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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration for the project "The Effectiveness of Horizontal Drains".

16. ABSTRACT

The effectiveness of horizontal drains installed in California over a period of 40 years is evaluated. Seven installations including Nojoqui Grade 1940, Cloverdale 1941, Whitmore Maintenance Station 1963, San Andreas 1964, Pacific House 1969, York Mountain 1972, and La Selva Beach 1974 were selected for the study. Major factors which influence the long-term effectiveness of horizontal drains are discussed. These factors include lithology, location, orientation, spacing, pH, mineral content, age and maintenance programs. Drain cleaning equipment and techniques were studied. A new cleaning system utilizing high pressure water was developed and is described. Horizontal drain evaluation, inspection, cleaning and repair forms designed for field use were developed during the study and are included with the final report. A comparison of steel and PVC casing is made, including cost, handling, transport, installation and resistance to corrosive action of groundwater.

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

June 1980

FHWA No. F-6-1
TL No. 632161

THE EFFECTIVENESS OF HORIZONTAL DRAINS

Study Made by .... Engineering Geology and Technical Services Branch

Under the General Direction of .... Robert W. Reynolds, CEG

Under the Supervision of .... Marvin L. McCauley, CEG

Principal Investigator .... Duane D. Smith, CEG

Report Prepared by .... Duane D. Smith, CEG

APPROVED BY

Neal Andersen

NEAL ANDERSEN
Chief, Office of Transportation Laboratory

CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quanity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2) square feet (ft^2) acres	6.432×10^{-4} .09290 .4047	square metres (m^2) square metres (m^2) hectares (ha)
Volume	gallons (gal) cubic feet (ft^3) cubic yards (yd^3)	3.785 .02832 .7646	litres (l) cubic metres (m^3) cubic metres (m^3)
Volume/Time			
(Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour(mph) feet per second(fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity(G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^2)
Force	pounds (lbs) kips (1000 lbs)	4.448 4448	newtons(N) newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds(ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds(ft-lbs) foot-pounds(ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi) pounds per square foot (psf)	6895 47.88	pascals (Pa) pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi $\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ (MPa $\sqrt{m}$)
	pounds per square inch square root inch (psi $\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ (KPa $\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

ACKNOWLEDGEMENTS

The author wishes to express his appreciation for the many hours of discussion and numerous informative field reviews of early drain installations so freely given by the late A. D. Hirsh. Through his firsthand experience and clear recollection, much has been recorded that would have been lost.

Special thanks are also extended to Marvin McCauley for his encouragement and critical review of this paper and to Oliver Braden for his genuine interest in the paper and his assistance in obtaining records and data.

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INTRODUCTION

Construction and maintenance of highways in hilly and mountainous terrain are often complicated by the reactivation of old landslides and by the development of new ground mass movements in unstable material during and following construction.

The presence of groundwater is the most important factor influencing the development of slides and embankment slipouts. Subsurface water reduces the stability of cut slopes and embankment foundations through reduction of the shearing resistance of soil, increase in the weight of the ground mass and seepage forces which add to the driving force.

Over the past 41 years, well over one million linear feet of horizontal drains have been used effectively in California as an economical method of draining unstable areas. During this period there has not been a systematic evaluation of the long-term effectiveness of these drains, nor is there any evidence in the literature of a similar evaluation in other states.

Initial work on the project, following the search of existing literature, was to review the files of all horizontal drain installations in the state. Twenty were selected from this number for a closer inspection. These sites were chosen because they represented a broad cross-section of geographical locations, environments, rock types, ages and designs under which horizontal drains have worked effectively.

Eight of the 20 sites were eliminated after contacting District maintenance and engineering personnel for the purpose of discussing drain performance, cleaning and maintenance records. Records of these projects were either missing or incomplete. Other drain installations had been destroyed or buried as a result of curve corrections or changes in grade or alignment.

A final selection of seven installations was made for this study. Figure 1 is the form developed during the study for use in field evaluating each site.

It was apparent during the course of the study that it would be very difficult, if not impossible, to numerically evaluate the increase in soil strength developed by a horizontal drain installation without extensive soil and rock testing that was well beyond the scope of this study. Therefore, an empirical system was used by the investigator based on observation, experience and a history of movement derived from the records and memories of maintenance personnel in the area.

