UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

Western District
Metal and Nonmetal Mine Safety and Health

ACCIDENT INVESTIGATION REPORT
SURFACE NONMETAL MINE
FATAL FALL OF HIGHWALL ACCIDENT

Portable Crusher #2, ID No. 45-03226
Lloyd Logging, Inc.
Wenatchee, Chelan County, Washington

May 19, 1995

By

Dennis Harsh
Mine Safety and Health Inspector

Arnold E. Pederson
Mine Safety and Health Inspector

Western District Office
3333 Vaca Valley Parkway, Suite 600
Vacaville, California 95688
Fred M. Hansen
District Manager

Accident Investigation Report

Surface Nonmetal Mine

Fatal Fall of Highwall Accident

Portable Crusher #2, ID No. 45-03226
Lloyd Logging, Inc.
Wenatchee, Chelan County, Washington

May 19, 1995

Authority—This report is based on an investigation made pursuant to the Federal Mine Safety and Health Act of 1977, Public Law 91-173, as amended by Public Law 95-164.

Section A—Identification Data

1. Title of investigation: Fatal Fall of Ground
2. Date MSHA investigation started: May 19, 1995
3. Report release date: September 27, 1995
4. Mine: Portable Crusher #2
5. Mine ID number: 45-03226
6. Company: Lloyd Logging Inc.
7. Town, County, State: Wenatchee, Chelan County, Washington
8. Author(s): Dennis D. Harsh, Arnold E. Pederson

Section B—Mine Information

9. Daily production:
10. Surface employment: 10
11. Underground employment:
12. Name of coalbed:
13. Thickness of coalbed:

Section C—Last Quarter Injury Frequency Rate (HSAC) for:

14. Industry: 6.16
15. This operation: 9.13
16. Training program approved.
17. Mine Profile Rating:

Section D—Originating Office

18. Mine Safety and Health Administration
Coal Mine Health and Safety District No. :

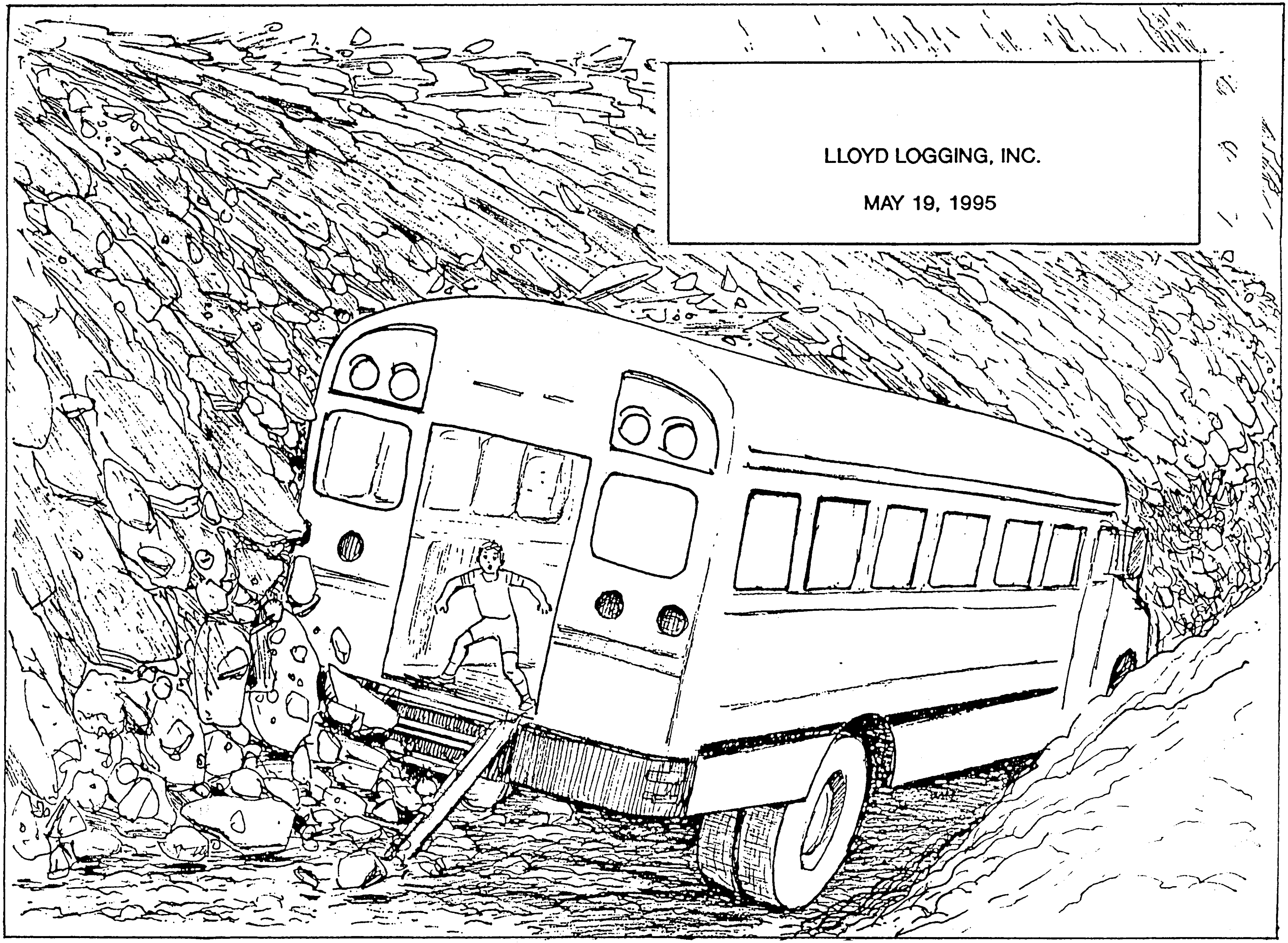
Address

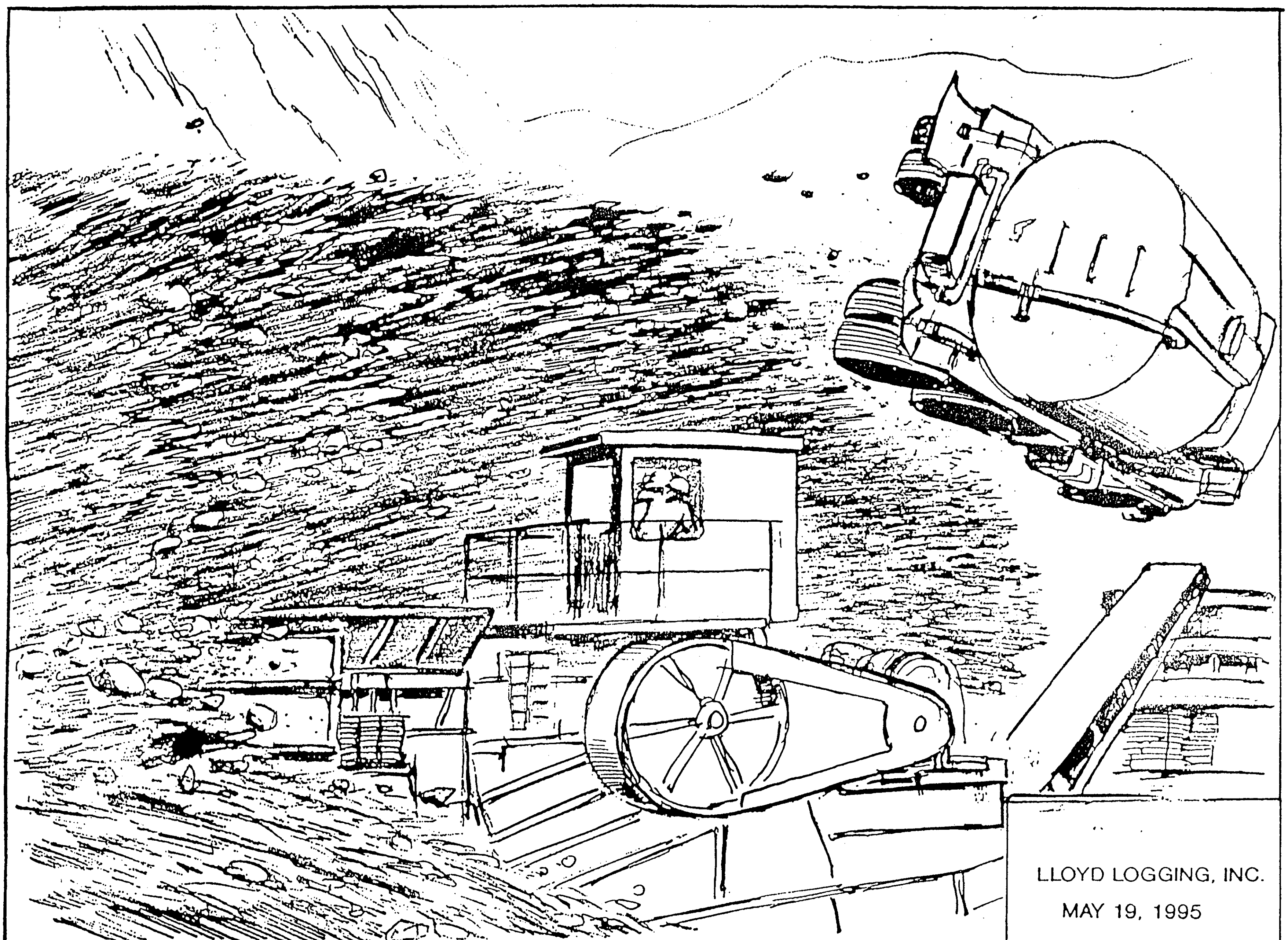
Section E—Abstract

A crusher operator and the five year old son of another employee were fatally injured when a massive slope failure occurred in a gravel terrace remnant. Approximately 1.25 to 1.50 million cubic yards of material was involved in the slope failure that covered the majority of the crushing/screening plant and related equipment.

Section F—Mine Organization

Company officials:	Name	Address
19. President:	Jean Lloyd	20268 Hwy. 20-0 P.O. Box 218 Twisp, WA 98856
20. Superintendent:	Mark Bakken	Rt.1 Box 67 Rosalia, WA 99170
21. Safety Director:		
22. Principle officer—H&S:	Donald Maples	Box 233 Winthrop, WA 98862
23. Labor Organization:		
24. Chairman—H&S Committee:		


LLOYD LOGGING, INC.
MAY 19, 1995


LLOYD LOGGING, INC.
MAY 19, 1995

GENERAL INFORMATION

Timothy D. Grace, a 28 year old crusher operator, and Tory Davis, the five year old son of a mine employee, were fatally injured May 19, 1995, at approximately 9:30 A.M., when a massive slope failure engulfed the crushing/screening plant and related equipment. Grace had 5 years of mining experience, with about 4 weeks at this mine site.

Tory Davis, whose mother was a part time sampler and truck loader, was at the mine at the time of the accident because she had not been able to find day care for him.

The accident occurred at Portable Crusher #2, owned and operated by Lloyd Logging, Inc. of Twisp, Washington. The mine, known as Edwards/Staples and owned by Morrill Ashpalt Paving, was located on Highway 97A approximately 5 miles north of Wenatchee, WA.

The mine employed 10 persons who worked one of two shifts, averaging eight hours a day, five days a week.

Material was extracted from the mine with a dozer and front end loader. It was then crushed and screened. Processed material was conveyed into hoppers, loaded on trucks, and transported to both on-site and off-site locations.

Collin Galloway, MSHA Coeur d'Alene Field Office Supervisor, was notified of the accident by Jean Lloyd, President of Lloyd Logging Inc., May 19, 1995, at 12:00 P.M. Rescue and Recovery was started the same day. An investigation of the event was initiated May 22, 1995, at 7:00 a.m.

Principle operation officials of Lloyd Logging's Portable Crusher #2 were:

Jean Lloyd, President
Donald Maples, Vice President
Robert Lloyd, Treasurer
Mark Bakken, Superintendent

The last regular inspection of the mine was completed May 10, 1995.

PHYSICAL FACTORS

The processing plant was located in an area that was 75 to 180 feet west of Highway 97A. The plant consisted of crushers, shaker screens, vans, conveyors, and related equipment.

Gravel, silty sand, and cobbles were being mined. A D8 Caterpillar bulldozer pushed the material from the south end of the pit towards the jaw crusher. A Caterpillar 980 C front-end loader was used to feed the material into the jaw crusher.

The crusher operator was stationed inside a converted Model 14E Caterpillar motor grader cab that was adjacent to the jaw crusher. The cab was used to control noise, dust, and environmental conditions that would adversely affect the operator.

A school bus that had been converted to an aggregate testing lab and lunch room was located at the north end of the plant, about 220 feet from the jaw crusher. The bus was approximately 8 feet wide and 25 feet long. It was parked between a stock pile and the pit wall.

The talus, a slope formed by the accumulation of rock debris, averaged 250 to 300 feet high and butted against a solid vertical metamorphic rock face that was estimated to be 1500 feet high. The face of the slope was very uneven but sloped about 70 degrees downwards toward the east. The floor of the pit was estimated to be 200 feet wide and extended from the toe of the gravel bank to the highway. There was a gravel bench rising about 30 to 40 feet above the pit floor. The talus extended upward from the rear of the bench.

DESCRIPTION OF ACCIDENT

Timothy Grace started his shift at 5:00 A.M. on May 19, 1995. He was assigned, by Mark Bakken, Superintendent, to operate the crushing/screening plant. The control booth, where he performed his duties, was located at the jaw crusher.

Prior to the ground fall, Thomas Farrow, D-8 dozer operator, was pushing materials northward from the old to the new plant location. Matthew Bakken, operating a Caterpillar 980 C front end loader, was picking up the material and loading the feed hopper.

At approximately 8:45 A.M. Farrow noticed two bolts missing from the dozer track and trammed to an area where repairs could be made. The mine mechanic, Kyle Carlson, was operating a R-22 Euclid haul truck. He turned the Euclid over to Marvin Tracy so he could make repairs on the dozer. Mark Bakken had left the mine site to obtain dozer parts from a nearby Caterpillar dealer.

At 9:30 A.M. Matthew Bakken put a scoop of material in the crusher hopper and backed away. He then realized that his loader and the ground beneath it was rising. The loader tipped over with the cab hitting the parts van, a 40 ft. semi-trailer used to store equipment and supplies. Both the loader and the van were pushed to the center of the adjacent highway by the moving material.

Carlson and Farrow, sitting on the disabled dozer, noticed puffs of dust near the top of the talus slope. They also detected ground vibrations and the movement of two large boulders above and behind the loader. Both men ran toward the highway after seeing the loader start to topple and the water truck, which was parked on a bench above the plant, being hurled over the cone crusher. Upon reaching the highway, they turned to see equipment partially buried, diesel fuel spilling from the generator fuel tank, and other crew members fleeing the landslide.

Donald Black, a truck driver from Morrill Asphalt Paving Co., was sitting under a conveyor discharge waiting to receive a load of material. While observing Diana Davis walking toward him, he saw puffs of dust at the top of the talus and large rocks falling. Realizing the mountain was coming down, he yelled for Davis to run for the road. He then put his truck in gear and drove to safety. Looking in his rear view mirror, he saw the hopper being knocked over. Black parked his truck at the highway and went to assist Diana Davis who was hysterical. Her five year old son was in the old school bus that had been serving as a lab and lunch room. The bus was now covered by the landslide.

A passing motorist called 911 on a cellular phone and a truck driver, who had arrived at the site just after the slide, radioed for help. Rescue workers found the body of Tory Davis at 12:02 p.m., May 20. Timothy Grace was located at 7:00 p.m., the following day. Recovery efforts were completed at approximately 10:00 p.m., May 21.

The Ballard Ambulance Service transported the victims to the Central Washington Hospital in Wenatchee, Washington. Dr. Gerald Rappe, Pathologist, determined both victims died instantly due to crushing trauma.

CONCLUSION

The massive slope failure which occurred at the Edwards/Staples gravel pit on May 19, 1995, was the result of an unrecognized geotechnical hazard. All available evidence indicates that commonly accepted and prudent open-pit mining practices were being followed. The presence of glacial deposits of rock flour, clays, and silts (varved clays) containing low-strength materials beneath the alluvium gravel deposits being mined, presented unique, and unrecognized hazards to normal pit-type, gravel mining operations. The intermittent yet continuing mining of material over many years resulted in the gradual removal of the laterally constraining and counter balancing weight of the alluvium gravels, and allowed the tremendous weight of the towering talus slopes to initiate a classic, deep-seated, rotational failure through the extremely weak and highly saturated foundation clays.

Interviews with witnesses and persons who had visited the pit prior to the slope failure, and a review of MSHA records, indicated that Lloyd Logging, Inc. was maintaining pit walls in accordance with normally accepted, prudent mining practices. However, without subsurface exploration and a mining plan which would recognize and accommodate the presence of the glacial clays, failure of the slope became more likely as material continued to be removed. The presence of remnant deposits of glacial clays within the Columbia River valley is well documented, and one such deposit was thoroughly investigated during the construction of the nearby Rocky Reach Dam.

VIOLATIONS

No violations of mandatory standards were observed, the following order was issued during the investigation.

Order No. 4342044, 103(k) issued 5/19/95. A highwall failure occurred at the Portable Crusher No. 2 where material was being processed. Two people were trapped when the high wall collapsed. This order prohibits any unauthorized persons access to the accident site.

