by the Federal Railroad Administration, Amtrak, and the Southern Railway System.

There were no depositions taken or public hearing held as a result of this accident.

APPENDIX B

EXCERPTS FROM AMERICAN RAILWAY ENGINEERING ASSOCIATION MANUAL FOR RAILWAY ENGINEERING (FIXED PROPERTIES)

* * *

1 2 2.2 4 Cuts in Non-Uniform Soils

Cuts in soils which are layered or contain pockets of varied soil types should be designed on the basis of a slope stability analysis The coarser layers or pockets frequently are water-bearing during some part of the year and drainage must be provided. Effective drainage may stabilize the slope in a cut when soil properties are favorable

In addition to the improvement of soil properties from drainage, berms are usually effective in increasing stability in non-uniform soil areas Berms at the line of change of soil types allow the slope to be varied for each soil.

* * *

1.2.2.2.6 Control of Slopes

In every soil type the control necessary to maintain the cut section should be a consideration in design Berms, drainage, erosion protection, filter layers, vegetation and slope angle selection may be used Details are given in Articles 1 4 3 and 1 4 5 Cribs or retaining walls may be used in troublesome sections Details of design are given in Chapter 8, Concrete Structures and Foundations While slope control techniques add to costs, they will pay dividends in reduced requirements for slope restoration and ditch cleaning

* * *

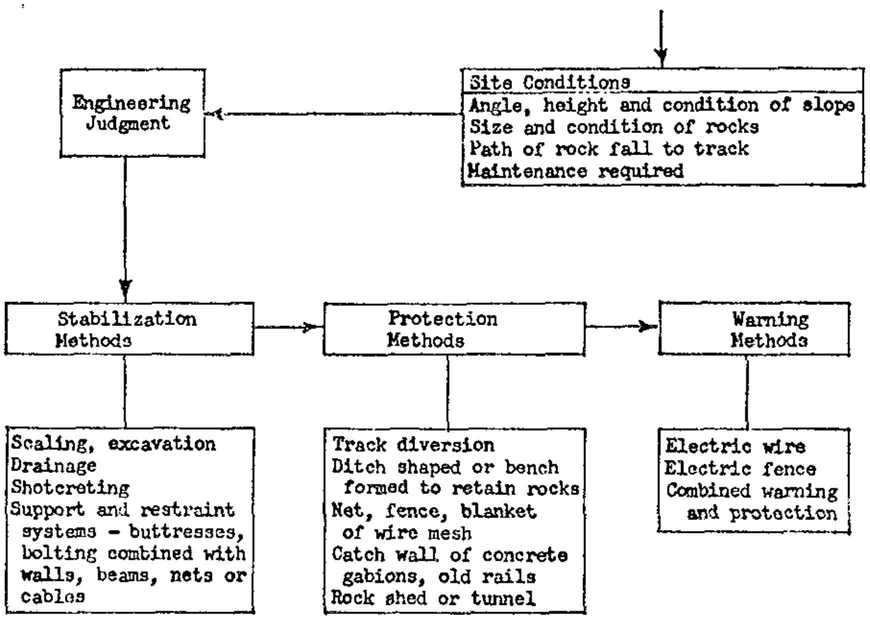

Fig. 1 4 2—Procedure in choosing treatment at site of rock fall.

1 4.2 MAINTENANCE OF ROCK SLOPES

1.4 2.1 Rock Falls

Rock falls occur in cuts and on sidehill portions of railway lines in rough terrain Where rock faces have been exposed for a number of years, single rocks or small groups of rocks are usually involved rather than the failure of entire slopes For this reason, accurate prediction of rock falls is not possible However, an experienced person can assess the risk of rock falls at particular locations in a general way

Rock falls incur costs due to the regular maintenance work involved, track patrols, train delays and rerouting required, and of course damage to equipment, injuries and sometimes deaths are incurred The cost of protection cannot be justified as a return on investment; safety is the main concern