A new program of drain cleaning, maintenance and rehabilitation was developed during this study. Existing drain cleaning equipment developed years ago for use in two-inch steel cased drains was observed in the field during the study. Demonstrations of high water pressure cleaning systems were set up with equipment manufacturers at two of the seven selected installations. A third system owned and operated by Contra Costa County was also observed in the field. Several other sources of drain cleaning equipment or equipment which could be adapted to the cleaning of drains were contacted.

DIST._____CO._________RTE.________P.M._________LOCATION______________________________

INSPECTED BY____________________DATE__________________ENVIRONMENT________________________

SAMPLED_____________PHOTOGRAPHED________________RAINFALL_____________________INITIAL COST________________

DATE INSTALLED__________NO. DRAINS________AVE. LENGTH___________TOTAL LINEAL FT__________________________

COLLECTOR SYSTEM___________NO. DRAINS LOCATED_______________CONDITION_________________________________

LAST CLEANED_______NO. DRAINS LOCATED__________NO. FT. CLEANED____________CLEANING COST__________________

DATES CLEANED__________________CLEANING COSTS_________________CLEANED BY________________CASING____________

INITIAL FLOW______________FLOW PRIOR TO CLEANING_______________FLOW AFTER CLEANING________________________

VERTICAL BORINGS__________WATER LEVELS_______________HISTORY OF MOVEMENT__________________________________

____

SLOPE INDICATORS___________SURVEY POINTS___________CORRECTIVE WORK___________________________________

LITHOLOGY____

_________________________BEDDING_________________JOINTS______________FOLIATION_____________________________

FAULTS AND SHEAR ZONES______________SIZE_________________________ATTITUDES__________________________________

WEATHERING: DEGREE__________THICKNESS OF ZONES_____________ORIENTATION OF ZONES____________________________

WATER IN FRACTURES______________SPRINGS OR SEEPS_____________CLAY MINERALS PRESENT_________________________

COMMENTS____

____

EFFECTIVENESS RATING VERY______MODERATELY__________FAIRLY___________POOR_____________UNKNOWN____________

Horizontal Drain Installation
Field Evaluation Form

Figure 1

CONCLUSIONS

The following findings and conclusions are based upon analysis of the data developed in this study.

1. High pressure water cleaning systems currently used for cleaning sewers and unplugging culverts can be easily adapted for horizontal drain cleaning.

2. The high pressure water system is superior to the old air-motor and "E" rod systems because it is easier to use, faster, effectively scours slots, perforations and walls of the casing and, if used properly, will not damage PVC.

3. The optimum pressure for a water cleaning system appears to be between 1600 and 2000 psi while the minimum volume required for thorough flushing is 30 to 35 gpm.

4. A 40 year life span is about the maximum that can be expected from a perforated metal pipe casing, with perhaps 30 years as a more practical guide. Although difficult to evaluate, there is probably a slight, but gradual decrease in efficiency with age.

5. The slotted PVC, although only in service for 11 years, is in excellent condition and should give longer service than metal casing.

6. Slotted PVC casing allows considerably less sediment to enter the drain than the standard 3/8-inch perforated metal pipe. Slot size should be based on mechanical analysis of sediments.

7. A drain maintenance program should be established with provisions for annual inspections for cleaning and repair of damaged outlets or collector systems.

8. Most drains need to be cleaned only every 5 to 8 years. Heavy root growth or exceptionally fine-grained sediments may reduce this period to every second year.

9. Cementation, fabric or structure, discontinuities, grain size and permeability are major lithologic factors which influence drain effectiveness.

10. The design of a horizontal drain installation, including the location, orientation, spacing, length and grade should be based on the geology of the site.

11. Exposed PVC drain outlets should be protected against rockfall and straying vehicles by use of a galvanized pipe sleeve over the plastic. Paddle markers or similar devices should be used to mark drain outlets in the field for easy location.

12. The most effective method of maintaining continuity in a horizontal drain program is to permanently assign qualified personnel the full-time task of inspecting, cleaning, replacing or repairing horizontal drain installations on a regional or state-wide basis.

IMPLEMENTATION

Forms developed in this study can be used by District offices or other highway departments to evaluate, inspect, clean and repair horizontal drain installations.

An improved horizontal drain program can be established by permanently assigning qualified personnel the full time task of inspecting, cleaning, repairing and replacing drains on a regional or state-wide basis.