/S/ Dennis Harsh
Mine Safety and Health Inspector

/s/ Arnold E. Pederson
Mine Safety and Health Inspector

Reviewed and Approved By:

Fred M. Hansen
Fred M. Hansen
District Manager

APPENDIX

1. INVESTIGATION PARTICIPANTS
2. RECOVERY PARTICIPANTS
3. AERIAL PHOTOGRAPH OF ACCIDENT SITE
4. RECOVERY PHOTOGRAPHS
5. DATA SHEET
6. REPORT OF TECHNICAL INVESTIGATION

APPENDIX I

INVESTIGATION PARTICIPANTS

Morrill Asphalt and Paving Company, Inc.
Stanley E. Evenhus, General Manager
Gary Kneidler, Superintendent

Goodfellow Brothers
James Goodfellow, Owner

Chelan County Sheriffs Office
Michael Harum, Sheriff
Daryl Mathena, Undersheriff

Chelan County Public Works Department
Richard J. Anderson, P.E.
Director/County Engineer

Chelan County PUD
William Christman, Senior Civil Engineer
Daniel Garrison, Civil Project Engineer

Washington State Department of Transportation
Donald J. Senn P.E.
Regional Administrator

Washington State Department of Natural Resources
Lorraine Powell, Geologist

Hammond, Collier and Wade'Livingstone Associates Inc.
Jonathan B. Hamilton, Geologist

Mine Safety and Health Administration
Arnold E. Pederson, M/NM Mine Inspector
Dennis D. Harsh, M/NM Mine Inspector
Robert L. Ferriter, Supervisory Mining Engineer, DSHTC
David M. Ropchan, Senior Mining Engineer, DSHTC

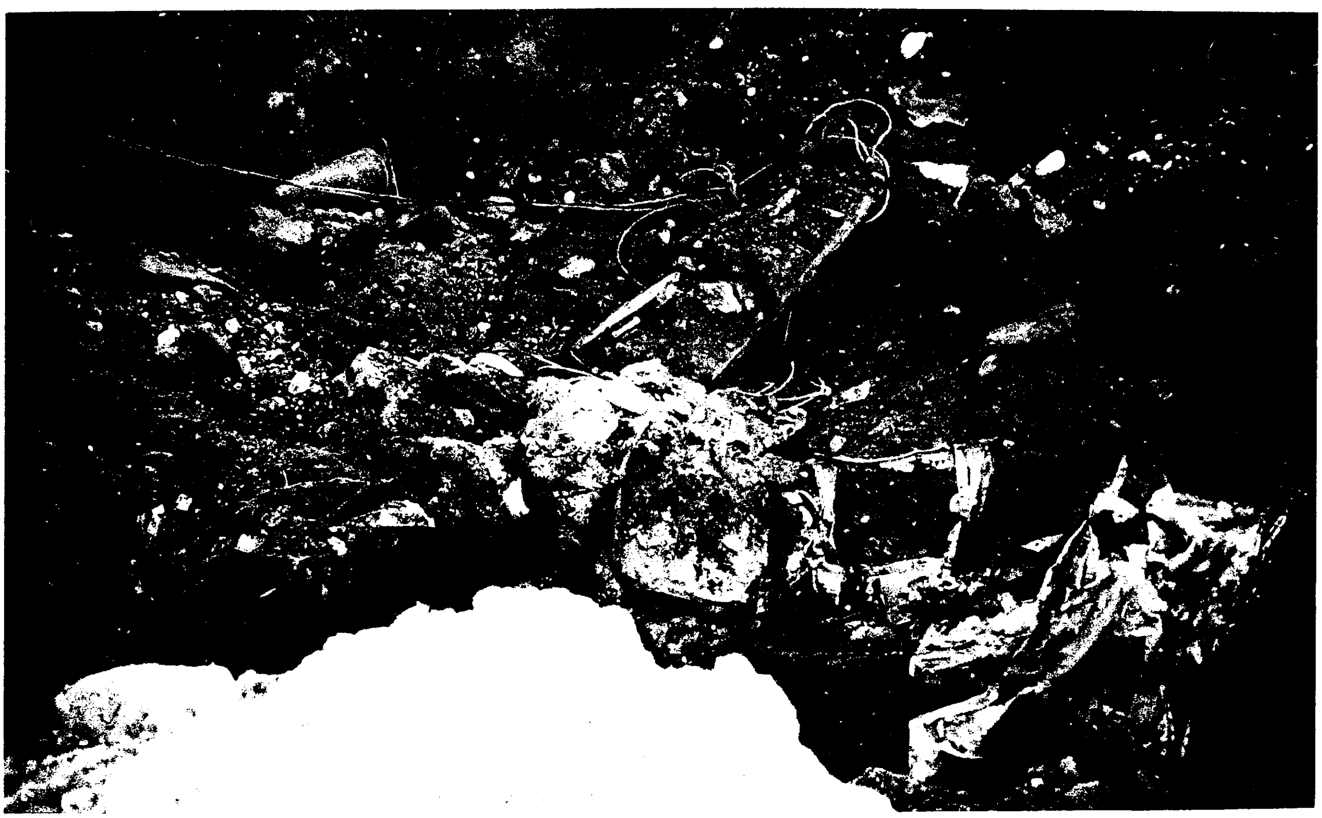
APPENDIX II

RECOVERY PARTICIPANTS

Ballard Ambulance Service
Chelan County Fire District 7
Chelan County Public Utility District
Chelan County Public Works Department
Chelan County Sheriff Department
Chipman Construction Inc.
City of Wenatchee
Fraley Construction
Goodfellow Bothers
Lloyd Logging, Inc.
Morrill Asphalt Paving Company, Inc.
Pipkin Construction
Red Cross
Sheriffs Posse
Washington State Department of Transportation
Washington State Department of Labor and Industries
Washington State Patrol

AERIAL PHOTO OF ACCIDENT SITE. LLOYD LOGGING, INC., MAY 19, 1995

RECOVERY PHOTO 1. - Recovery of Victim No. 1. Victim was found inside of crushed bus, May 20, 1995.



RECOVERY PHOTO 2. - Wreckage of crusher cab recovered at Victim No. 2 location, May 21, 1995.

RECOVERY PHOTO NO. 3. - Recovery site of Victim No. 2, Crusher operator. Note clay-like material (upper material) interface with silty-sand (lower material). Crusher cab debris was recovered at clay/sand interface, slightly buried in the sand, May 21, 1995

Data Sheet

U.S. Department of Labor
Mine Safety and Health Administration

Section A—Victim Data

1. Name	2. Sex	3. Social Security Number
Timothy Grace	☒ Male ☐ Female	2633

4. Age	5. Job Classification
28	Crusher Operator

6. Experience at this Classification	7. Total Mining Experience
5 years, 1 month	5 years

8. What activity was being performed at time of accident?	9. Victim's Experience at this Activity	10. Was victim trained in this task?
Operating Crushing/Screening Plant	5 years, 1 month	Yes

Section B—Victim Data for Health and Safety Courses/Training Received *(related to accident)*	Date Received
11.	
12.	
13.	
14.	

Section C—Supervisor Data *(supervisor of victim)*

15. Name	16. Certified
Mark Bakken	☐ Yes ☒ No

17. Experience as Supervisor	18. Total Mining Experience
	7 years, 3 months

Section D—Supervisor Data for Health and Safety Courses/Training Received *(related to accident)*	Date Received
19.	
20.	
21.	
22.	

23. When was the supervisor last present at accident scene prior to the accident?	24. What did he do when he was there?
0915	Observing material processing and equipment operation.

25. When was he last in contact with the victim?	26. Did he issue instructions relative to the accident?
About 0800	No

27. Was he aware of or did he express an awareness of any unsafe practice or condition?

No. Was not aware of any ground problems.

Report of Technical Investigation
Surface Nonmetal Mine
Massive Slope Failure

U.S. Department of Labor
Mine Safety and Health Administration

1995

Portable Crusher No. 2
Mine ID: 45-03226
Lloyd Logging, Inc.
Operating at the
Morrill Asphalt Paving
Co. Gravel Pit
Wenatchee,
Chelan County,
Washington

May 19, 1995

EXECUTIVE SUMMARY

Investigative effort to explain the slope failure at the Morrill pit was concentrated in four primary areas; the geologic environment in which the failure occurred; index testing of soil samples to determine soil classifications; mapping of before and after failure slope configurations; and computer modeling of likely failure surfaces.

The geologic structure which precipitated the slope failure was the varved clays deposited during Ice Age glacial activity. These bedded deposits of glacial rock flour interbedded with thin layers of silts were exposed in the southwest corner of the failure area and are very similar to the deposits investigated and described by the engineering firm of Stone and Webster during the construction of Rocky Reach Dam. From geologic studies of the Columbia River Basin, it is well documented that the basin in the vicinity of Wenatchee and Rocky Reach Dam were covered by a large, deep-water lake fed by glacial streams approximately 10,000 years ago. Varved clays are geologic evidence of lacustrian deposits and indicate that the entire valley was once covered by a large lake several hundred feet deep.

After the Ice Age, the changing river channel eroded the varved clays in the main channel, but left remnant deposits in protected areas on both sides of the valley. This accounts for both the clay deposit near Rocky Reach Dam and the Morrill pit deposit. Ensuing Columbia River flood stages account for the typical deposits of sandy gravels, cobbles and silty sands overlying and adjoining the varved clay remnant at the Morrill site. Eroding metamorphic rocks from the Entiat mountains north of the site formed the several-hundred-foot-high deposits of colluvial talus lying atop the gravels. Typically, this talus is also deposited in and intermixed with the clays, sands and gravels, and can create a zone of more permeable material.

Similar deposits of talus can be observed in several locations along the north side of the Columbia River between Wenatchee, Washington and Rocky Reach Dam. Although the exact pre-failure thicknesses and lateral extent of the varved clays, interbedded sand lenses, and silty sand, gravel and cobble beds will never be known, this report presents a reasonable, well-documented estimate.

Index testing of clay samples taken from exposed clays at the Morrill pit indicate that the material is a CL or ML material within the unified soil classification system. Typically these materials exhibit low shear strength and low permeability rates. High moisture content reduces the material's shear strengths drastically. Fine sand lenses suspected to have been interbedded within the clay beds were assumed to exhibit cohesion values approaching zero.

Moisture content determinations conducted on the same test samples indicated that the samples resided very near the liquid limit for the clay material. Considering that these samples were all taken nearly 6 weeks after the accident and after exposure to intense sun, it is the investigators' opinion that at least portions (some beds) of the varved clays were either in or very close to a liquid state at the time of failure. Removal of the gravel deposit at the toe created the conditions for the slope failure and, when coupled with the driving weight of the colluvium material above the low-strength clays, the rapid eruptive, uplifting nature of the failure.

Both historic and after failure maps were used to obtain topography of the accident area (See Appendix B). Apparently mining and material removal had been conducted at this site for many years by various operators. Comparisons of earlier aerial maps with current descriptions of the pit configuration indicate that several hundred-thousand cubic yards of material had been removed from the site prior to the failure. Excavation of this material removed much of the lateral restraint which buttressed the slope and the gravity weight which counterbalanced the downward force of the talus and alluvium material on the varved clays. This excavated area created an imbalance of forces regarding the stability of the slope. The underlying foundation soils were unable to withstand the tremendous pressures being placed upon them by the talus slopes and remaining gravels. Computer modeling of the failure was conducted to ascertain and verify a probable mode of failure. Field measurements and locations of uplifted material were used where possible to compare calculated failure surfaces to field evidence. Input soil parameters for density, shear strength and cohesion were estimated from soil index testing and properties of similar materials. Therefore, sufficient investigation, materials testing and computer analysis have been conducted to allow validation of a reasonable, rotational failure mode.

Computer analysis using a Simplified Bishop failure program (PCSTABL5M) was performed to determine a probable failure surface. Parameters for alluvium and colluvium materials were varied slightly during the search routines. Soil index testing results dictated shear strength inputs of 15° or less, zero cohesion and a wet density of 145 lbs/ft^3 for foundation materials. Zero contact friction was assumed between the Entait mountain metamorphics and the talus/alluvium materials. These parameters are in close agreement with soil parameters determined from other landslide failures in glacial deposits within the Columbia River valley. From these calculations, a deep-seated rotational failure was projected.

AERIAL PHOTO OF ACCIDENT SITE. LLOYD LOGGING, INC., MAY 19, 1995

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UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

INVESTIGATION OF MASSIVE SLOPE FAILURE
PORTABLE CRUSHER NO. 2 (ID NO. 45-03226)

LLOYD LOGGING, INC. OPERATING AT MORRILL
ASPHALT PAVING COMPANY GRAVEL PIT
WENATCHEE, CHELAN COUNTY, WASHINGTON

MAY 19, 1995

BY

ROBERT L. FERRITER
SUPERVISORY MINING ENGINEER

AND

DAVID M. ROPCHAN
SENIOR MINING ENGINEER

ISSUING OFFICE
GROUND SUPPORT DIVISION
ROBERT L. FERRITER, CHIEF

DENVER SAFETY AND HEALTH TECHNOLOGY CENTER

BILLY D. OWENS, CHIEF

P.O. BOX 25367, DENVER FEDERAL CENTER
DENVER, CO 80225

Field evidence verifying this type of failure was found in:

1. Witnesses statements stating that the ground rose up underneath them or their equipment and carried them east toward Highway 97A. One eyewitness stated that the ground rose up in the south and continued to raise in a northward direction. A second witness stated that the wave-like motion traveled across the talus slopes from south to north.

2. Comparison of pre- and post-failure location of a front-end loader (weight 50,000 lbs) and a crawler tractor (weight 80,000 lbs). Both pieces of equipment were lifted up and carried approximately 130 feet east toward Highway 97A.

3. The post-failure exposure of varved clays on the surface approximately 40 feet higher than the pre-failure pit floor.

4. The movement and uplifting of one large boulder (approximately 15-ft x 15-ft by 10-ft-thick and weighing 120 tons) approximately 150 feet horizontally and 40 feet in elevation.

5. The opposing dips of the silt and clay beds near the south end of the failure area. Beds of silty sands and clay which were flat-lying prior to the slope failure are now broken in two, separated and dip in opposing directions. The northern beds dip to the north and the southern beds dip to the south. Rock and soil debris fill the space between the exposed beds.

6. The "carpet-like" movement of the soil and vegetation mantel which has slid almost intact from the talus slopes down and over the top of the alluvium material. In the investigators' opinion, this indicates that the talus followed the rotational failure downslope, allowing the carpet of vegetation to slide almost intact over the top of the displaced alluvium and talus.

INTRODUCTION

On May 19, 1995, at 9:30 a.m. a massive slope failure engulfed a gravel pit (owned by Morrill Asphalt Paving Company) located about 5 miles north of Wenatchee, Washington and just to the west of highway 97A (figure 1). This slope failure or landslide partially covered a crushing and screening plant, owned and operated by Lloyd Logging, Inc., that was operating in the pit (figure 2). Two fatalities resulted from the slope failure, the crusher operator and a 5-year-old boy who was spending the day at the site with his mother. The boy's mother was employed by Lloyd Logging Inc., to do quality control testing at the pit. The boy was in a surplus school bus which had been converted into a materials testing lab. Other employees in the pit observed the failure but either "rode it

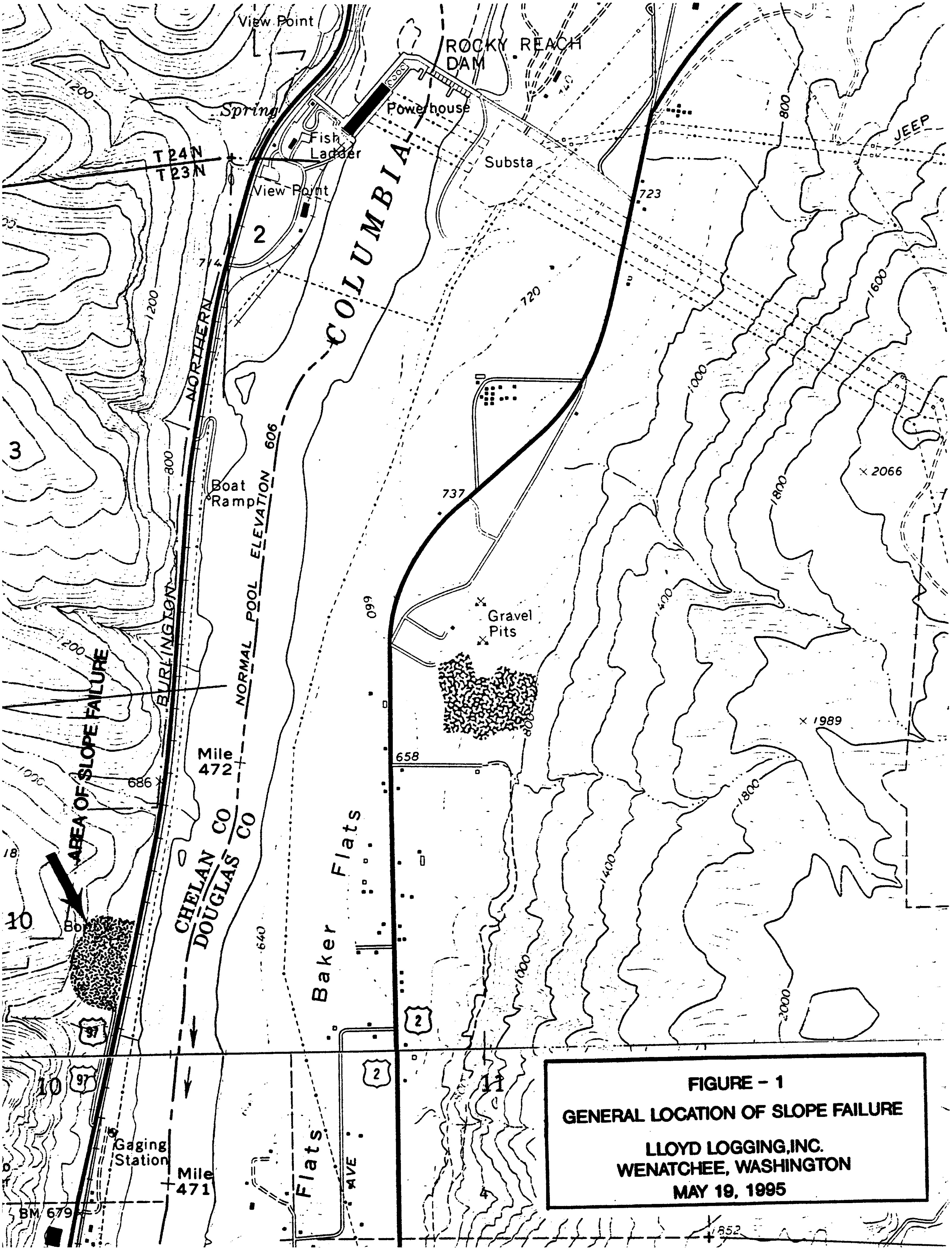
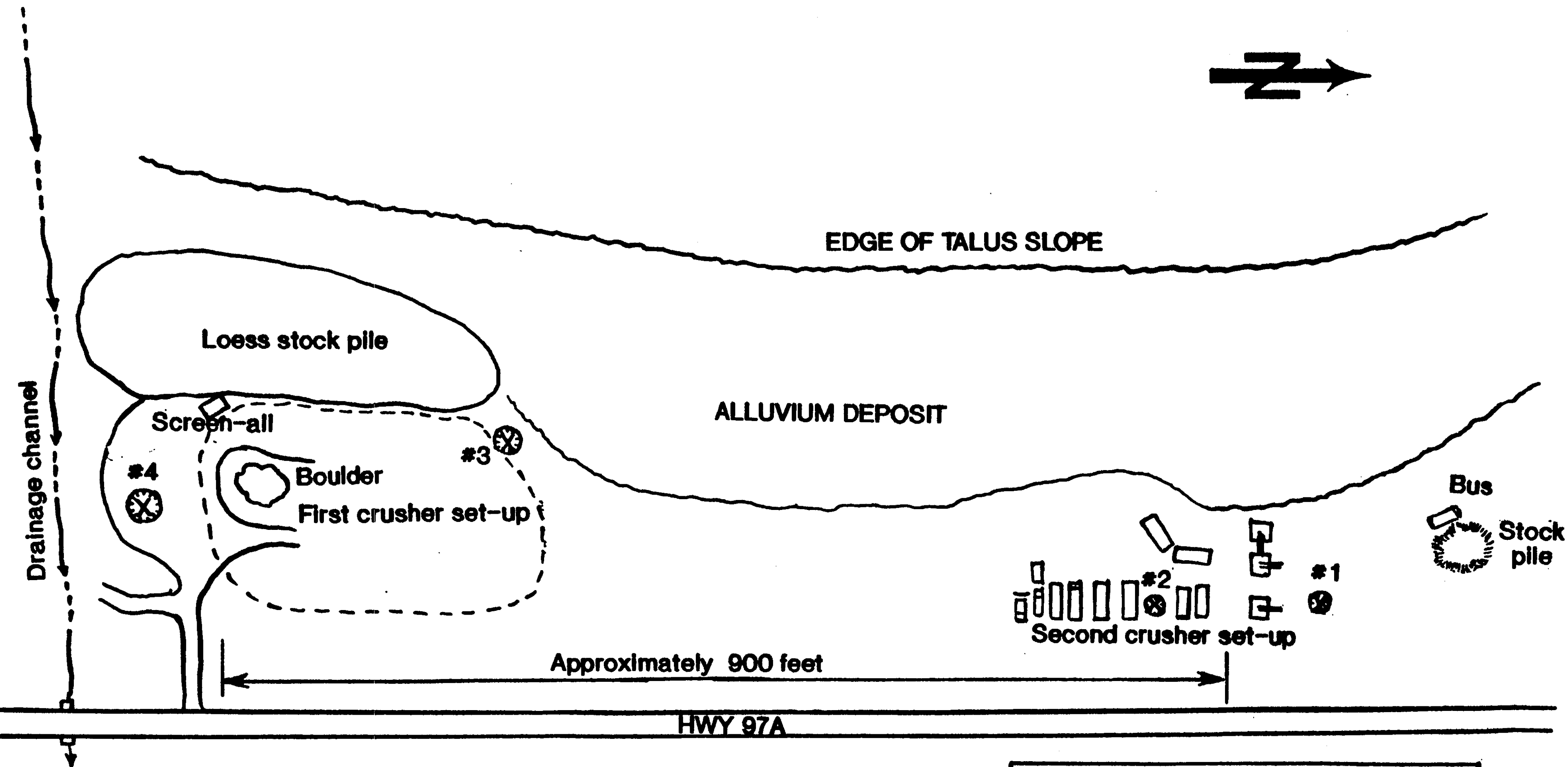


FIGURE – 1

GENERAL LOCATION OF SLOPE FAILURE

LLOYD LOGGING, INC.
WENATCHEE, WASHINGTON
MAY 19, 1995



Exploration pits are numbered 1 to 4

FIGURE - 2

APPROXIMATE LOCATION
OF CRUSHER SET-UP
AND EXPLORATION PITS
LLOYD LOGGING, INC.