1.4.2 2 Methods of Treatment

From an analysis of site conditions and performance, the most suitable treatment of a dangerous rock slope can be chosen Methods of treatment should be considered in the following priority if the danger of rock falls is to be reduced:

(1) Stabilization, or preventing rocks from moving out of place unexpectedly (as with rock scaling and rock pinning or bolting)

(2) Protection of track, or keeping rocks which do move out of place from reaching the track (as with walls or rock sheds)

(3) Warning traffic when rocks arrive in the vicinity of track (as with electric warning fences)

Stabilization and protection measures offer a positive solution to the problem and the latter can be combined with warning methods Warning methods by themselves have no effect on the causes of danger

The recommended approach to a rock fall problem at a particular site is shown in Fig 1 4 2 Methods are explained in Ref 3

1.4.2 3 Planning

Remedial work should be planned by railway engineering staff with particular experience in rock-fall problems, using consulting advice where needed

Good records are the basis for good planning and priorities Records should include the time and exact location of accidents and delays to traffic, of all rocks found on track, and of the removal of ditch debris, as well as plans and maintenance required for all stabilization and protection installations.

A regular annual inspection should be made, preferably with an experienced consultant, to appraise hazards and decide on action and priorities required Rock work is best done by experienced contractors, with a contract drawn up to allow flexibility in the work if conditions are found to be different than expected

1.4.3 MAINTENANCE OF EARTH SLOPES

1 4.3.1 Types of Maintenance Required

Slopes of fills and cuts along the railway right-of-way are subject to the continuing effects of gravity and running water. As a result, periodic maintenance is required to restore roadbed shoulders, clean ditches, fill gullies and prevent erosion by rain, waves or currents Emergency maintenance operations are required if failure of the roadbed, or earth slopes above or below track, endangers traffic

Some of these maintenance operations are discussed elsewhere:

- protection against erosion by waves and currents, Part 3, this chapter
- protection against erosion by rain and seepage, Article 1 4 5

1 4.3.2 Restoration of Roadbed Shoulders

Roadbed shoulders become too narrow with time to support the full ballast section This results from the settlement of roadbed, requiring track to be raised, or from erosion and gullying of the shoulders Restoration of the roadbed shoulders (bank widening) is frequently required before ballast can be added and retained on the edges of the roadbed It plays an important part in strengthening the roadbed to carry the wide, deep ballast sections required for heavier wheel loads and more frequent traffic.

Planning for shoulder restoration includes the work of extending culverts to the new limits of fills, and the choice of suitable material and filling and placement methods Particular care should be taken that the pattern of natural drainage is maintained Shoulder restoration work is usually done well in advance of subsequent track improvements

Materials should be stable and erosion-resistant (see Column 7 in Table 1 2 5). Pervious fills should only be bank-widened with pervious soils so that fill drainage can take place

After culverts are extended, vegetation and organic matter should be cleared from the slope and foundation area on which fresh material is to be placed to avoid potential sliding planes This is particularly important with sidehill fills The original slope materials should be benched and blended with each layer of new fill to obtain a good bond The roadbed shoulder should be graded as uniformly as possible and sloped outward so that rainfall may drain out of the ballast and not form channels and gullies in the fill shoulder

Suitable material for shoulder restoration may be available from side borrow or from adjacent cuts, thereby improving drainage and flattening cut slopes at the same time Material should be chosen to be at a water content generally suitable for compaction Excessively wet material should not be used Hauling can be done with scrapers, placing material in horizontal layers, working up from the toe of the existing fill Bulldozers can trim the material to a final slope of about 2 to 1

If material is hauled in by train and dumped down the slope, the material should be spread in layers and shaped by bulldozers working back and forth and up and down the bank to a final slope of about 2 to 1 In no case should the new material be left at the angle of repose This decreases the stability of the original slope which carries the new fill, and leads to rapid settlement and erosion of the new material

In all cases the new fill should be compacted from bottom to top with at least two complete coverages of bulldozer treads, and left with a smooth uniform surface Where the width of the fill will allow, a more satisfactory job will be obtained by the use of regular compaction equipment