High pressure water cleaning systems used for unplugging culverts and cleaning sewers can be easily adapted for horizontal drain cleaning by modifying the hose diameter and nozzle configuration.

The effectiveness of proposed horizontal drain projects can be greatly improved by designing the installation on the basis of the geology of the site.

DISCUSSION

A. Case Histories

Seven installations have been selected for evaluation in this study because they represent a good cross-section of the diverse conditions under which horizontal drains successfully perform in California (Figure 2).

Rock types include serpentine, granitic rocks, clay shale, volcanic agglomerate, tuff, phyllite, dune sand, sandstone and shale. Environments range from the Alpine type of the 5,000 foot elevation of the Sierra Nevada Mountains to marine environment of the low coastal ranges near the Pacific Ocean.

The Nojoqui Grade and Cloverdale installations are typical of the earlier installations in which "Hydrauger" drilling equipment (Figure 3) and perforated metal casings were used while the York Mountain and La Selva Beach projects are typical of installations in which modern technology, equipment and plastic casing were employed.

1. Whitmore Maintenance Station

On February 1, 1963 after exceptionally heavy rain had fallen over a four day period, two large slipouts occurred on the newly constructed eastbound lanes of Interstate 80 near the Whitmore Maintenance Station. The site is located at the 5,000 foot elevation in the Sierra Nevada Mountains between Sacramento, California and Reno, Nevada. Annual precipitation for the area is approximately 67 inches.

HORIZONTAL DRAIN INSTALLATIONS LOCATION MAP

1. WHITMORE MAINTENANCE STATION
2. SAN ANDREAS
3. PACIFIC HOUSE
4. COVERDALE
5. NOJOQUI GRADE
6. LA SELVA BEACH
7. YORK MOUNTAIN