MAY, 1995

out" in equipment or outran the slide on foot. The slide buried some equipment, but lifted and pushed much of the plant before it out onto the highway.

A massive recovery effort was begun almost immediately after the failure to search for victims. The first victim was recovered the next day, the second was recovered a day later (figure 3). Recovery photos 1, 2 and 3 show the condition under which the victims were buried. An investigation into the cause of the slope failure was begun on May 22, 1995.

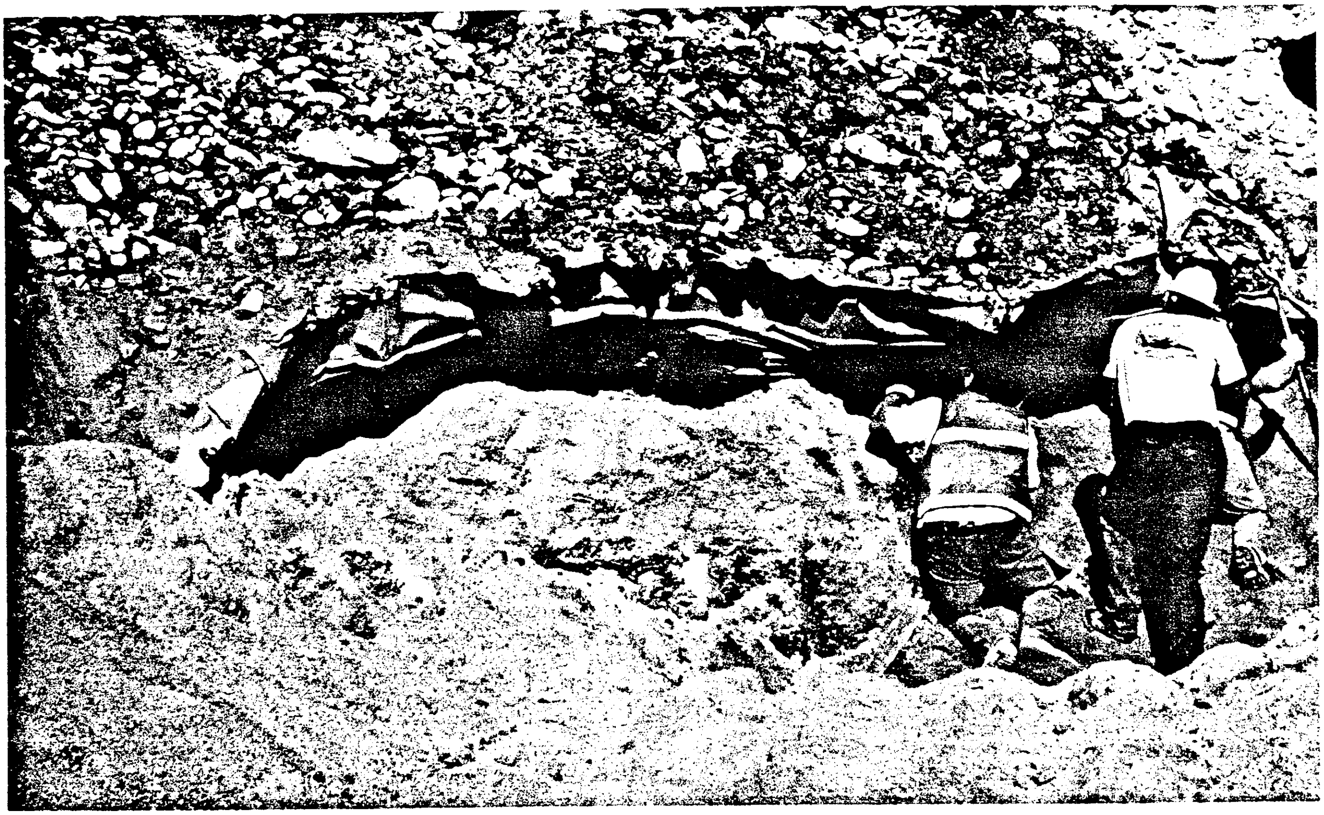
The investigation into the slope failure involved detailed site examination of the post-slide material and configuration including soil testing and mapping; interviews with personnel of Lloyd Logging, Inc. and Morrill Asphalt Company on the description of the event and the pre-event operation of the pit; examination of records held by the Chelan Public Power District on the geology of the area and geotechnical investigations conducted during the construction of Rocky Reach Dam; and information and photographs from the State of Washington, Department of Natural Resources and Department of Transportation. Records of the U.S. Weather Bureau station in Wenatchee and the National Earthquake Information Center of the U.S. Geological Survey (USGS) were also examined.

Although exact pre-failure geotechnical conditions at the failure site will never be known, all available sources of relevant investigation were explored to provide as complete an investigation as possible.

The discussion of the information collected and analyzed is presented as follows: description of the slope failure, geology, estimate of pre-slide pit geometry, factors affecting the stability of the slope, physical properties of soil samples, and computer generated stability simulations.

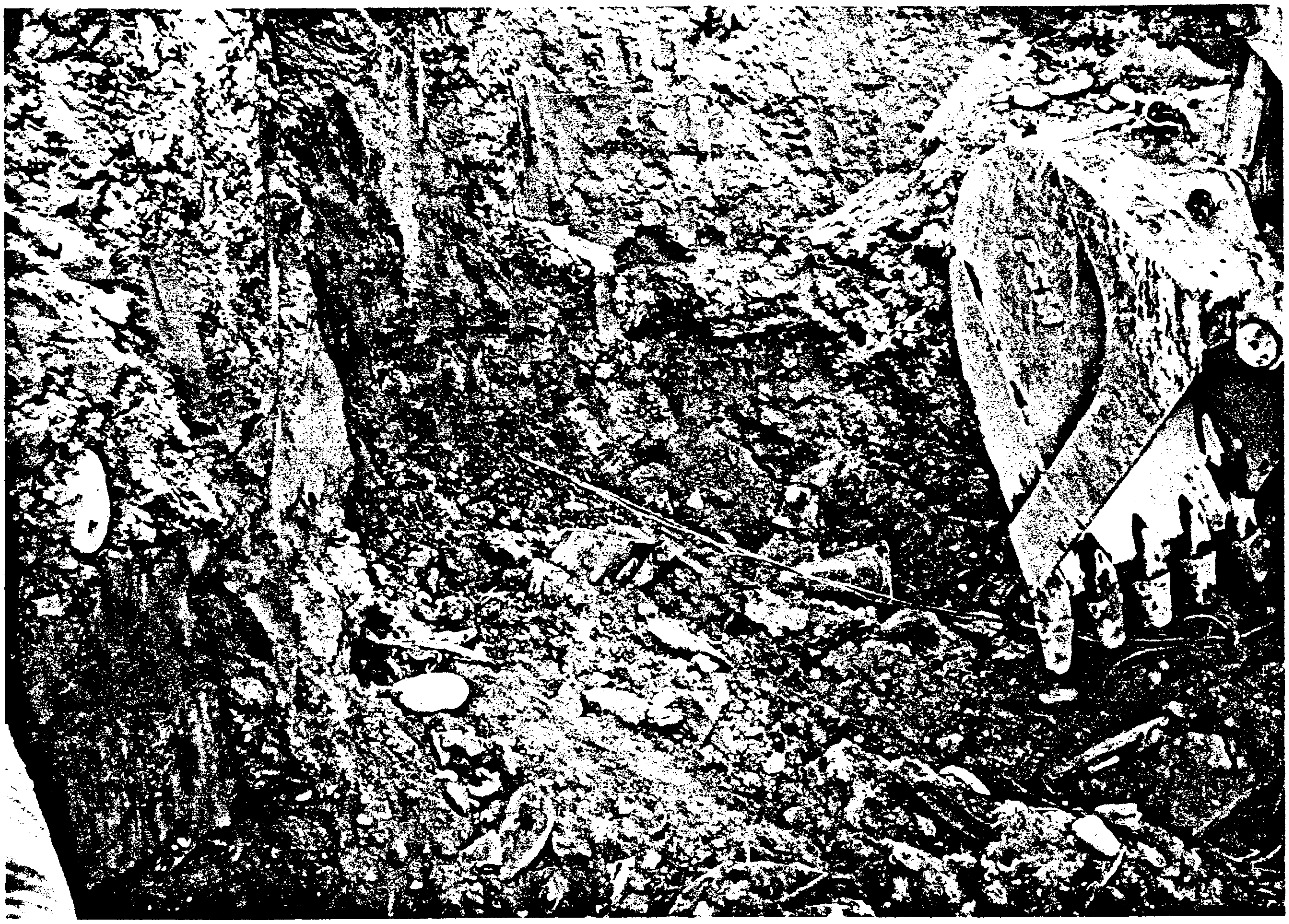
DESCRIPTION OF THE SLOPE FAILURE

The slope failure at the Morrill pit was a violent, massive failure involving the foundation, alluvium (gravel) deposit and the entire talus slope above the pit. The lateral dimension along the scarp or gneiss surface to the west was approximately 1100 feet. The lateral runout was estimated as ranging from 150 to 200 feet. At one point slide material blocked one lane of highway 97A to a depth of approximately 20 feet (photo 1). The dynamic force of the slide created a new land form in the shape of a gigantic standing wave of debris with a crest some 50 to 60 feet above the highway elevation and a hole or pocket behind where the talus slope had existed. The map in Appendix B and photos 2 and 3 show this new land form. The failure did not involve the entire length of the excavated gravel



RECOVERY PHOTO 1. - Recovery of Victim No. 1. Victim was found inside of crushed bus, May 20, 1995.

RECOVERY PHOTO 2. - Wreckage of crusher cab recovered at Victim No. 2 location, May 21, 1995.



RECOVERY PHOTO NO. 3. - Recovery site of Victim No. 2, Crusher operator. Note clay-like material (upper material) interface with silty-sand (lower material). Crusher cab debris was recovered at clay/sand interface, slightly buried in the sand, May 21, 1995

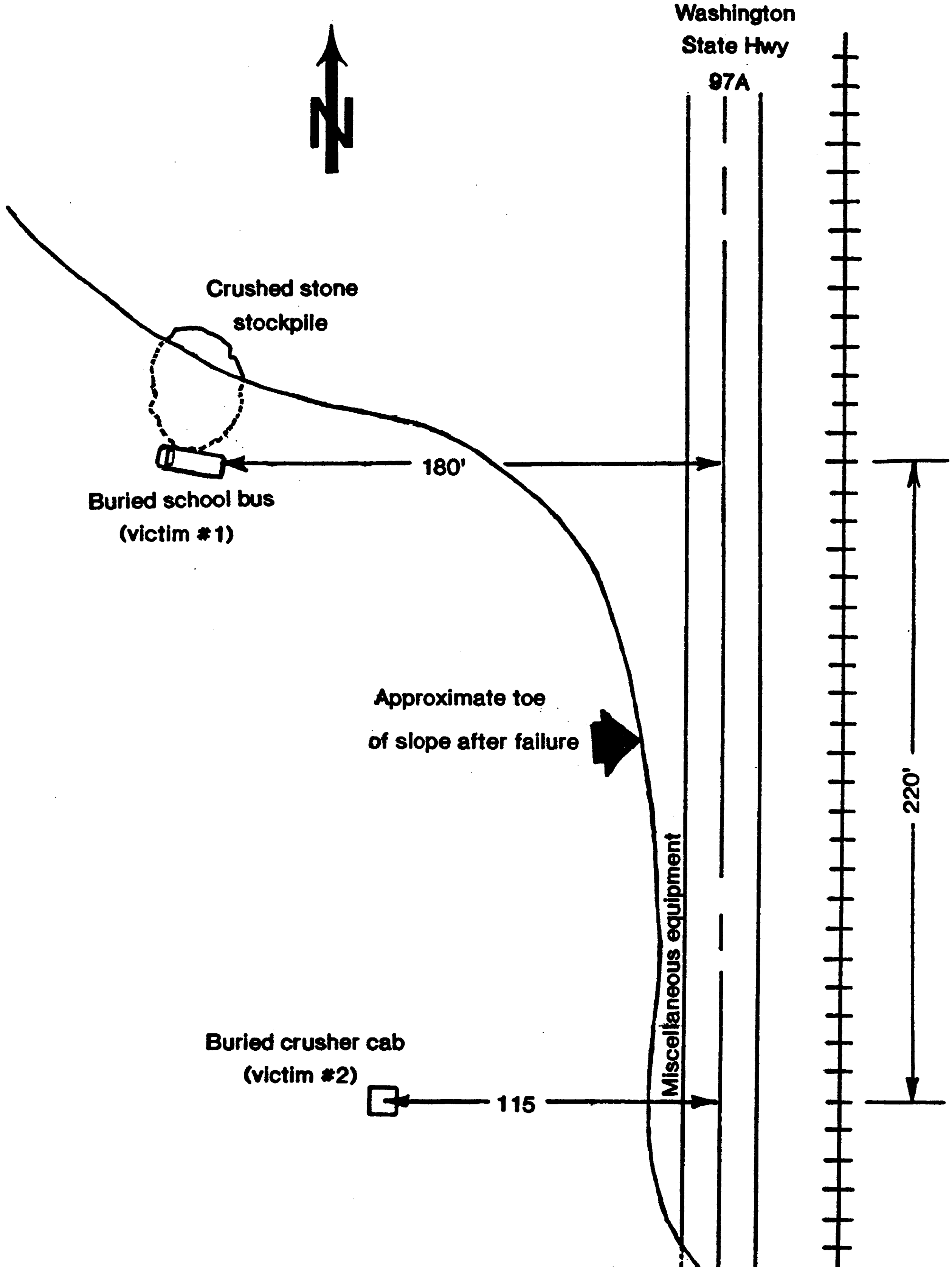


FIGURE - 3

LOCATION OF ACCIDENT VICTIMS
LLOYD LOGGING, INC.

MAY 19, 1995

pit. There are small areas at the north and south limits of the slide that did not come down, but these are considered unstable. Some of the talus material at the upper reaches of the slope did not come down immediately, but much of this remnant continued to ravel down at least a month after the failure (photo 4). The failed talus slope uncovered a rock face in the metamorphic basement rock of the valley estimated to be about 200 feet high although slough has covered some of the lower portions of this exposed rock.

Eyewitness accounts stated that the failure started at the south pit (deepest area excavated) and ran northward. The existing south pit has been mostly filled with slide material except for the very most southern part. Evidence (photos 5 and 6) shows where equipment tracks made on the pit floor and a boulder estimated at 120 tons that was also setting on the pit floor have been raised 30 to 40 feet and carried about 150 feet laterally from their original location. This material was near the front and western limit of the slide. Also varved clays were observed at the top of the slide material that filled the south pit (photos 5, 7, 8 and 9). About 20 feet below this surface expression of varved clays, massive clay material was observed in the south face of the slide material, in this south pit. The south end of the slide also shows a "stepped" surface, especially through the finer sedimentary material (photo 5). The tan colored material in photo 5 is wind blown soil (loess). The slide has spread this material horizontally approximately 200 hundred feet from its original position.

The east face of the slide facing or adjacent to state highway 97A was heavily excavated and altered during the recovery operation. For the most part this area of the slide has the appearance of gravel and silty gravel. However, in the excavations to recover the victims, thick beds of clay/silt were observed (photos 10 and 11) that were 25 to 30 feet thick. These thick beds were sitting on top of what had been the north pit floor and had to have risen up from below the level of this floor.

Much of the top area of the slide is covered with a mantle of talus and shrub growth that has been loosened but not tumbled. Much of this material appears to have ridden down like a carpet on top of the slide (photos 2, 3, and 4). There are cracks and evidence that rocks have moved in this carpet of material. Walking on it was difficult, as it felt compressible or airy under foot. Rocks were loose and sometimes quite unstable. The condition of this material is consistent with a foundation failure where the upper surface of the talus moved in mass as the lower section of the slide rotated up and out of position. Thus, much of the talus was loosened, but was not tumbled and mixed together.

The slope failure uncovered a large face of the Swakane gneiss against which the talus had been resting (photo 12). This rock face was estimated at 175 to 200 feet high and about 1100 feet across. The face is very uneven but slopes about 70 degrees downward toward the east. The rock scarp above the original slope is nearly vertical. Below and somewhat to the left of center in this face, a remnant of varved clay/silt was observed clinging to the rock surface. This is indicated by the arrow in photo 12 and is shown in detail in photo 13. This is significant as it is estimated to be about one third of the height of the original talus slope.

Cross-sectional views developed from the map of the post-slide topography illustrate the frontal ridge created by the slide and the hollow or depression located where the talus slope was located (figure 4).