The stability of fills with weak foundations should be checked before bank widening operations, as the weight of the new fill may cause a foundation failure (Article 1 2 3 2) The addition of seed and mulch immediately after completion of the new fill will reduce erosion of the slopes (Article 1 4 5 3) Such treatment may be required by environmental authorities

Shoulder restoration work is done with off-track equipment supplied by either the railway company or an experienced contractor. The work is usually done at one time at all locations required along a particular section of track If done by contract, bids for the work may be obtained on an agreed unit basis on which an experienced contractor can estimate, such as a cost per mile for each actual mile of work involved If there is not sufficient fill available, the contractor may be required to provide suitable material as part of his contract

1 4.3 3 Restoration of Earth Slopes

1.4 3 3 1 Basic Principles

An earth slope either above or below track which has failed so as to involve the safety of traffic must be repaired immediately However, repairs should be carried out with the basic principles of slope stability in mind Only in this way will the necessary immediate repairs tie in with long-term stability requirements. Neglect of this will lead to recurring instability or added costs in subsequent restoration work

In an earth slope there are forces tending to cause sliding and forces resisting sliding Forces causing sliding are gravity and water Gravity acts through:

- the weight of earth in a slope,
- the weight of fills, stockpiles, structures, or traffic on a slope
- vibrations from earthquakes or traffic

Water acts through:

- the weight of water in a slope, particularly after rain or rapid draw-down of ponded water levels,

- the pressure of seepage water within the slope,
- the pressure of hydrostatic water in ground cracks in the upper part of of the slope,
- the softening of material in the slope,
- undercutting of the toe of the slope by erosion

The resisting forces are made up of the strength of the soil along the sliding plane in the slope, and the weight of earth tending to be displaced at the toe of the slope Slides occur when sliding forces increase or resisting forces decrease enough to cause movement Sliding surfaces within the ground are often, although not always, shaped like the arc of a circle During a slide, gravity carries material down at the top of the slope and out at the toe In this way it reduces the sliding forces as well as increasing the resisting forces The effectiveness of any form of slope stabilization will depend on how it affects these two forces.

1.4.3.3 2 Planning

Landslides occur most frequently at times of high groundwater or heavy rainfall. They seldom occur without advance cracking of the ground or other signs

Planning for stabilization of an unstable slope should always start with a thorough inspection of the slope, if possible with an experienced geotechnical engineer, to find out what is happening The inspection should extend up and down hill from the track for a distance well beyond the obvious signs of instability A local failure will sometimes be part of a much larger movement going on in the general area

Observations should be made of

- any recent excavation or filling,
- crack or bulges in the slope,
- water seeping into or out of the ground, wet areas,
- damming effects of frozen ground,
- direction, extent and depth of the movement, judging by the displacement of ground cracks, tracks, fence lines or leaning trees

These observations should be supplemented by an analysis of the slope stability, based on drilling, soil sampling and testing whenever warranted by the importance of the problem and the time available

1.4.3.3.3 Methods

Methods of restoring slope stability are chosen on the basis of site observations and analyses made, and the suitability, feasibility and economics of the various alternatives It is sometimes possible to gain time to implement these measures by temporarily moving the track away from the unstable area

Methods are reviewed in Table 1 4 1

1 4.4 WIDENING OF CUTS

1.4.4 1 Rock Cuts

Before excavation is planned, a survey should be made of the engineering characteristics of the exposed rock. Details of dip, joints, stratification, general competence and zones of weakness should be noted, along with the depth and type of overburden

The new slope should be suited to the characteristics of the rock in which it is made so that minimum maintenance results. For example, steeply dipping rock should be cut at the angle of dip See Article 1 2 2 1 for the procedure to arrive at