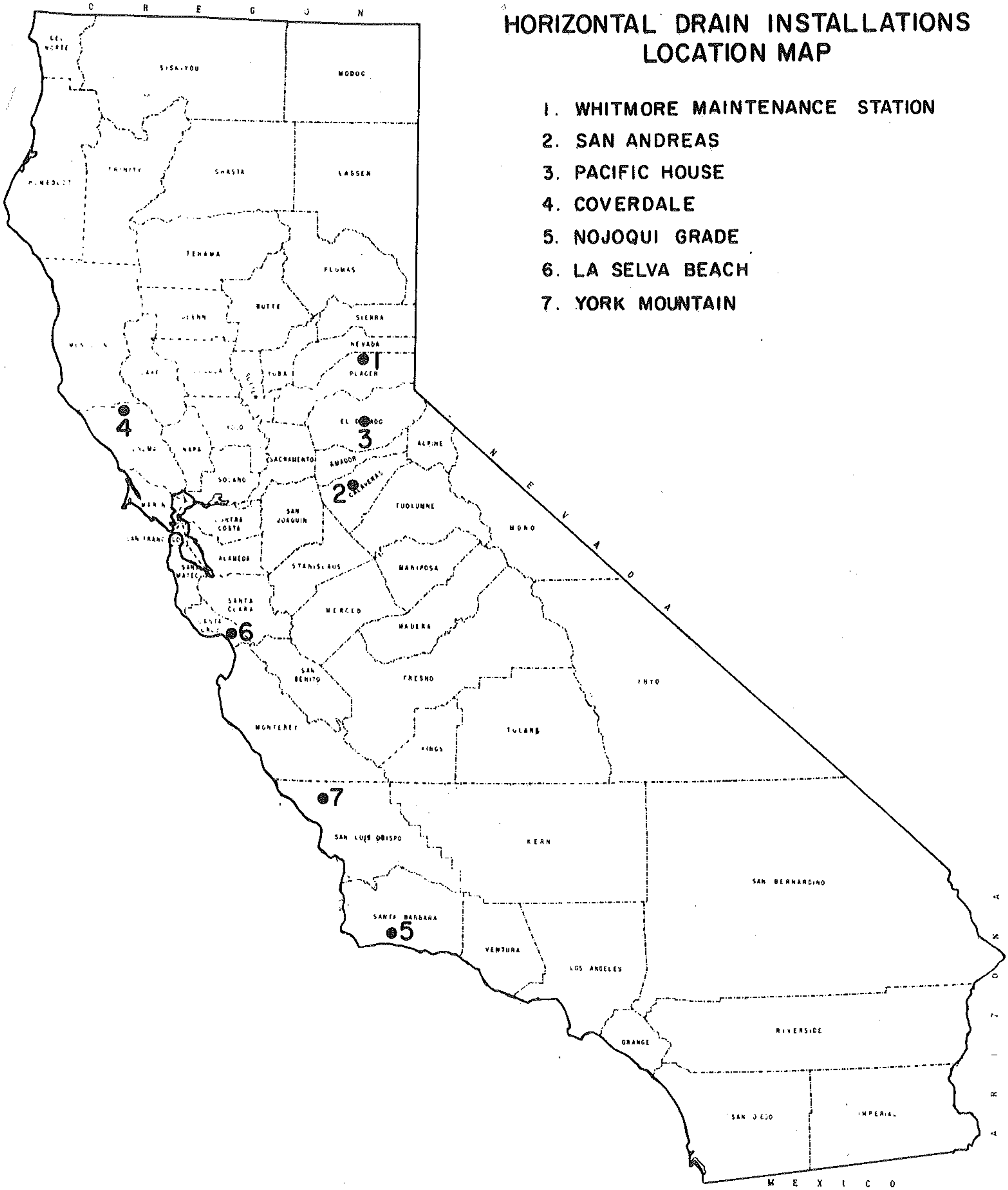


FIGURE 2

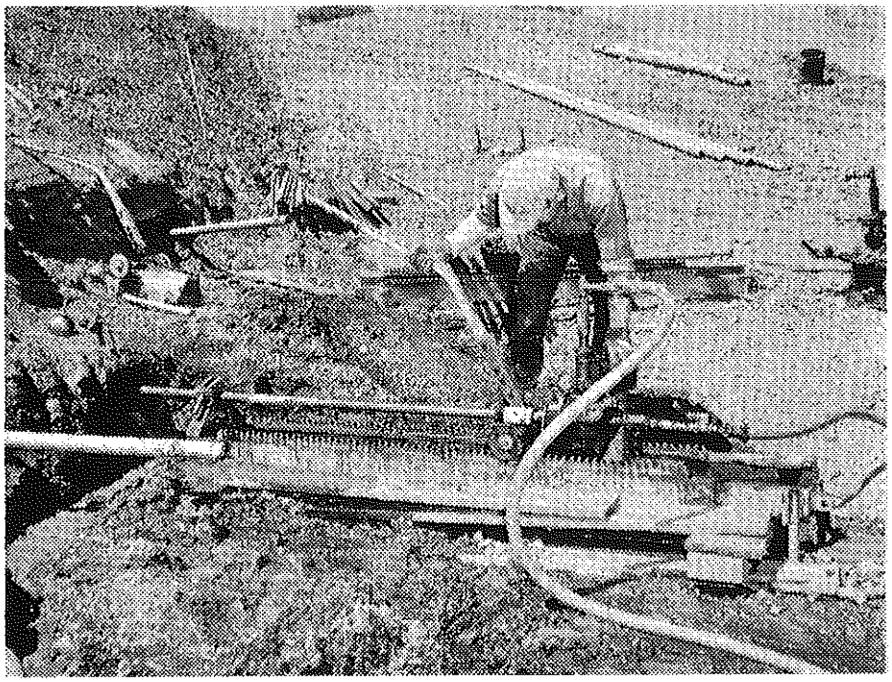


Figure 3. "Hydrauger" first used in 1939 to install horizontal drains by California Division of Highways.

One of the slipouts was located directly above the maintenance station (Figure 4), while the other was located approximately one mile west of the maintenance station (Figure 5). All three lanes were affected by the failures, and traffic was rerouted over the westbound lanes.