Although the drainage just to the south of the slide area was running water, there was no evidence of flowing water in the slide area. There were some areas on the exposed rock face that appeared dark as if water was present; however, access to verify this condition was not possible.

GEOLOGY

The description of the geology of the area in which the slide occurred is taken mainly from reports prepared in relation to construction of the Rocky Reach Dam which is located about 1 1/2 miles upstream (north) from the slide area. These reports along with other geological papers are listed in the references section.

The foundation or bedrock in the Columbia River valley in the area of the slide is a metamorphic biotite gneiss named the Swakane gneiss. This biotite gneiss is "of rather uniform composition and structure. The rock is exceedingly well foliated and fine grain" (1). The gneiss is found on both sides of the river in the area. "The channel at the dam site is carved entirely in the Swakane gneiss" (2). The cliffs on the west side of the river adjacent to the slide area and the resulting talus slopes are all of this material. Although faults were discovered in this bedrock beneath the foundation of the Rocky Reach Dam, there is no indication of active faults in the area of the slope failure. The gneiss therefore has been eroded to form a trough in which recent glacial and talus materials have been deposited.

Foundation studies for Rocky Reach Dam describe the unconsolidated glacial material that forms much of the current land forms within the valley. Foundation drilling revealed the lowest alluvial

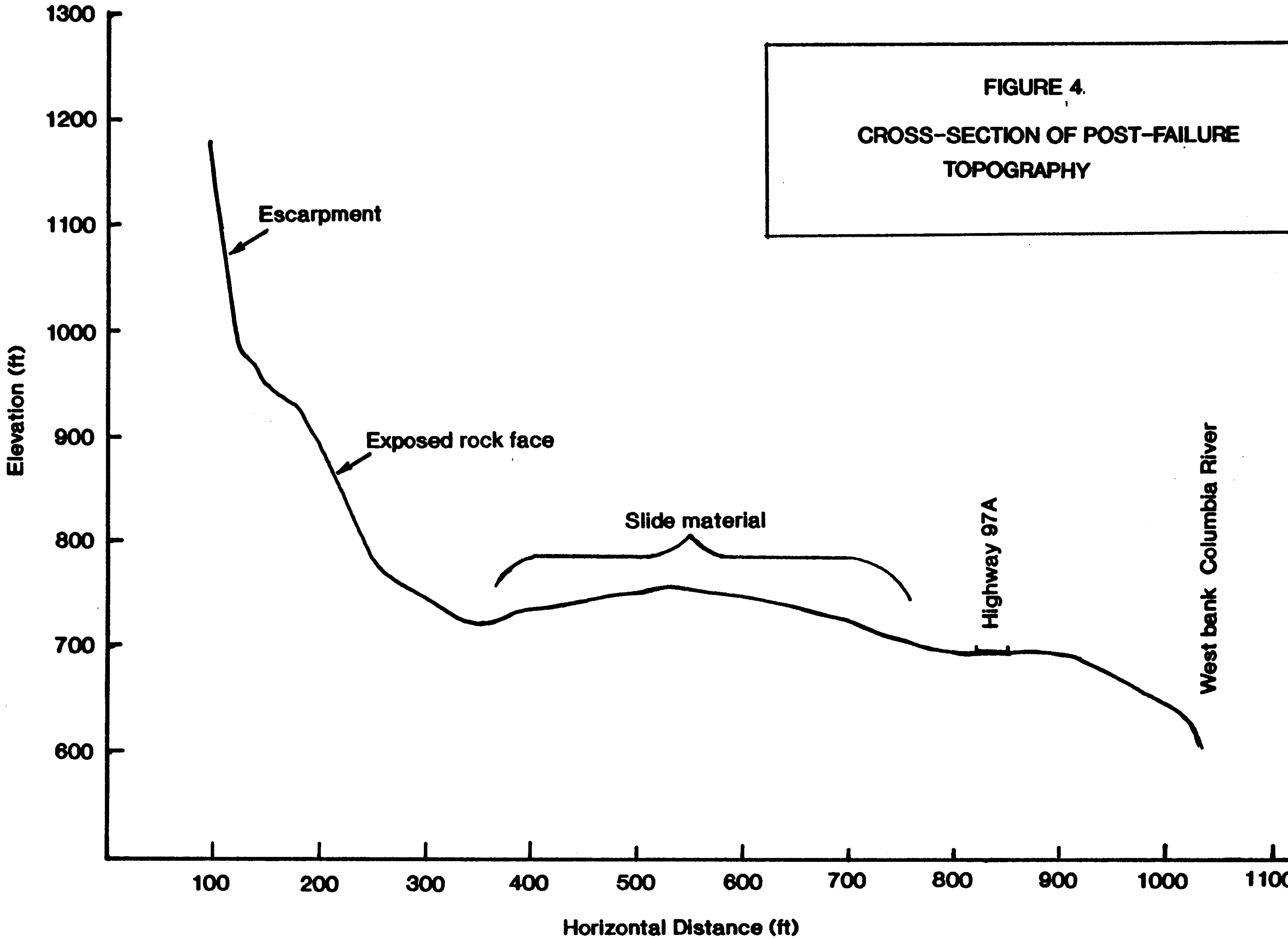


FIGURE 4.
CROSS-SECTION OF POST-FAILURE TOPOGRAPHY

material to be relatively coarse-grained sands and gravels that probably covered the entire bedrock valley (1).

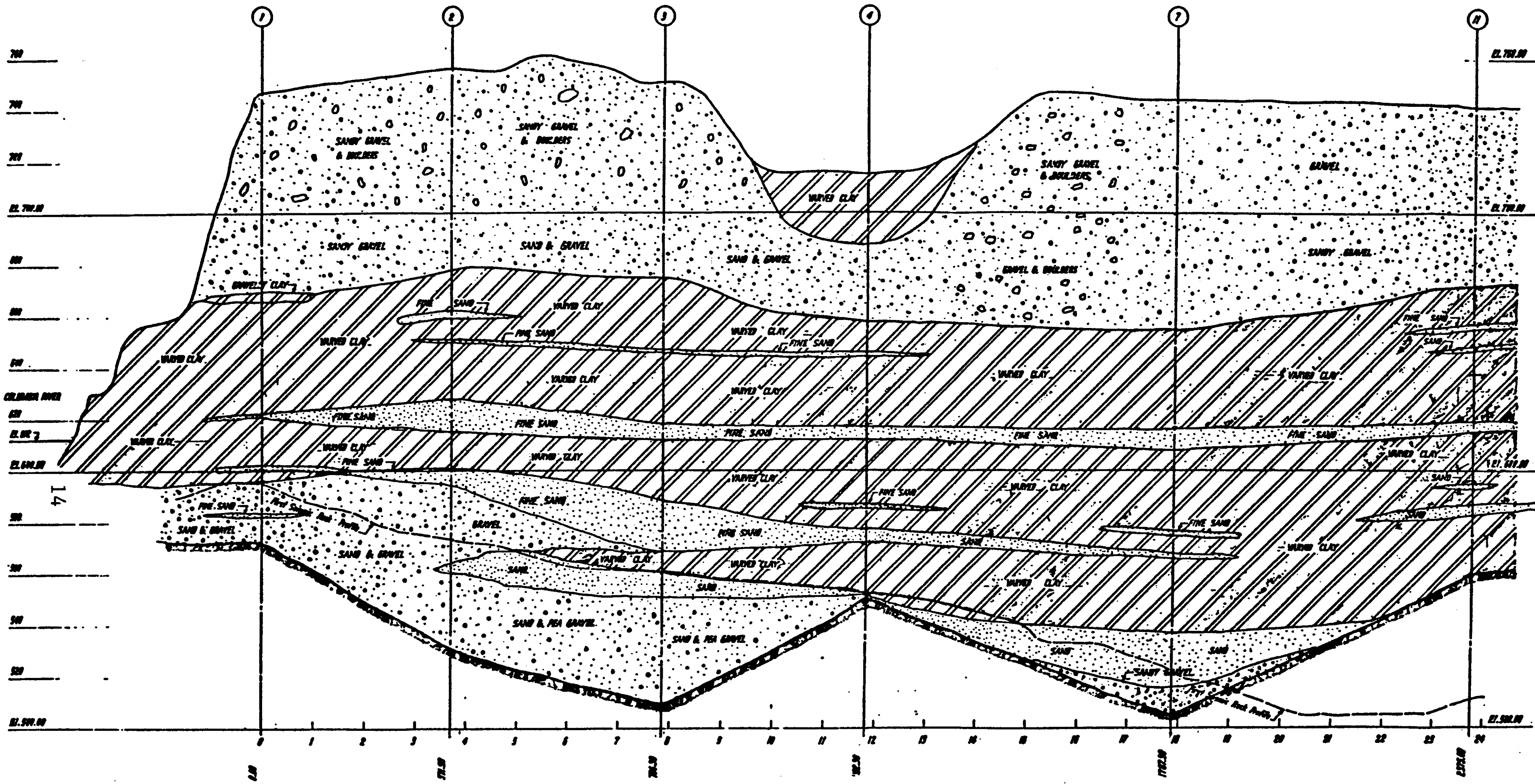
Of primary significance in these studies is the occurrence of finely stratified silts and clays referred to as "varved silt or varved clay because of its banding" (2). Subsequent to the deposition of the previously described sands and gravels, an Ice Age lake formed in the Columbia River caused by some downstream blockage estimated to be some 25 miles below Rocky Reach Dam (2). The resulting lake produced an extensive and deep deposit of banded or varved silts and clays. This deposit has been encountered in areas almost 300 feet above the current river level (4). Subsequent erosion by the river after the lake drained probably eroded much of this soft material. "Nevertheless, fairly extensive patches still remain" (2).

After erosion of the silts and clays, the river continued to deposit coarse sands and gravels. In some areas these covered the varved clays, but in some places they may have abutted against them. Thus, the sedimentary stratigraphy as revealed in foundation drilling on the east side of the valley for Rocky Reach Dam indicates a thick deposit of varved silts and clays sandwiched between layers of poorly sorted, coarse grained sands and gravels (figure 5).

These foundation studies examined the area of the valley close to the river. Near the side slopes of the valley, variations in the depositional environment could have been produced by local alluvial outwash from side drainages and continuous rock fall from the boundary cliffs producing talus not only on top of but also mixed with other sedimentary layers. Peck (2) explains that this could produce deposits more pervious than in the remainder of the sediments. Peck also discusses direct glacial deposition in the area of the dam.

Because of their believed contribution to the slope failure, additional detail on the varved clays and silts are presented here from a Stone and Webster report (3) prepared during construction of Rock Reach Dam.

> The clay and silt member is generally massive but contains lenses or layers of very fine to medium fine, uniform clean sands (figure 5). Many of these sands were water bearing and have been represented as continuous layers. They are considered to have very low strength (ML in the soil classification system). These sand layers in the varved clays/silts were considered to be responsible for old landslides in the river bank (prior to construction of the dam)



(Plate 5 Section A – A from Stone and Webster Report)

FIGURE 5

CROSS-SECTION SHOWING VARVED SILTS AND CLAYS WITH SAND LAYERS BETWEEN SAND AND GRAVEL BEDS

(From Rocky Reach Dam Investigation)

The varved clays/silts pinch out about 1000 feet upstream of the dam site but are thicker toward the south (the slide area). It is probable that the number of sand members and coarseness of grading of the sands also increased toward the south. It is also probable that this series of beds extends southward in the valley nearly to the Wenatchee River.

The report also states that the upper surface of the clay/silt beds slopes or dips downward toward the north and slightly toward the river.

Although the Stone and Webster foundation investigation involved the east bank of the river about 1 1/2 miles upstream of the slide area, it is reasonable to assume that these glacial sediments extend south into the area of the valley containing the slope failure. The existence of remnant varved clay/silt beds was identified on the exposed bedrock surface above the slide rubble at an estimated height of approximately 100 feet above the highway level. In addition, discussion with Morrill Asphalt Paving Company personnel established that clay was found in a test pit on the property line between the Edwards (north pit) and Staples (south pit) (figure 6) properties at the elevation of and about 100 feet west of the highway.

The clay was also detected in a previously operated pit on the east side of the railroad, along the river somewhat south of the current pit. The clay was said to be 8 to 10 feet above the river level. Thus, there is evidence of a remnant deposit of varved clay/silt running from the west bank of the river up to a point on the escarpment about 100 feet above highway level. It is probable that a very thick sequence of varved clay/silt underlaid the talus material to the west of the gravel pit and that the sand and gravels forming the deposit being mined did not extend under the talus to the gneiss bedrock. The existence of this remnant deposit may be in part due to the protection this bedrock escarpment would have given from lateral erosion.

ESTIMATE OF PRESLIDE PIT GEOMETRY

There are no maps to show the configuration of the pit immediately prior to the slope failure. This gravel pit has been worked intermittently over a period of many years by several different operators. The best estimate of the configuration has been developed from the combination of aerial photos taken in 1979 by the Washington Department of Transportation and descriptions of the layout of the pit from Lloyd Logging, Inc. employees. Photographs taken from across the river on the day before the slide give some general confirmation as to the shape of the pit. Both eyewitness interviews and photographs indicate that pit walls were moderately

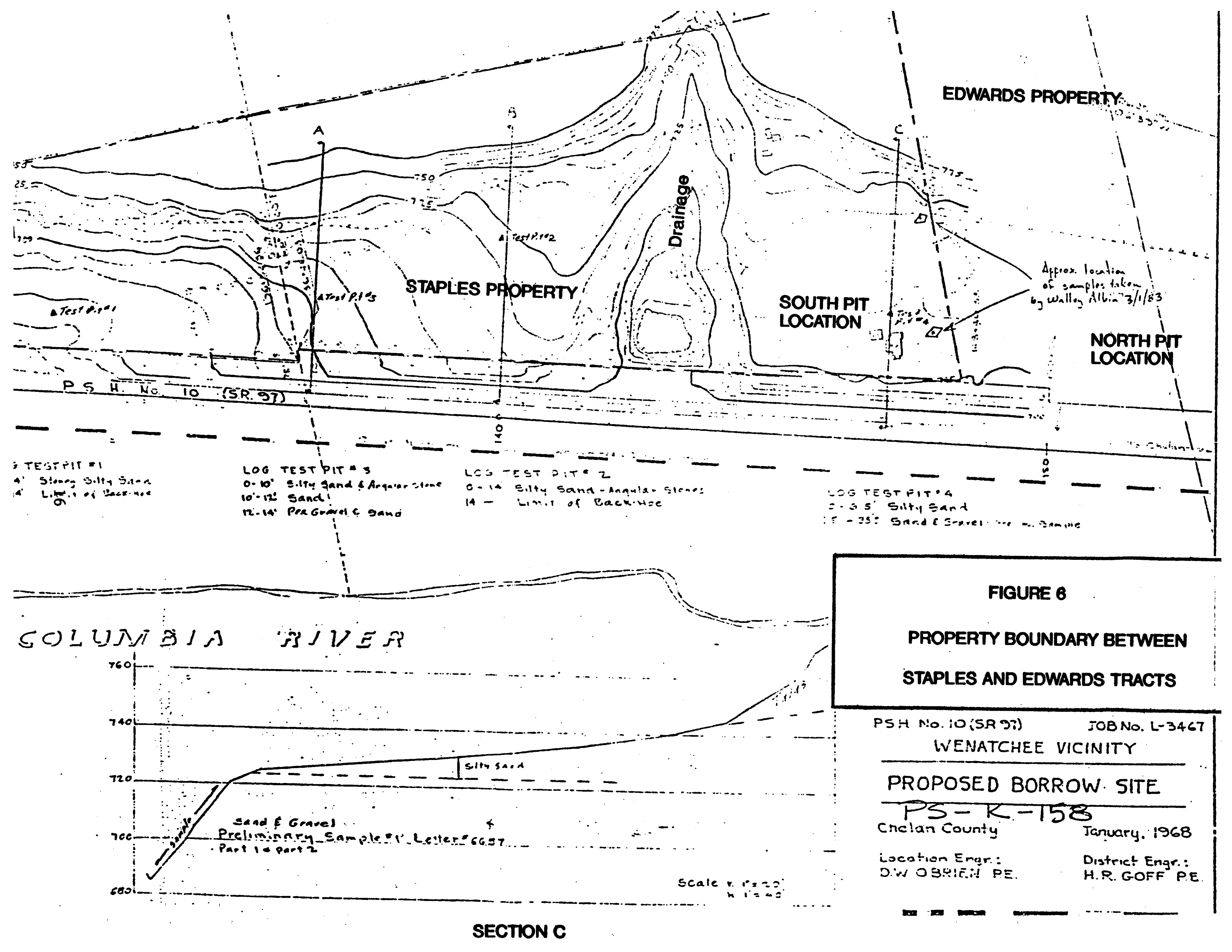


FIGURE 6

PROPERTY BOUNDARY BETWEEN STAPLES AND EDWARDS TRACTS

sloping, not vertical or extremely steep or high.

Aerial photos taken by the Washington Department of Transportation (strip photo) in May 1992 and by the U.S. Forest Service (stereo pair) in July 1992 indicate two separate pits with an unmined area of the gravel bench between. This unmined area would have acted as a buttress against the talus slope. Production records provided by Morrill Asphalt Company indicate a volume of about 160,000 cubic yards has been removed since 1992 although there is no indicated production in May, June or July 1992. What has become the north pit was initially operated in the 1950's during construction of Rocky Reach Dam. The south pit has been operated since about 1983. Production volume from previous operators in both pits could not be determined. Photos taken at the south pit 2 weeks prior to the failure indicate that most of the remnant bench area between the north and south pits had been removed (photo 14). A photo taken from across the river the day before the failure also indicates that most of the remnant bench had been removed (photo 15).

According to Lloyd Logging personnel, the floor of the north pit was about 200 feet wide from the highway to the toe of the gravel bank. Then there was a gravel bench rising about 30 to 40 feet above the pit floor. The talus slope extended up from the rear of the bench.

The cross-section (figure 7)prepared from the map of pre-mining topography shows a probable profile of the pit prior to failure.

FACTORS AFFECTING THE STABILITY OF THE SLOPE

As described in the report "Landslides: Analysis and Control" (5), the important factors in evaluating landslides are: (1) topography, (2) geology, (3) ground water, (4) weather, (5) vibration and (6) history of slope changes.

Topography is the first factor to consider because some difference in elevation is necessary to provide the potential energy to drive a landslide. Obviously the steeper the gradient of the surface and the greater the mass of the potential slide, the more energy can be developed in a failure. The topography in the area of the pit shows a very dramatic rise to the west. The talus slope towered almost 300 feet above the pit floor. Also, the near vertical scarp in the metamorphic rock that rises above the talus is a good indicator of a sliding surface on the uphill side of the slope. This combination insures a significant potential for a slide if foundation materials beneath the talus are weak.