TABLE 1.4.1

METHODS FOR STABILIZING EARTH SLOPES

Method	Remarks
Reducing sliding forces	
1. Remove soil at top of slide area, flatten slope	Not always feasible.
2. Divert surface water flows	Use ditches, lined if necessary, or flumes.
3. Lower ground water level within sliding mass	Often applicable. For surface water use intercepting trenches, perforated pipes. For subsurface water use drilled-in horizontal or vertical drains.
4. Eliminate leakage from culverts	Not always feasible.
Increasing resisting forces	
5. Install pervious blanket	To keep slope surface material in place, preventing gullying and sloughing.
6. Construct berm over lower portion of slide area and beyond toe	Useful if feasible. Proportion berm on basis of stability analysis, ensure outer slope of berm is stable. Use free-draining material, or install granular blanket on slope under berm and provide through drainage. Compact berm material. If toe of slope is eroded by current or waves, install berm of riprap material.
7. Install wall or crib (see Chap. 8, Parts 5 and 6)	Must be founded on stable ground. May be expensive.
8. Install vertical piles along track	Only successful if sliding forces are small. Drive row of piles on both sides of track and tie rows together with cables or rods under track to form a crib.
Special methods	
9. Drill in anchors with beams and lagging	Must be conservatively designed by experienced engineer, especially if planned for permanent support.
10. Densify soil by vibration or compaction	Only possible with some granular soils. Specialized technique.
11. Grout, freeze, or apply electro-osmosis	Applicable only to special conditions. Very expensive. Experienced advice required.
12. Plant stabilizing vegetation on face of slope	Reduces water content of slope to shallow depths. Experienced advice required.

the best design slope This may include benches, or a slope varying with the weathering resistance of the various rock layers Drainage should be provided to reduce erosion and weathering.

Methods of treatment to stabilize the slope or protect the track from falling rocks may be considered as an alternative to widening an unsafe rock cut, or applied in conjunction with excavation of the new slope

The method of blasting chosen is most important in reducing future rock scaling and other maintenance work required The use of presplitting for producing a clean finished rock face should be considered (Article 1 2 2 1 5)

1.4 4.2 Earth Cuts

Cuts are widened in railway maintenance work to improve drainage, increase the stability of slopes, reduce difficulties in maintaining track or clearing snow, or sometimes to obtain borrow materials Whatever the reason, it is important that a well drained stable cut is obtained in either earth or rock

Methods of choosing safe slopes for cuts in various soils are given in Article 1.2.2 2 The reduction of seepage pressures within the slope by means of horizontal drains may be critical in cuts in water-bearing layers of soil If slope stability analysis is not practicable, choice of a safe slope may sometimes be derived from observation of nearby cuts or natural slopes in similar soils, if care is taken to make allowance for differences in the level of the groundwater table, vegetation, and other influences on stability

In making the cut, even temporary over-steepening (or undercutting) of potentially unstable slopes should be avoided, especially if the work is done during a wet season Piles and lagging or crib walls can be used to support the back slope of the ditch if there is restricted right-of-way width to cut an entire bank back to a stable slope (and temporary stability of an undercut slope can be asssured) Drainage through the supporting structure should always be provided

In sidehill cuts, material excavated from the upper ditch or slope should never be cast over on the downhill shoulder This practice promotes failure of the downhill slope (Article 1 2 3 7) Such excavated material should be loaded and taken away.

The original vegetation will help to bind a slope together and provide subsurface drainage by transpiration It should be preserved to the maximum extent possible on stable slopes On freshly cut slopes, vegetation should be re-established to prevent erosion (Article 1 4 5) Surface drainage in a widened cut should be planned according to Article 1 2 4 2 A drainage system which is balanced to handle both slope and roadbed drainage throughout the cut is essential Drainage of water from the top of the slope should be intercepted and brought around or down the slope without causing surface erosion.

1.4.5 DRAINAGE AND EROSION CONTROL

1.4.5 1 Ditches and Drains

Ditches of all types require periodic maintenance to preserve their function Excess vegetation and deposited soil should be removed Excessive scour must be corrected.