Vertical borings indicated the area was exceedingly wet and consisted of three distinct formations. These are the Mehrten, Valley Springs and Blue Canyon formations, listed in order of increasing age. The Mehrten formation is of mudflow origin and consists of moderately hard, deeply weathered, reddish-brown andesitic agglomerate and breccia with some beds of loose, brown volcanic ash. Pebble, cobble and boulder size volcanic, and rarely, granitic rocks, are enclosed in an abundant tuff matrix. There is some minor alteration to clay. This formation is highly permeable and large quantities of groundwater are discharged by numerous springs on both cut and natural slopes during periods of heavy rainfall. The Valley Springs formation is mostly of bedded rhyolite tuff that is extensively altered to kaolin within this area. Because of the high clay content, the Valley Springs formation is relatively impermeable. The fact that the harder, permeable Mehrten formation directly overlies the soft, clayey, impermeable Valley Springs formation has an important bearing on several stability problems in this area. The Blue Canyon formation is comprised of steeply dipping, thinly foliated phyllite and slate. The Blue Canyon formation underlies both the Mehrten and Valley Springs formations and is well exposed in road cuts east of the Whitmore Maintenance Station.

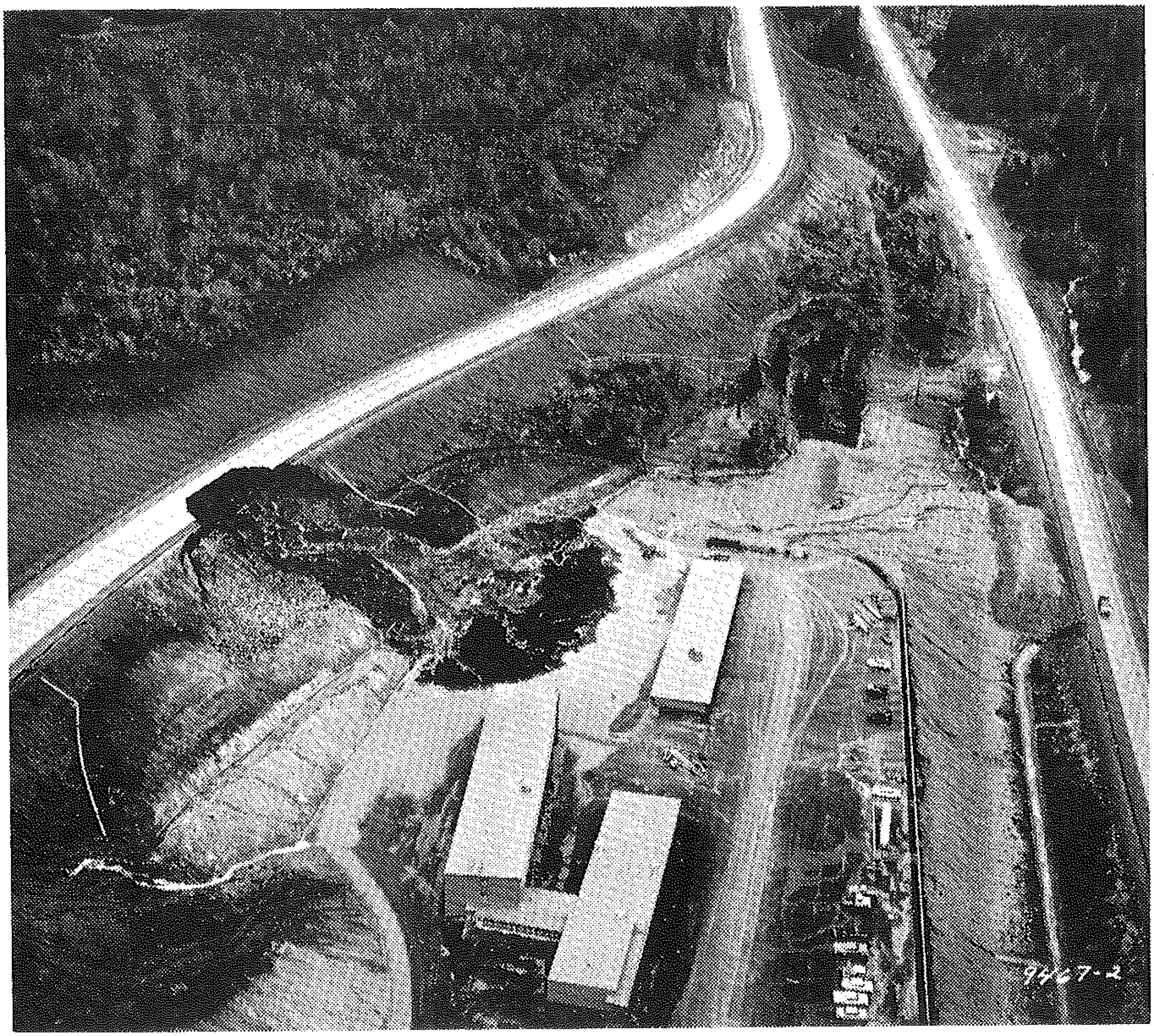


Figure 4. Embankment failure at Whitmore Maintenance Station, February 1963.