The geology is second in importance. The geologic nature of the potential slide material and the underlying foundation can

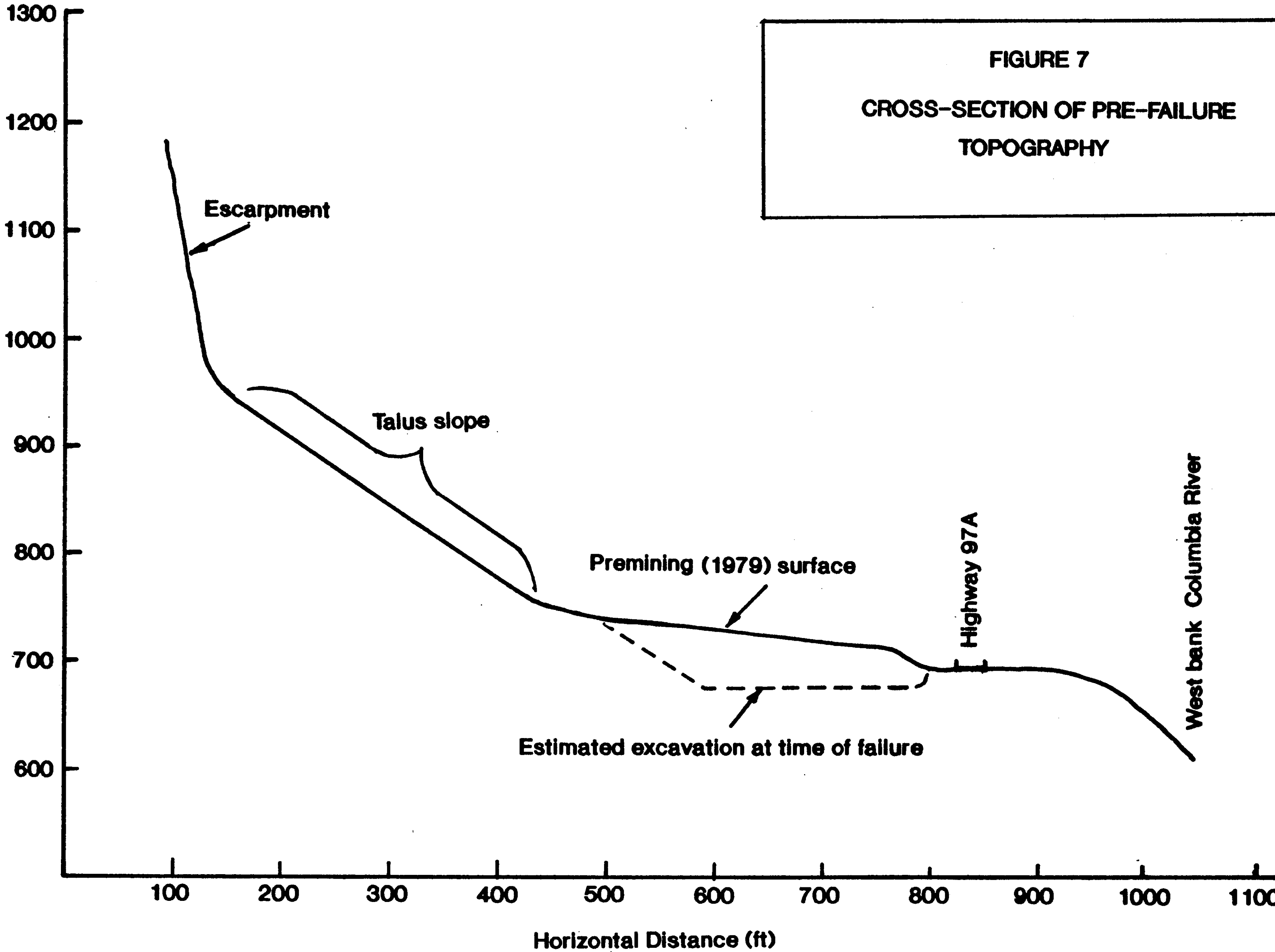


FIGURE 7

CROSS-SECTION OF PRE-FAILURE TOPOGRAPHY

determine whether a slope with a high topographic potential for a slide will fail or be stable. If the foundation under the talus-debris slope was a competent stable material, the slope might suffer narrow, surface slides with excavation. However, the presence of a very weak foundation material can be a key factor in creating a large or catastrophic failure if the toe area should be unloaded. In this case a large, thick remnant of a lacustrian deposit of varved silts/clays having a high moisture content and a low shear strength is believed to have underlain the talus slope at depth. In addition, as determined by other geologic investigations in the area, layers and lenses of clean sands (having no cohesion) were probably interbedded within the silts and clays. This very weak foundation material created a high potential for a "classic", deep-seated rotational failure below the talus slope.

The subsurface investigation that was done on the property where the test pits were dug was done only for the purpose of determining the thickness of recoverable sand and gravel. No evaluation to determine the type or quality of the foundation material under the gravel was ever performed.

The presence of ground water can create instability in otherwise stable slopes. In fine-grained materials such as silts and clays, increases in ground water levels can reduce the effective pressure in these materials thus reducing shear strength. The presence of sand lenses and layers will aggravate the situation especially where the resulting stratigraphy is poorly drained. No water was reported in the pit areas nor were any springs or water flows reported in the slope areas above the pit, but, if the subsurface materials were poorly drained, water infiltration into the foundation material could have been increasing and not been observed. Dark streaks running down the exposed rock face immediately after the failure could be indicators of zones of moisture along the interface between the talus and the metamorphic rock slope; however, there was no reasonable way to confirm this suspected presence of moisture.

The potential for ground water seepage pressure to cause problems in strata similar to that believed to exist under the slope that failed is emphasized in the following quotes from Terzaghi and Peck (6)

> "The erroneous but widespread conception that stiff clay and dense concrete are impermeable is due to the fact that the entire quantity of water that percolates through such materials toward an exposed surface is likely to evaporate, even in a very humid atmosphere. As a consequence, the surface appears to be dry. However, since the mechanical effects of seepage are entirely independent of the rate of percolation,

the absence of visible discharge does not indicate the absence of seepage pressures. Striking manifestations of this fact may be observed while an excavation is being made in very fine rock flour. The permeability of this material is very low. Yet, a slight change in the pressure conditions in the porewater may suffice to transform a large quantity of the material into a semiliquid." p.47

"One important class of slides, however, provides an exception to the general rule that slides do not occur over a broad front. If the geological conditions are such that the major part of the surface of sliding is located within a horizontal layer of coarse silt or sand that separates two layers of clay, the width of the slide measured parallel to the crest of the slope is likely to be very much greater than the length of the slide. Slides of this type are commonly caused by an excess porewater pressure in the sand or silt layer. In contrast to slides of the other types, they are not preceded by readily detectible symptoms of impending danger, and the failure occurs almost suddenly." p.415

Thus, although direct evidence of the presence of ground water is lacking, it can be inferred from the nature of the failure that ground water probably was a factor in the slope failure.

Both short-term changes in precipitation such as heavy storms and/or unusual seasonal variations in moisture can, through percolation, change the ground water levels in slopes which may influence their stability. U.S. Weather Bureau records from the Wenatchee, WA station indicate that whereas the normal precipitation in the area is about 9.92 inches per year, there had already been 7.96 inches in the first 5 months of 1995. (This included 3.55 inches of rain in January - a record). The spring of 1995 was an abnormally wet period for this area and it is highly probable that some of this moisture percolated down through the talus and colluvium into the silt/clay and sands below. The drainage to the south of the pit contains a minor intermittent stream that was flowing water at the time of the slide. This is an indication of increased ground water in the area.

Seismic activity is a known initiator of landslides. The Columbia River valley between Wenatchee and Chelan has experienced a concentration of low level seismic activity in the past, primarily around Entiat. There is an "earthquake point" about 20 miles north of Wenatchee where in 1872 an earthquake of 7.0 magnitude triggered a large slide that temporarily dammed the Columbia River. However, records at the USGS National Earthquake Information Center in Golden, Colorado indicated no seismic activity in the State of Washington on May 19, 1995. Thus seismic activity is not considered a factor in this slope failure. Likewise man made vibrations such as blasting or road or rail traffic are unlikely to have been a factor. No blasting was done at the pit or anywhere else in the immediate area. Other man made vibration sources could not have had a significant effect on the stability.

The history of changes in the slope configuration is significant in evaluating slope failures as steepening the slope or removal of material at the toe can frequently initiate slope failures. The change in configuration of this pit took place over a long period of time involving periods of activity separated by long periods of inactivity. Thus, the profile of this slope changed relatively slowly. Nonetheless, the mining of the gravel bench over a period of time removed the toe area at the base of the talus slope. The mining in the south pit was possibly as much a 20 feet below the highway level and at the last stages of operation encountered the clay/silt material suspected of underlying the talus. Thus, although no large scale mining of the talus slope was done, the mining at the bottom of the slope up to the talus removed both the lateral constraint against the toe and the gravity load of the bench gravel from the floor of the developed pit. When combined with the towering talus slope above the pit, the weak foundation material and the possible influence of ground water on the failure, the long-term mining directly contributed to the failure of the slope.

PHYSICAL PROPERTIES OF SOIL SAMPLES

Samples of the varved silts/clays were taken at each site where a victim was recovered and also at the south pit where these materials were exposed. The samples were tested at a commercial testing laboratory for the basic soil indexing properties of Atterberg limits (liquid limit, plastic limit), specific gravity and moisture content. No strength property determinations were made. The results of the tests are shown in the following table:

Sample No.	1	2	3	4
Soils Classification	CL-ML Silty Clay	CL-ML Silty Clay	CL Lean Clay	CL Lean Clay
Specific Gravity	2.75	2.73	2.75	2.76
Moisture Content	33.5	22.0	41.1	37.7
Liquid Limit	34.8	34.8	45.1	48.9
Plastic Limit	29.5	29.0	26.1	23.4
Plasticity Index	5.3	5.8	19.0	25.5

Sample 1 was taken 25 feet south of victim #2, sample 2 was taken from the exposed varved clays on top of the loess pile in the south pit, samples 3 and 4 were taken from a thick clay bed near the

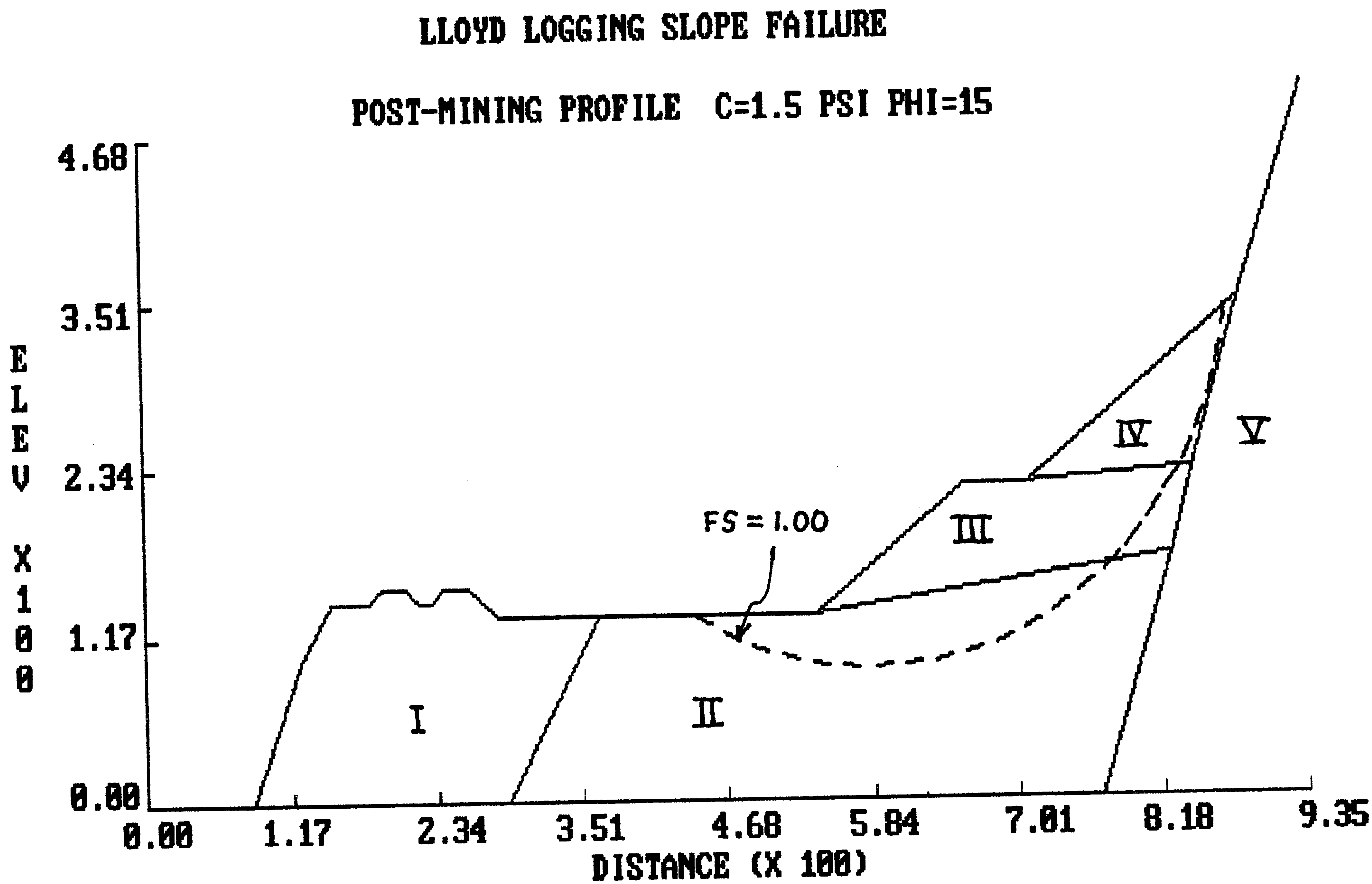

LLOYD LOGGING SLOPE FAILURE
POST-MINING PROFILE C=1.5 PSI PHI=15
4.68
3.51
2.34
1.17
0.00
ELEV X 100
0.00
1.17
2.34
3.51
4.68
5.84
7.01
8.18
9.35
DISTANCE (X 100)
FS = 1.00
I
II
III
IV
V

FIGURE 8.

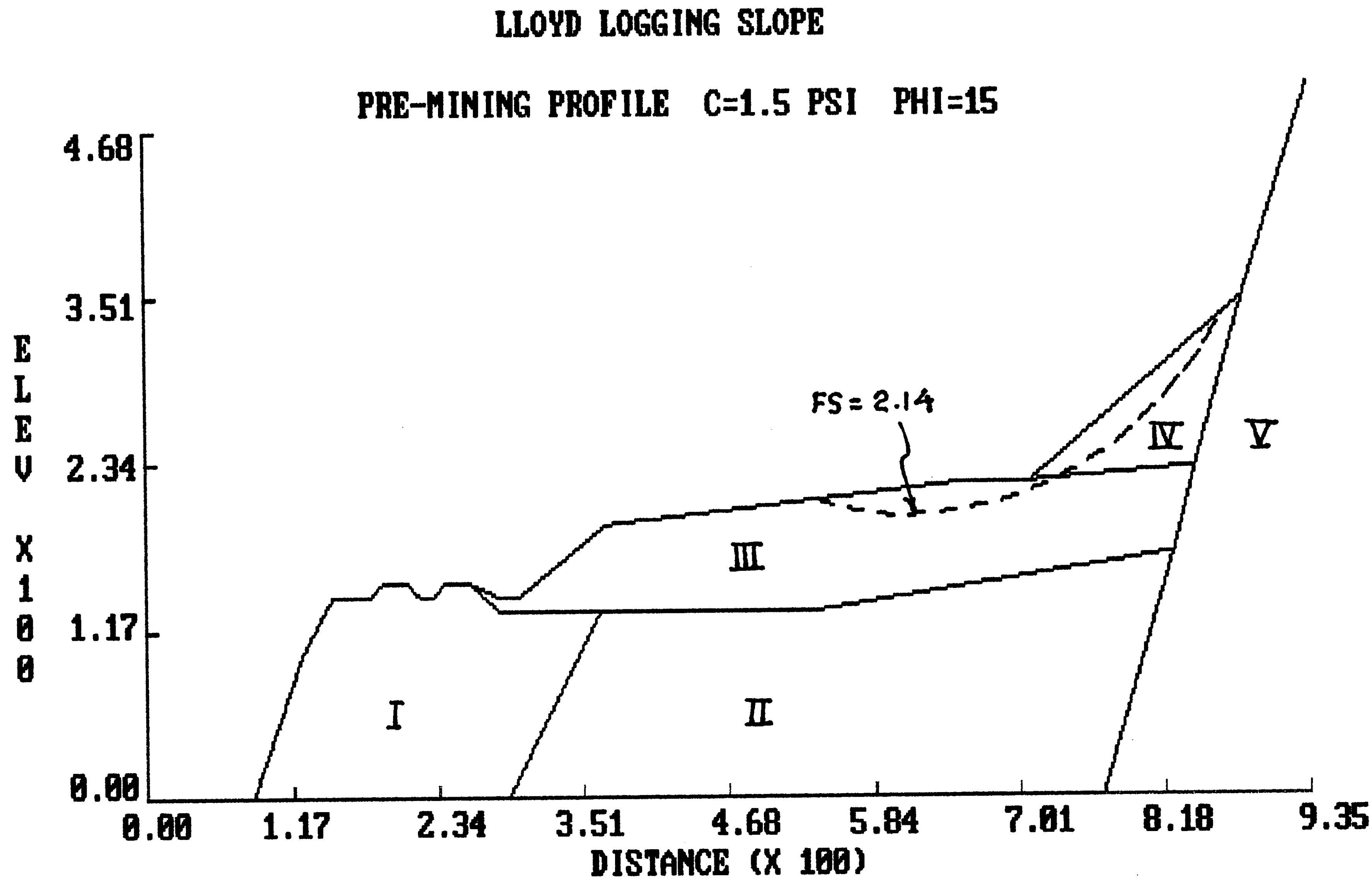

LLOYD LOGGING SLOPE
PRE-MINING PROFILE C=1.5 PSI PHI=15
ELEV X100
4.68
3.51
2.34
1.17
0.00
FS = 2.14
I
II
III
IV
V
0.00
1.17
2.34
3.51
4.68
5.84
7.01
8.18
9.35
DISTANCE (X 100)

FIGURE 9.