Less evident but also important is the periodic maintenance of subdrainage systems. Pipes and manholes should be periodically inspected and accumulations of sediment removed

It is not generally realized that drilled-in horizontal drains also require maintenance About once every 10 years, each pipe should be scoured to remove the accumulation of minerals tending to block the flow of water Failure to do so will lead to a build-up of seepage pressures, resulting in slope instability which the drains were installed to relieve

1 4.5 2 Erosion Control

Erosion of right-of-way slopes and ditches is caused by rainfall and frost, and affected by the steepness and height of slopes Resistance to erosion depends on the strength and cohesion of the slope or ditch soil and the presence of protective cover such as vegetation

Traditional practice has been to tolerate erosion if the track is not endangered and if the maintenance costs involved are not excessive This point of view is too restricted today, as the results of downstream silting must also be considered Erosion control where necessary on freshly cut slopes is good standard practice After erosion develops and gullies are formed, protection is more difficult to arrange

For all types of protection, a top ditch or other means to divert water from running over the top of slopes should be installed Slopes should be restored to a uniform condition by filling gullies with tamped earth Roadbed shoulders should be shaped to their design configuration to ensure uniform runoff

There are several methods of erosion control, including variations of seeding and sodding, the use of layers of coarser materials, and filter cloths These may be combined with flattening of slopes where warranted by soil conditions

1 4 5 3 Seeding and Sodding

Steps in seeding and mulching eroded slopes consist of filling gullies and placing topsoil where required, applying fertilizer, seed and mulch, and maintaining and reseeding as necessary Much detailed information can be obtained from the standards and specifications used by local highway authorities Suitable seed mixtures and fertilizers for particular locations can be recommended by agricultural bureaus Grasses or ground covers can be used to control erosion However, ground covers can be killed by chemicals used to control vegetation along the right-of-way

The application of seed and fertilizer is done on flat areas and moderate slopes with a seed drill, and on steep slopes with a hydroseeder A mulch spreader is used to apply straw tacked with asphalt Although this mechanical equipment is efficient and economical to use, small eroded areas can commonly be prepared and treated by hand, with substantial benefits Grass should be cut at least once to thicken the growth

Where active erosion of young growth may occur, jute matting can be used with seeding, giving good protection against erosion for at least two years Matting is effective on slopes up to 15 or 20% Seed and fertilizer is applied both under and over the jute, without mulch The matting should be applied according to specified procedures

Sod is costly and usually only used on areas where immediate vegetation coverage is required for aesthetic reasons Where necessary to prevent slippage on slopes, sod should be pegged in place Use of light wire netting over the sod, through which the pegs are driven, will assist in this

1 5 5.4 Filter Layers

Earth slopes can also be protected against erosion by a layer of coarser material In such cases it is essential to divert concentrated flows of water from the top of the slope and to fill gullies Filling gullies with coarse material will not in itself prevent further erosion.

The function and design of graded filter layers is given in Article 1 2 5.3 and Fig 1 2 6 This design method is used when water seepage from pervious layers in the slope causes erosion. The filter layer is designed to keep the underlying soil in place while at the same time carrying flow from both seepage and rainfall without eroding itself The thickness of the layer required depends on the intensity of rainfall A filter layer must be carefully designed and installed However, it will prevent erosion under conditions too severe for seeding or sodding to survive

1.4.5.5 Filter Cloths

The function of a filter layer in preventing erosion on an earth slope can also be performed by a filter cloth (Ref 4). These porous plastic membranes are available as woven cloth or as thin fibrous mats In either form they are designed to be fine enough to hold the slope soil material in place, but porous enough to allow passage of seepage water to prevent uplift pressure.

The performance of filter cloths is often superior to that of filter layers as they have a built-in filtering capability which does not depend on field workmanship Detailed installation procedures are available from manufacturers Generally, the slope to be protected must be uniform and gullies and holes filled. The cloth is spread loosely on the slope, with overlapping sheets pinned in place. A layer of random gravel or crushed stone is placed immediately on top of the cloth to keep it in place, working from the base of slope upward This material must be coarse enough to withstand erosion in itself

* * *

*U.S. GOVERNMENT PRINTING OFFICE : 1984 0-421-828/44