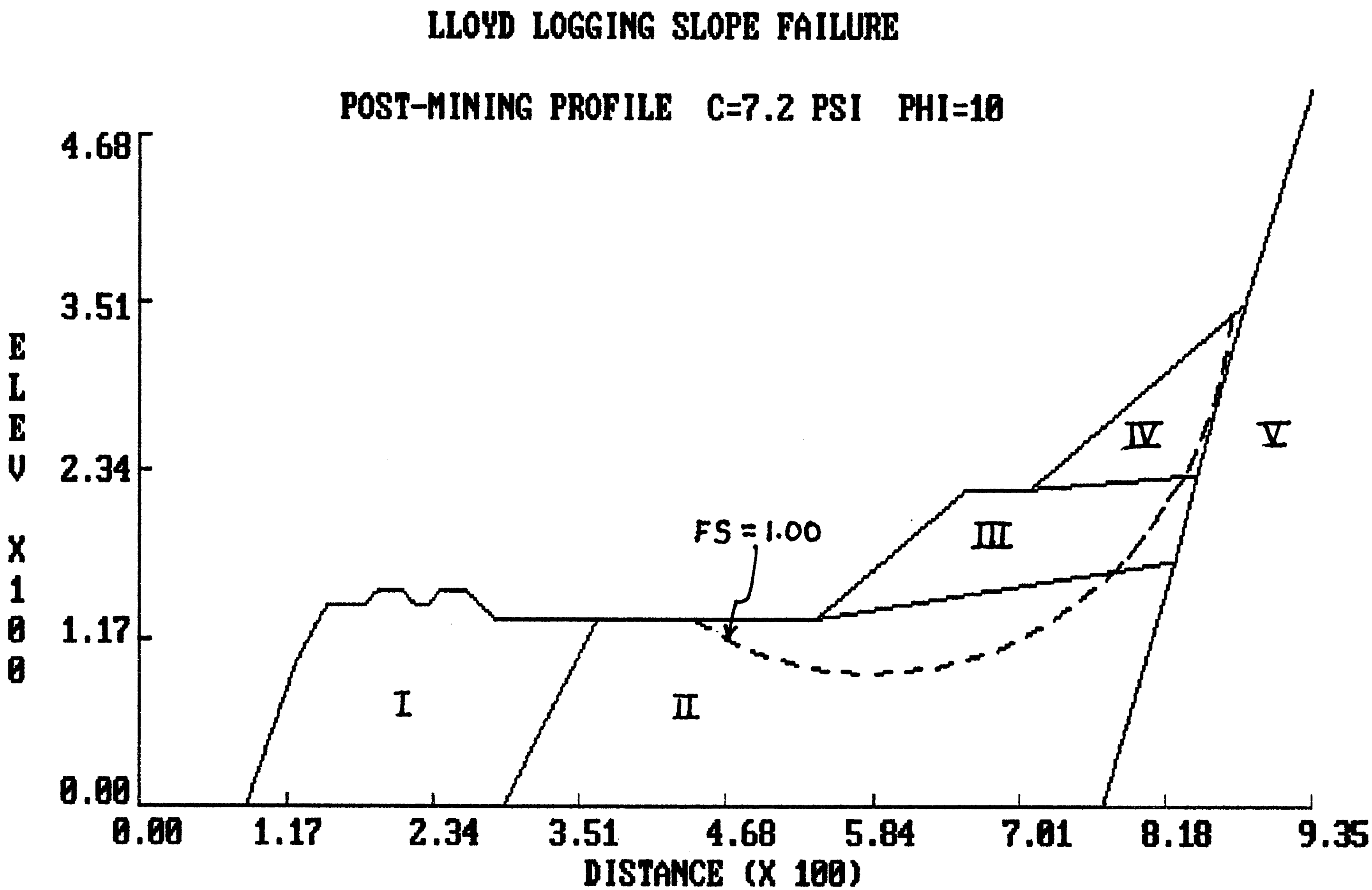

LLOYD LOGGING SLOPE FAILURE
POST-MINING PROFILE C=7.2 PSI PHI=10
ELEV X100
4.68
3.51
2.34
1.17
0.00
DISTANCE (X 100)
0.00
1.17
2.34
3.51
4.68
5.84
7.01
8.18
9.35
FS = 1.00
I
II
III
IV
V

FIGURE 10.

Interviews with witnesses and visitors to the pit prior to the slope failure, and a review of MSHA records indicated that the contractor, Lloyd Logging, Inc., was maintaining pit walls in accordance with normally accepted, prudent mining practices. However, without subsurface exploration and a mining plan which would recognize and accommodate the presence of the glacial clays, failure was predestined. The presence of remnant deposits of glacial clays within the Columbia River valley is well documented, and one such deposit was thoroughly investigated during the construction of the nearby Rocky Reach Dam.

RECOMMENDATIONS

In areas where glacial activity is known to have occurred, subsurface geotechnical investigations should be conducted prior to the commencement of open-pit mining operations. Based on the results of the geotechnical investigation, mining plans should be developed which recognize and control geotechnical hazards such as glacial clays to prevent future catastrophic slope failures.

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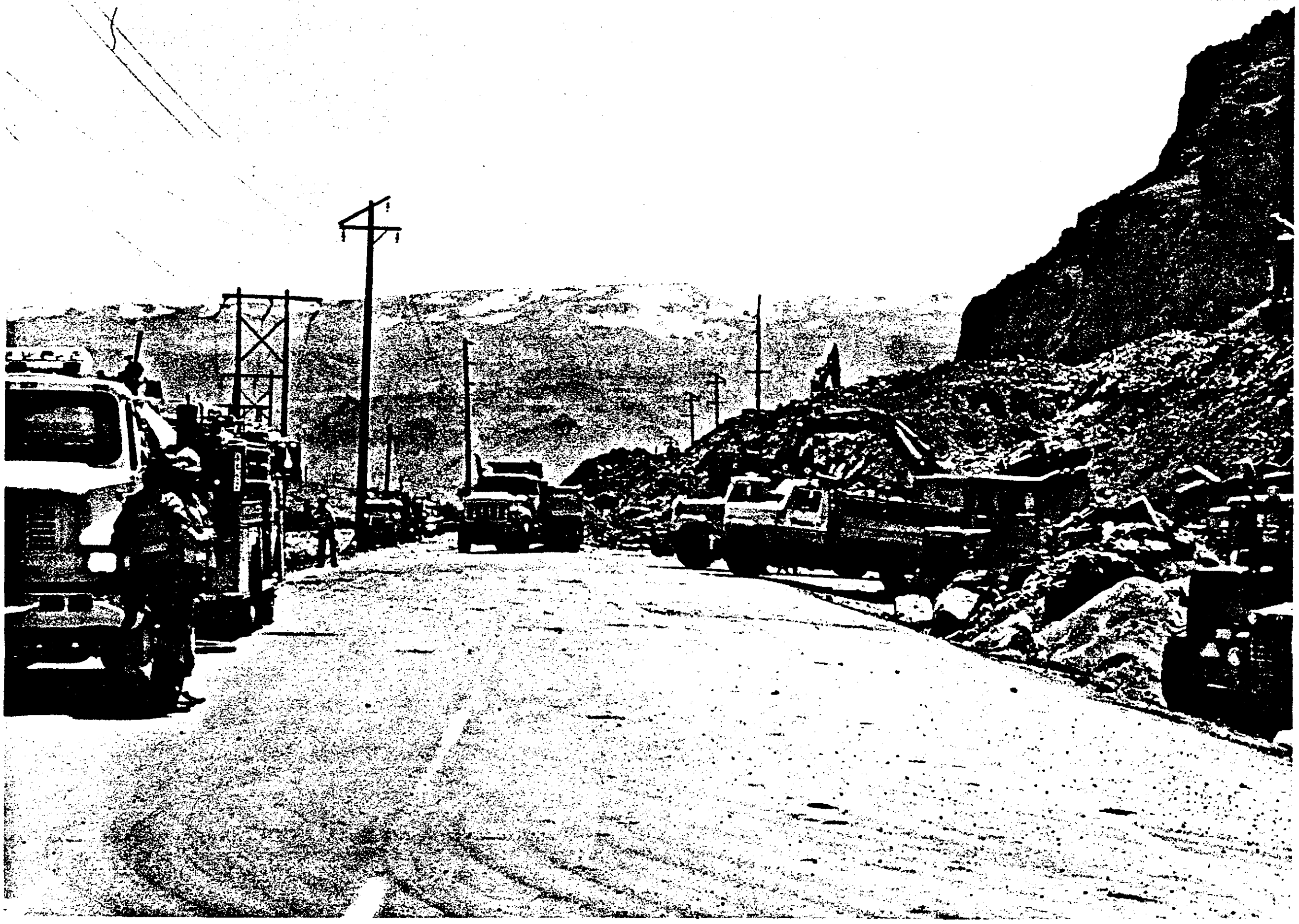


PHOTO 1. - Taken a few hours after the failure. Looking south on State Highway 97A. Slide material has run out about halfway across the highway to a depth of about 20' (Washington State Department of Natural Resources).

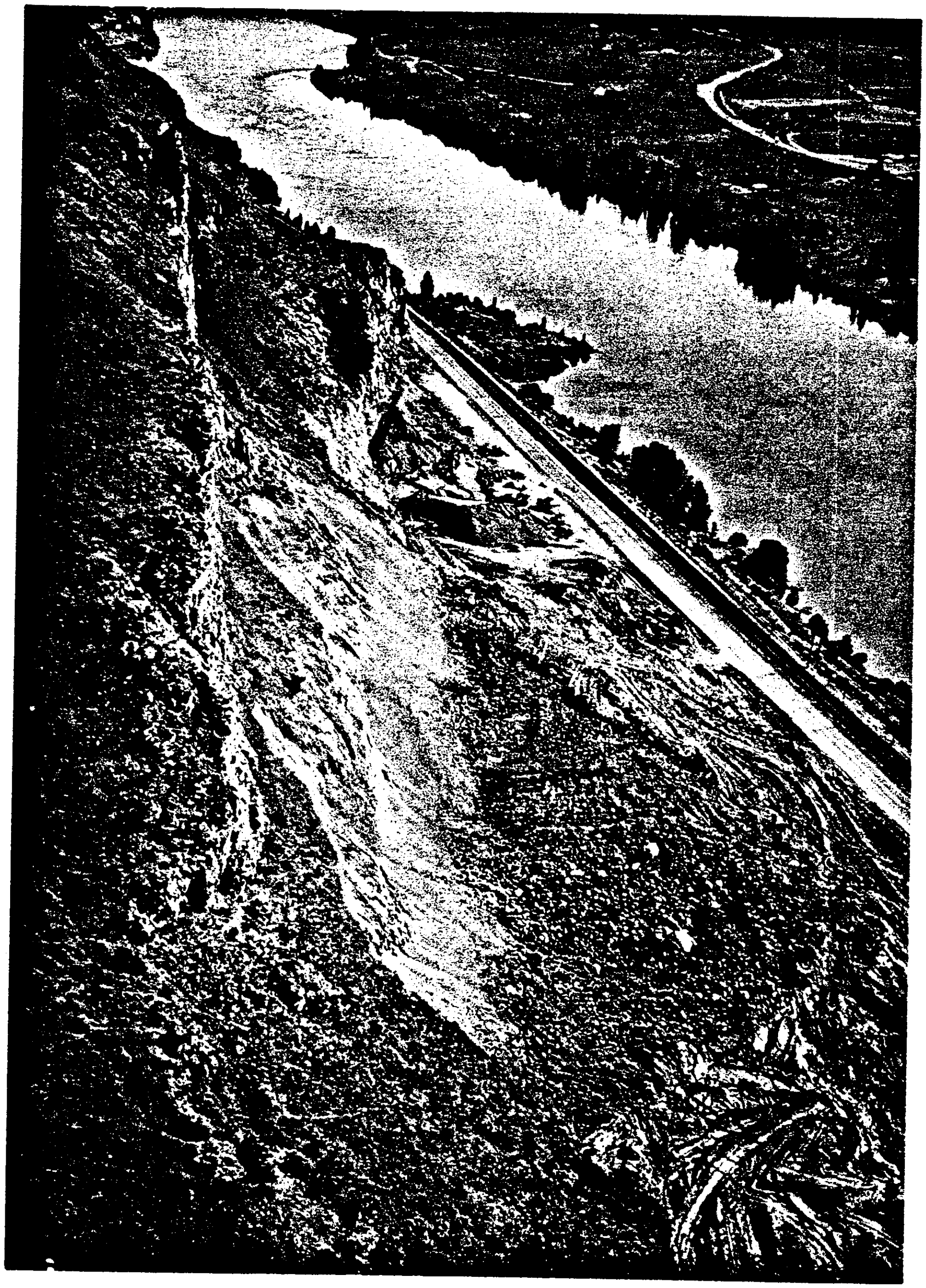


PHOTO 2. - Aerial view of slope failure looking down the vertical scarp above the slide area. The rock face against which the talus rested before the slide is partially obscured by post slide slough. Note the carpet-like appearance of the vegitated top surface of the slide area (below center-right).

PHOTO 3. - Looking to the north at the landform created by the slope failure. Much of the surface of the talus came down as a "carpet." The area near the gneiss rock surface (center left) is lower and has formed a pocket or shallow depression relative to the higher part of the debris to the right in the photo. Post failure slough has covered the talus near the rock surface. Varved clay remnent is shown at arrow.

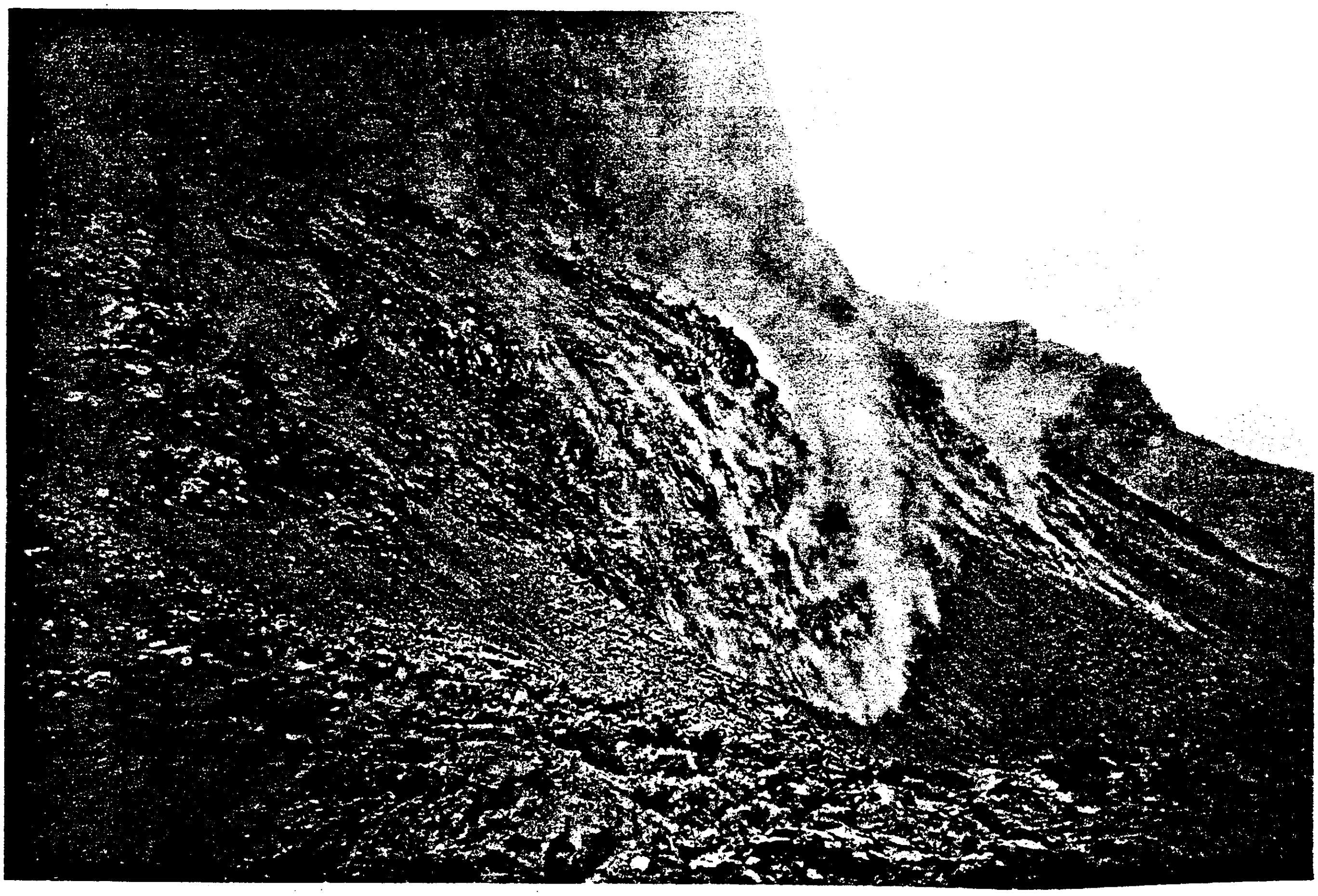


PHOTO 4. - Post accident drying, sloughing and adjustment of slope to new slope configuration.

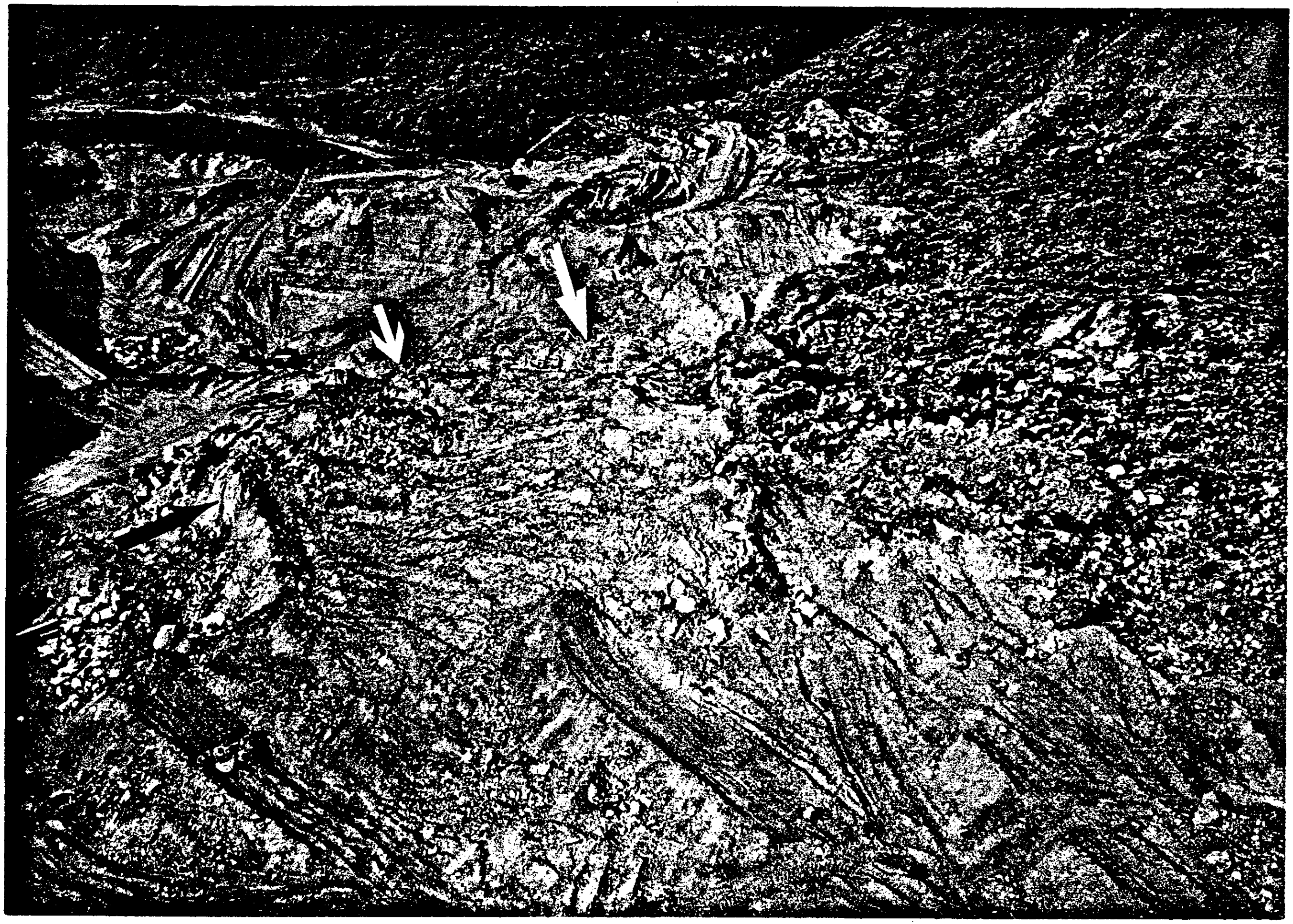


PHOTO 5. - Aerial photo of the south pit area after the failure. Highway 97A is just off the left edge of the photo. White arrows point to location of varved silts/clays observable in the slide material. Black arrow (on left) points to material that was originally in the pit floor about 150 feet to the right in the photo and 30 to 40 feel lower (as shown in photo 6). Just above the arrow is a 120 ton boulder that was displaced at the same time.

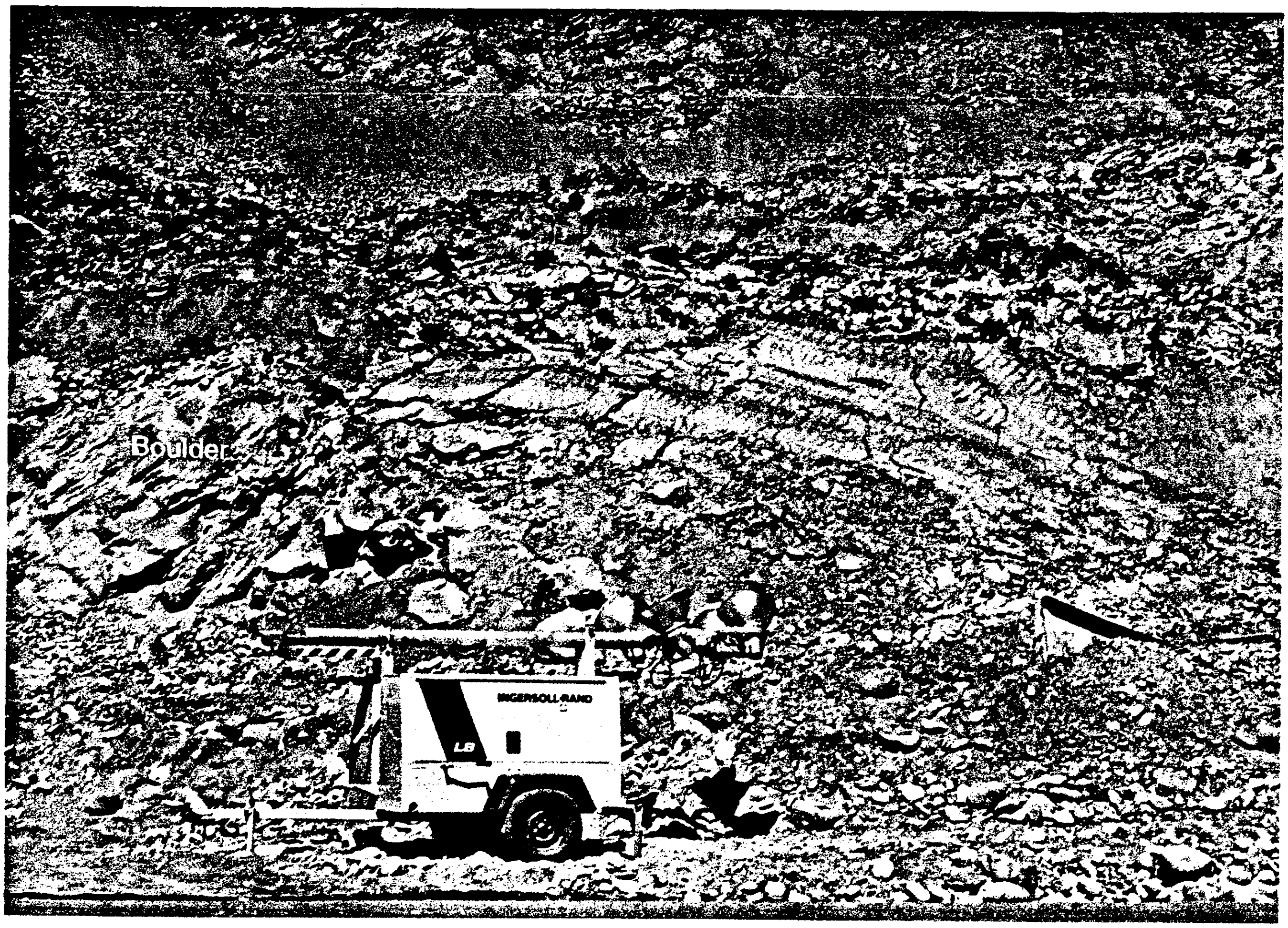


PHOTO 6. - Large boulder (on left) and upheaved pit floor with tire tracks. Both boulder and tire tracks were raised up 35 to 40 feet and moved approximately 150 ft. east.

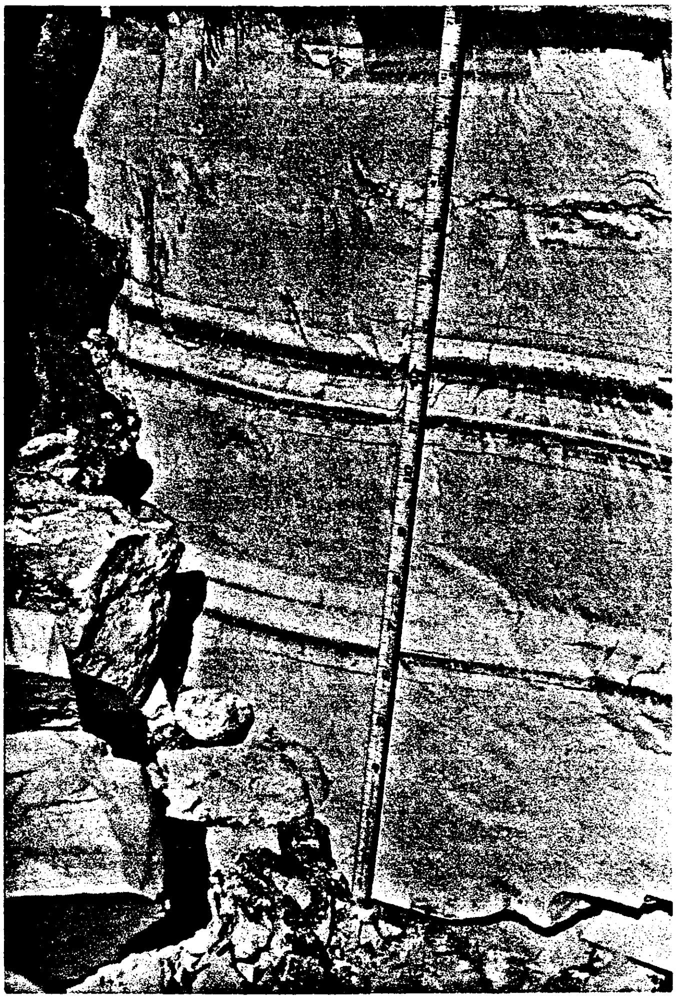


PHOTO 7. - Varved silt and clay with thin sand layers between varves. Located on upper surface of slide in south end of slope failure (See Photo 5).

PHOTO 8. - Another view of the varved clay and silt at the same location as photo 7. Note the very laminar structure of this material.

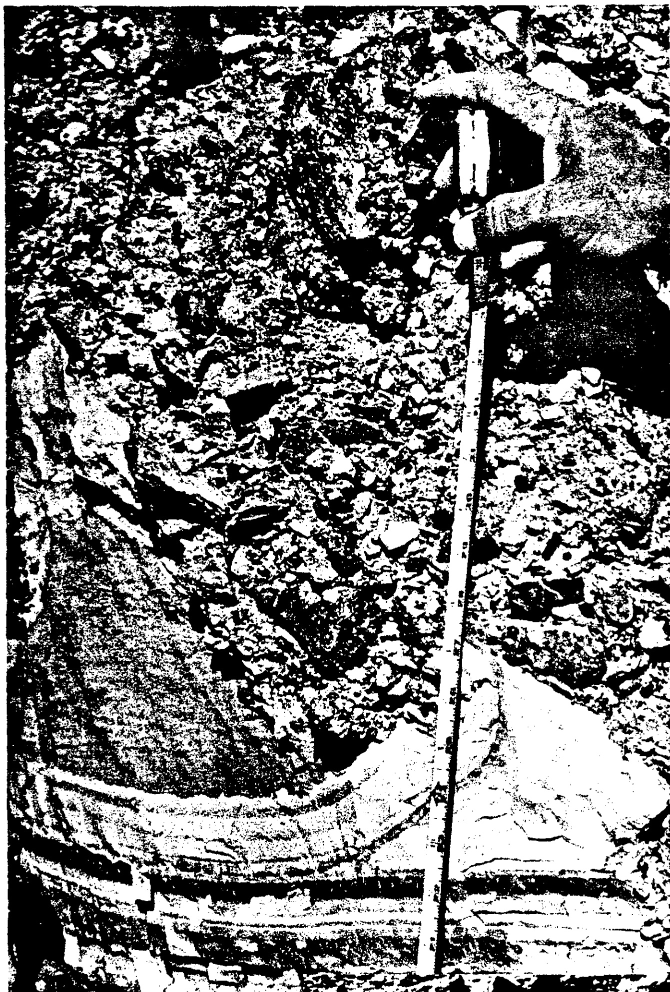


PHOTO 9. - Varved clay showing a historic slump-type failure feature where one bed has slid over another. Note gneiss coluvium (talus) on top of clay. This demonstrates that the clay material can fail under its own weight indicating a very low shear strength.

PHOTO 10. - Outcrop of varved clay near the north end of the slide. Note cobbles and gravels above clay.

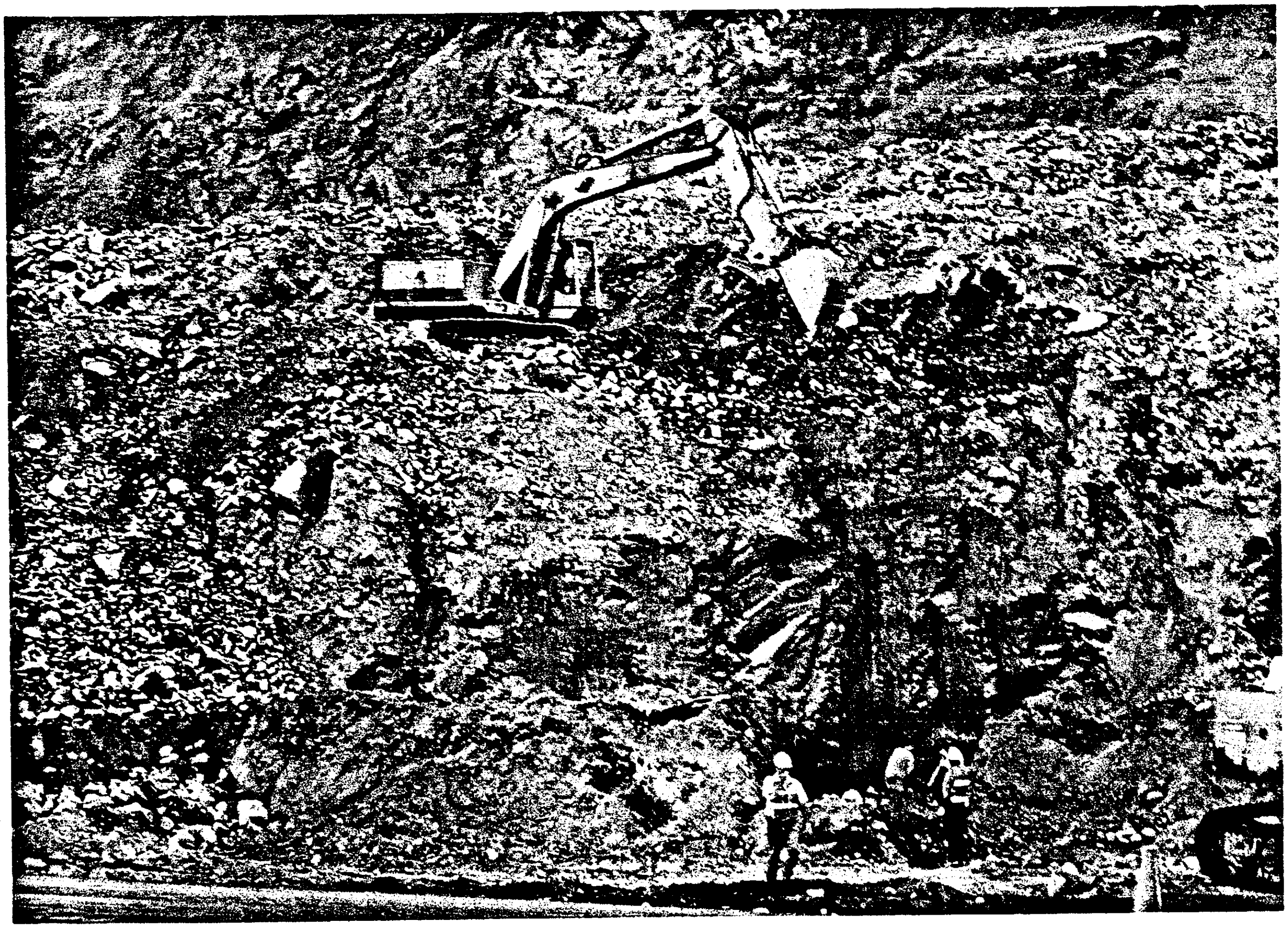


PHOTO 11. - Face of slide at the location where second victim was recovered in the north part of the pit. Tooth marks from backhoe denotes silt/clay layer 25 to 30 feet thick above pit floor.

PHOTO 12. - Aerial view of the rock surface of the Swakane gneiss exposed by the slide. Arrow points to the location of remnant area of varved silt/clay on the rock surface. Closeup of this is shown in photo 13.

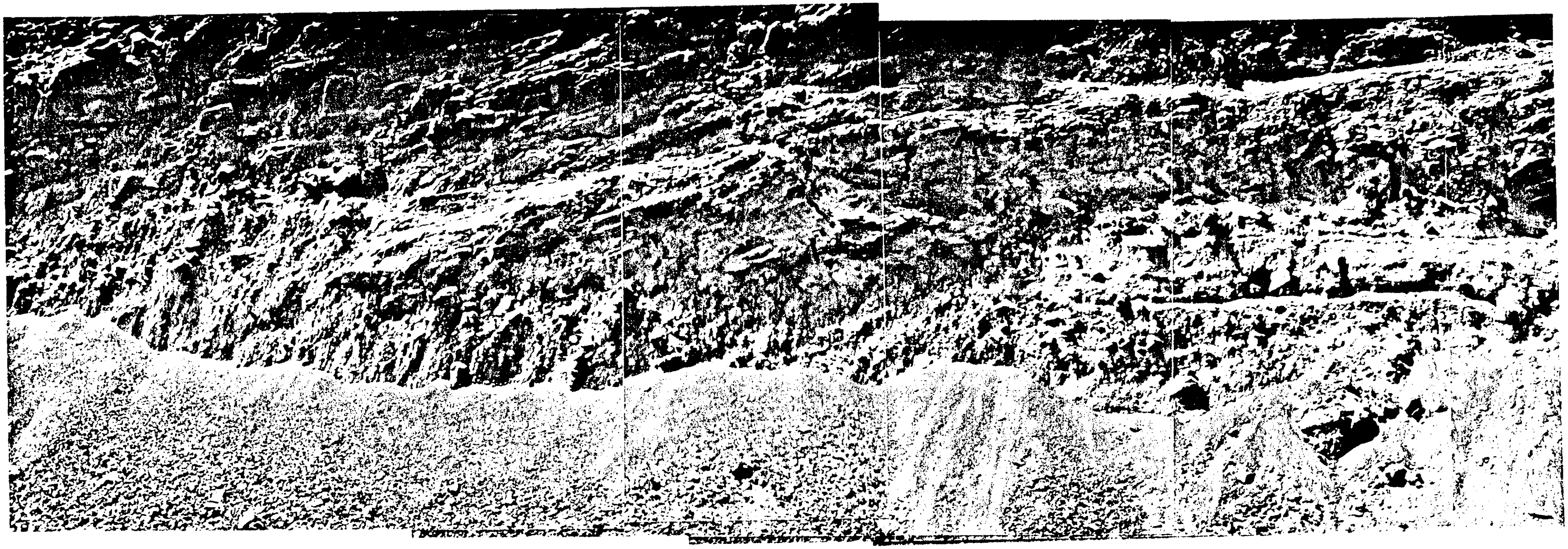


PHOTO 13. - Remnant of varved silt/clay beds on the gneiss rock surface exposed by the failure of the talus slope. Pieces of the gneiss talus are embedded in the silt/clays. This remnant is estimated to be about 100 feet above the pre-failure pit floor. Post failure slough covers the lower part of these silt/clay beds in the photo.

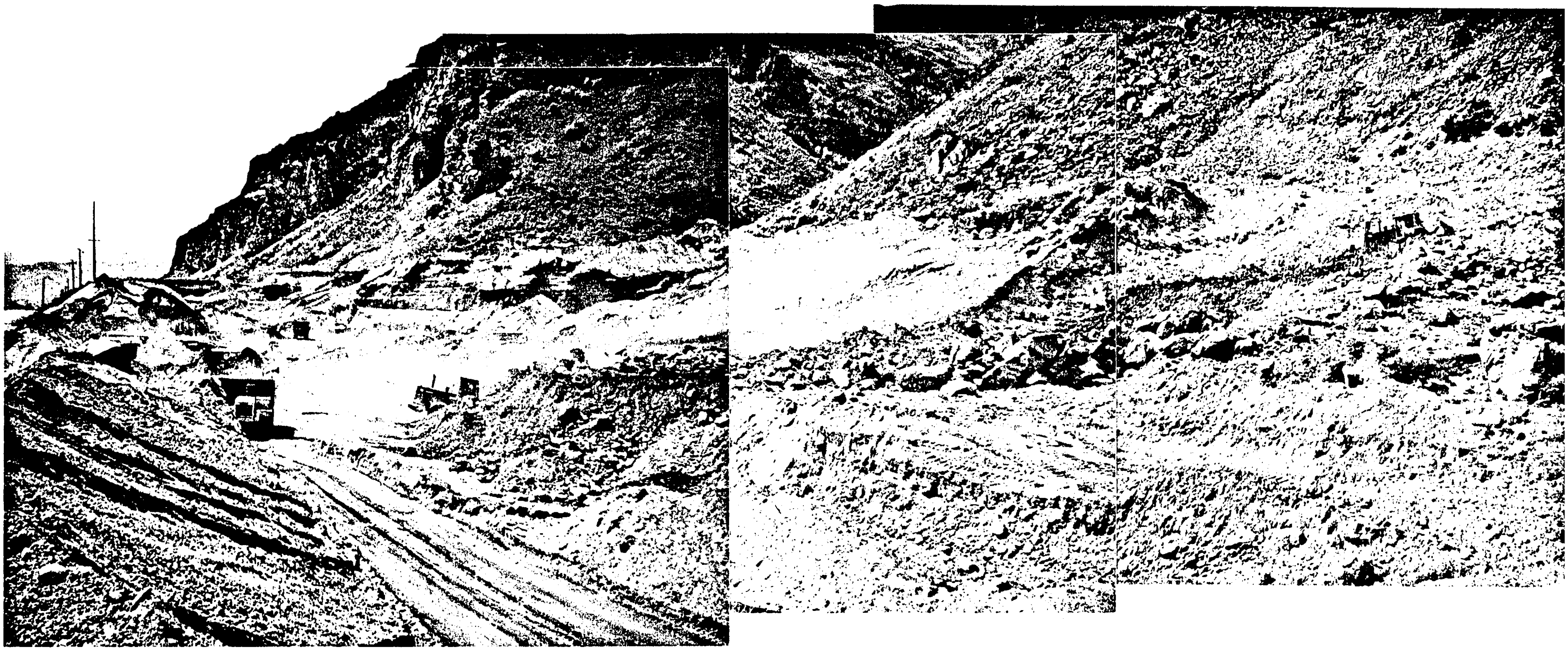


PHOTO 14. - Panorama shot of the south pit approximately 2 weeks prior to the slope failure. The gravel bench that originally separated the north and south pits has been largely mined out. (Washington State Department of Natural Resources).

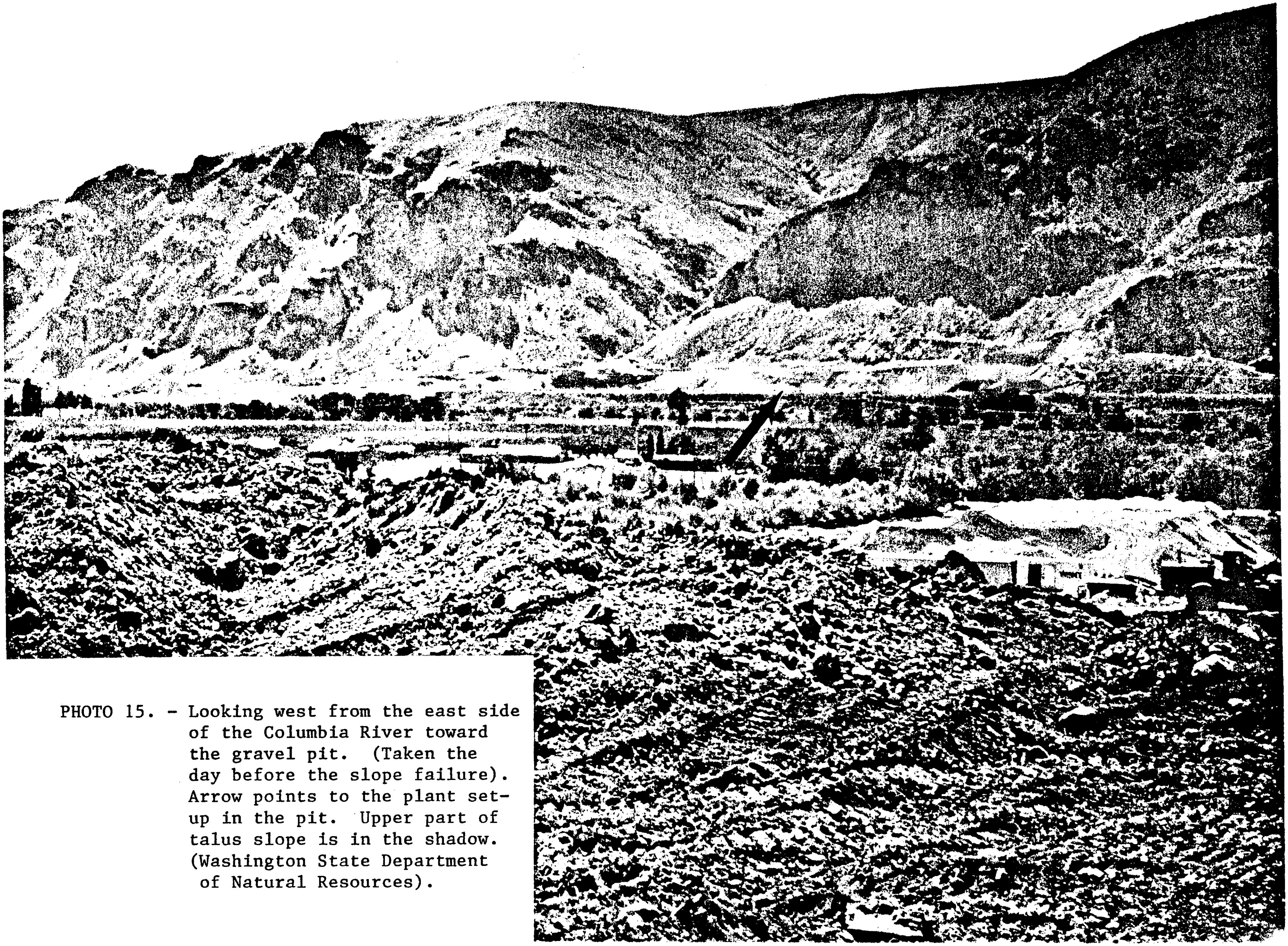


PHOTO 15. - Looking west from the east side of the Columbia River toward the gravel pit. (Taken the day before the slope failure). Arrow points to the plant set-up in the pit. Upper part of talus slope is in the shadow. (Washington State Department of Natural Resources).

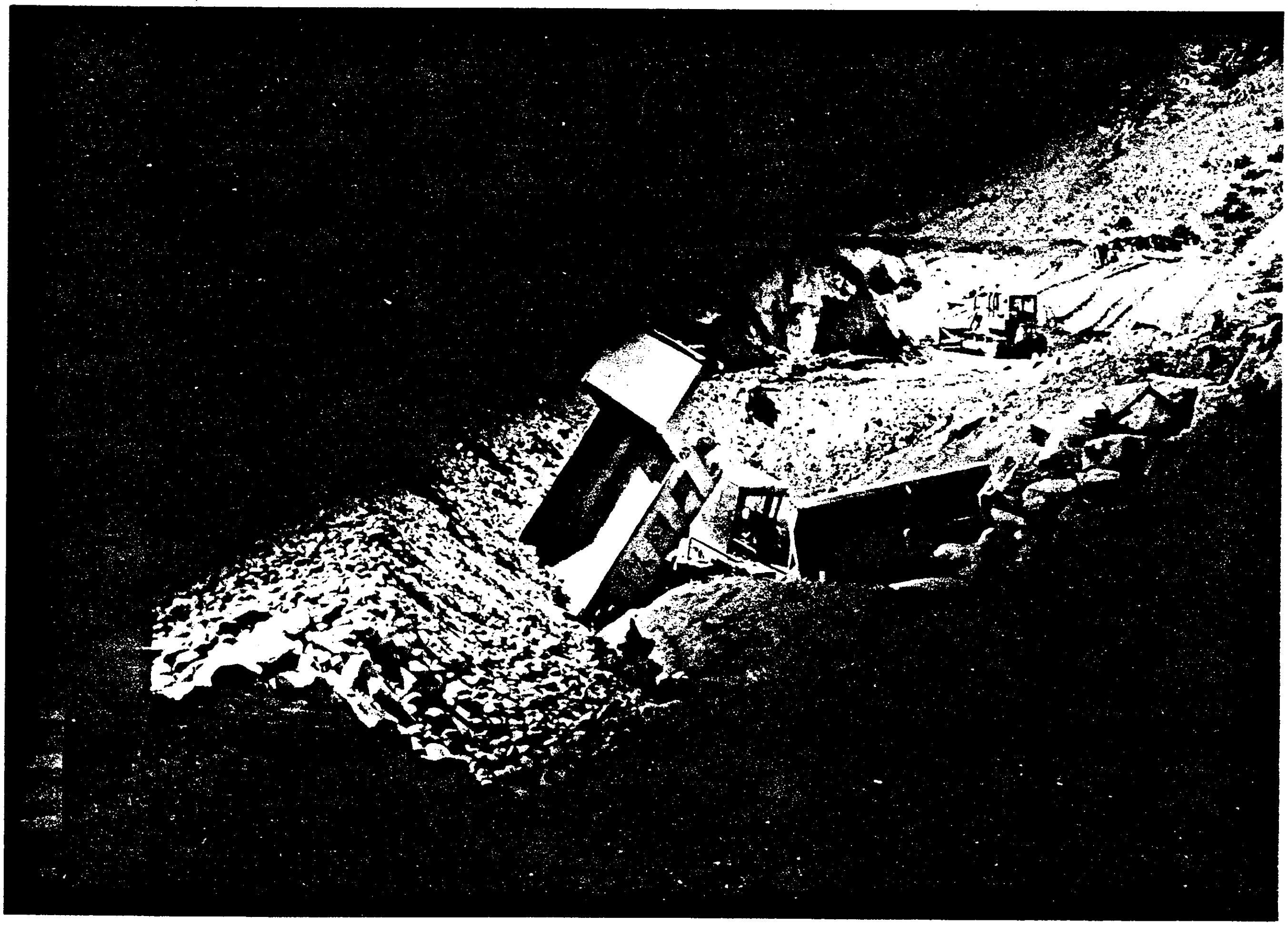
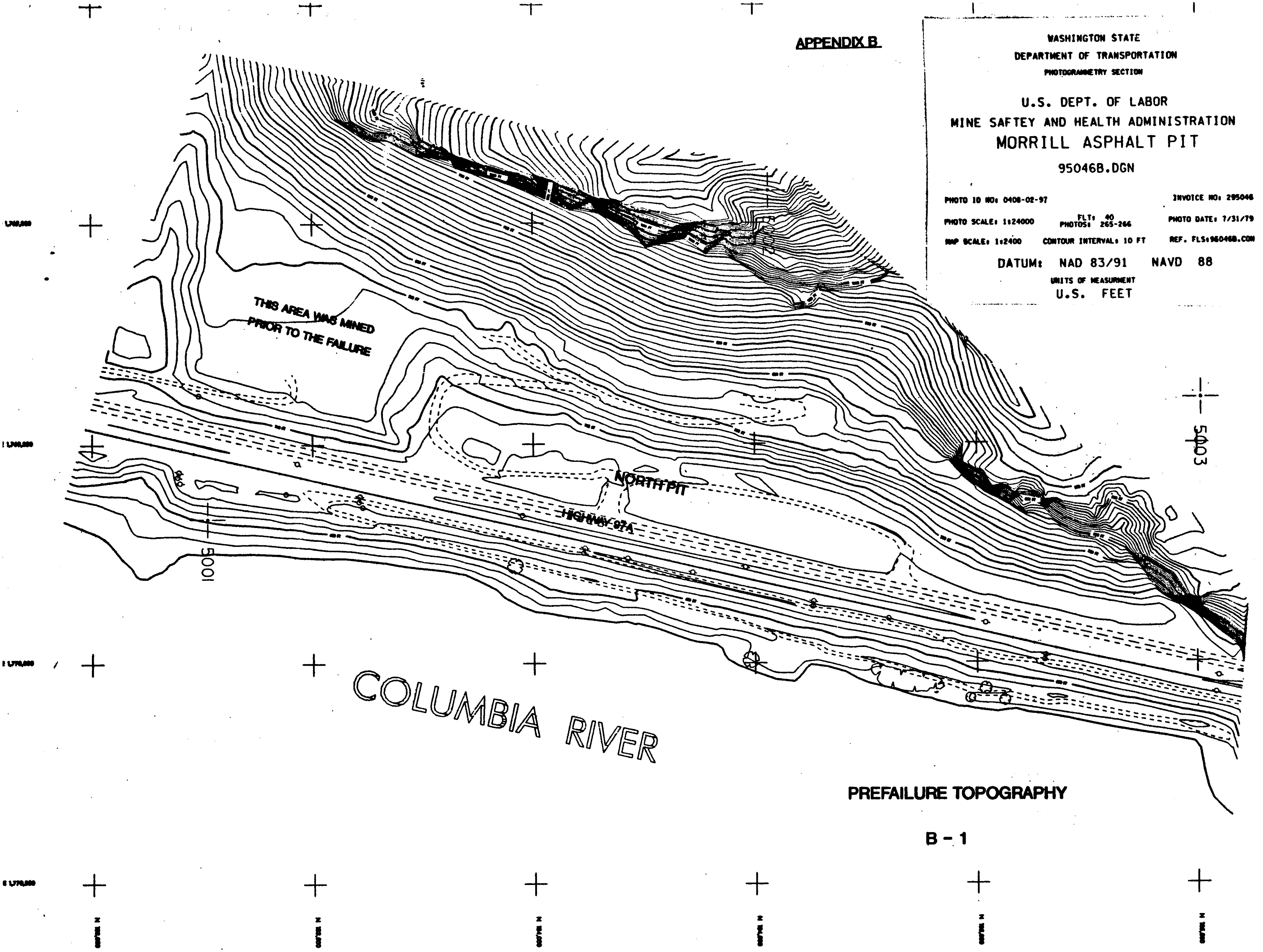


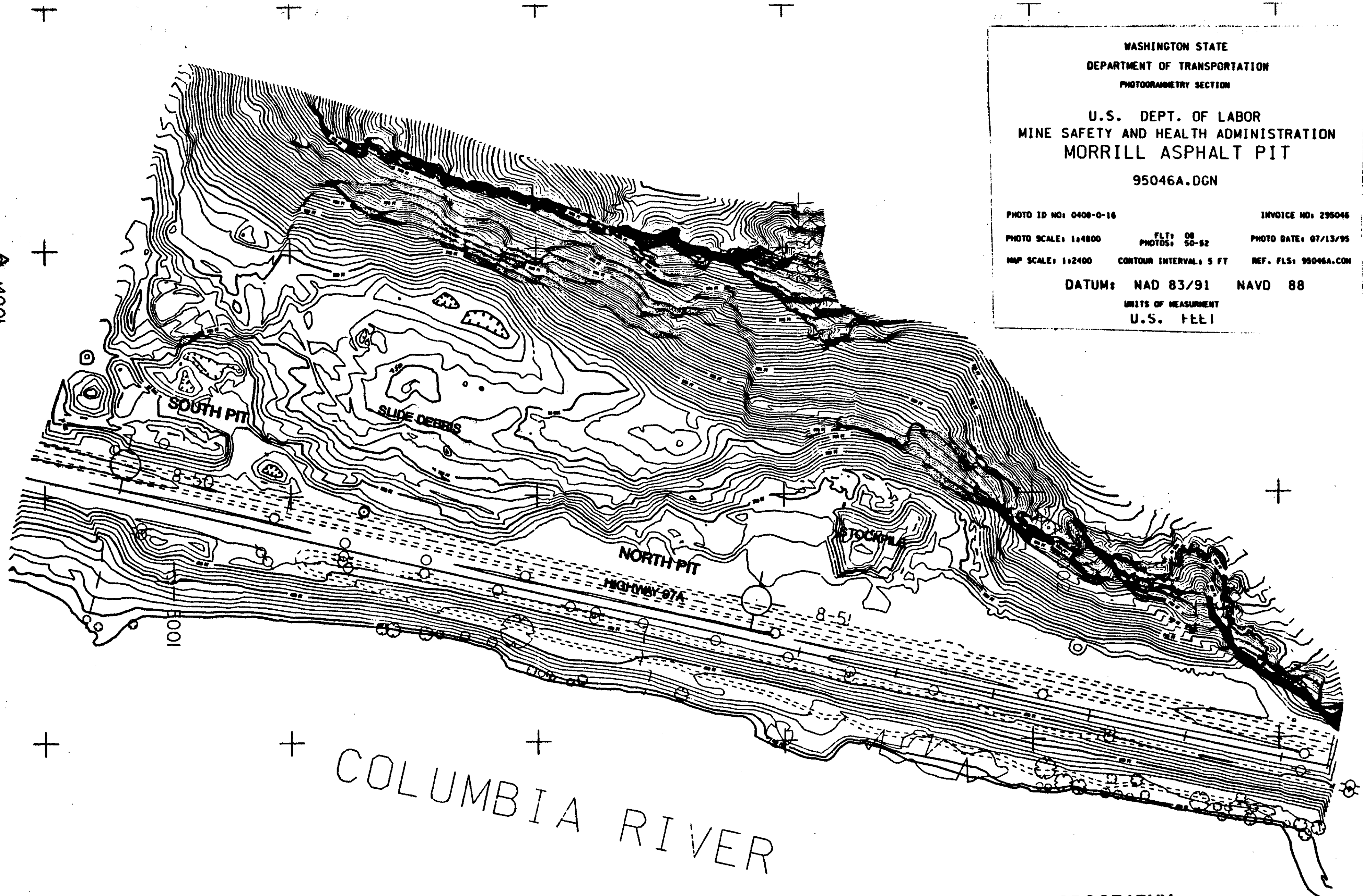
PHOTO 16. - Two Euclid dump trucks located at west end of accident site. Trucks were on pit floor near screen-all at time of accident. After accident, trucks were surrounded by gravel debris.

APPENDIX B



PREFAILURE TOPOGRAPHY

B - 1



POSTFAILURE TOPOGRAPHY

B - 2

APPENDIX C

INVESTIGATION PARTICIPANTS

Morrill Asphalt and Paving Company, Inc.
Stanley E. Evenhus, General Manager
Gary Kneidler, Superintendent

Goodfellow Brothers
Jim Goodfellow, Owner

Chelan County Sheriffs Office
Mike Harum, Sheriff
Daryl Mathena, Undersheriff

Chelan County Public Works Department
Richard J. Anderson, P.E.
Director/County Engineer

Chelan County PUD
Bill Christman, Senior Civil Engineer
Dan Garrison, Civil Project Engineer

Washington State Department of Transportation
Donald J. Senn P.E.
Regional Administrator

Washington State Department of Natural Resources
Lorraine Powell, Geologist

Hammond, Collier and Wade'Livingstone Associates Inc.
Jonathan B. Hamilton, Geologist

Mine Safety and Health Administration
Arnold E. Pederson, M/NM Mine Inspector
Dennis D. Harsh, M/NM Mine Inspector
Robert L. Ferriter, Supervisory Mining Engineer, DSHTC
David M. Ropchan, Senior Mining Engineer, DSHTC