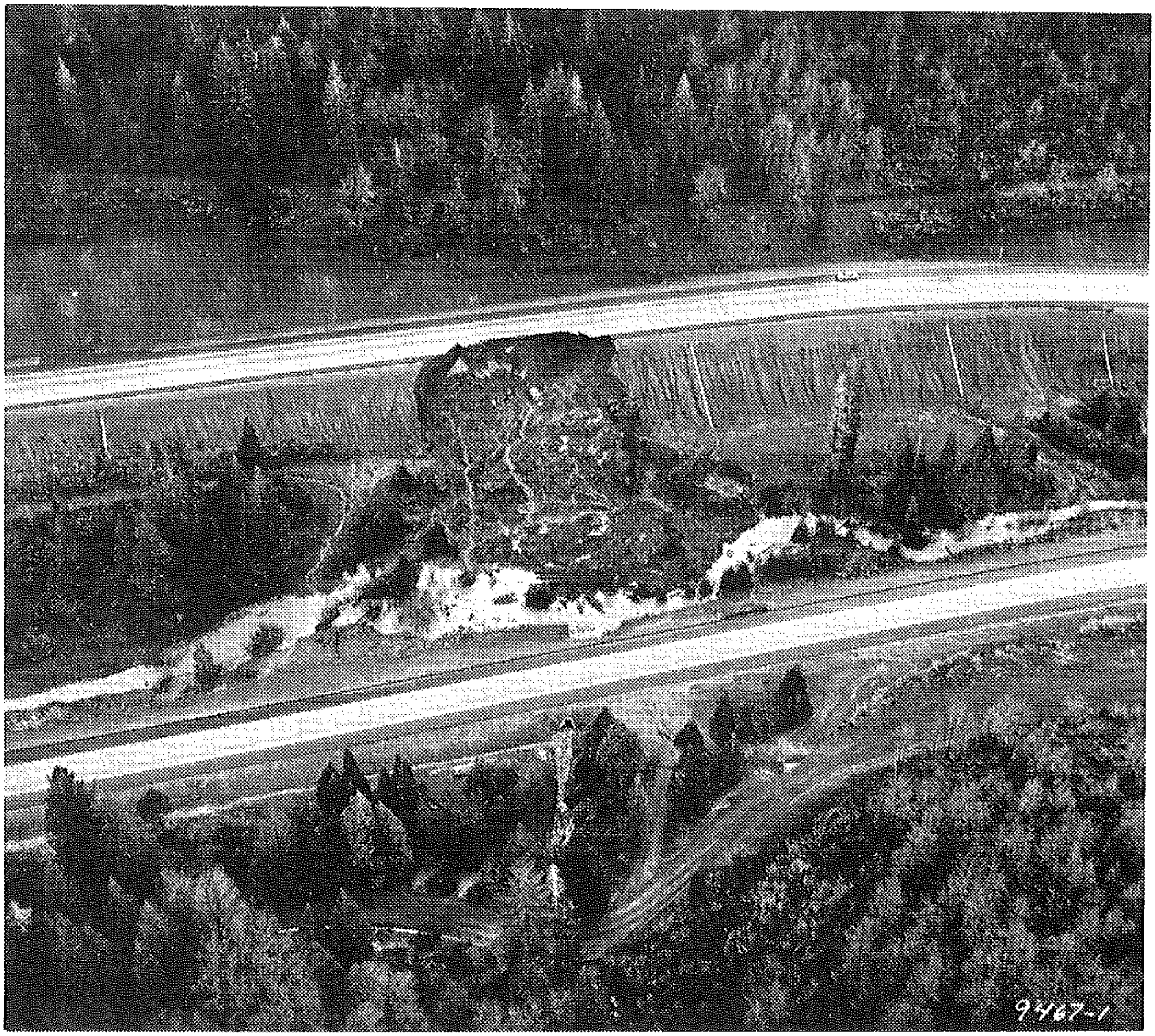


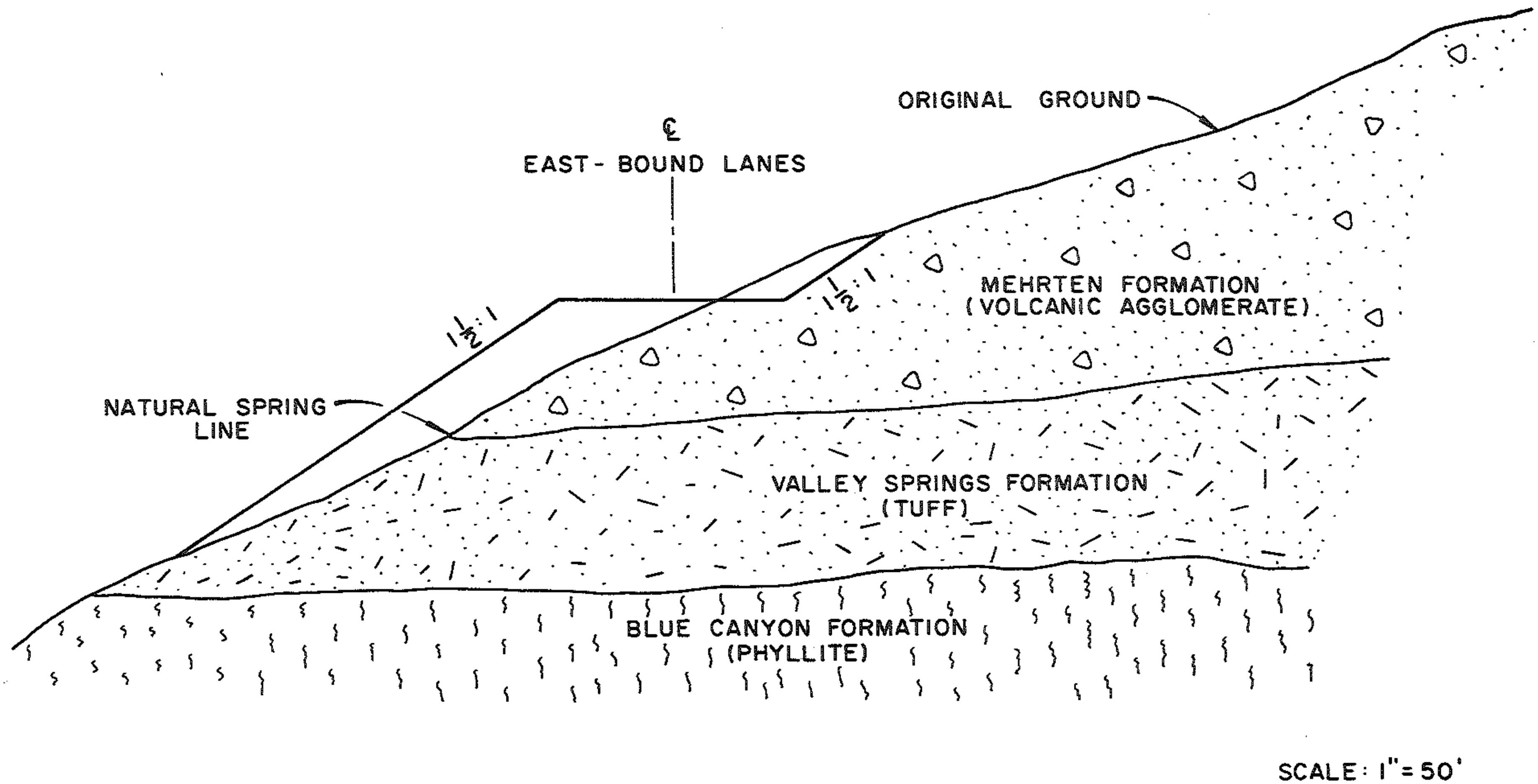
Figure 5. Embankment failure west of Whitmore Maintenance Station, February 1963.

The contact between the agglomerate and tuff is characterized by an undulating plane which dips gently to the north or into the roadway (Figure 6). A natural spring line had developed over the years where water which had percolated through the Mehrten formation and then moved downslope along the interface of the two materials had surfaced where topographic relief had exposed the dipping plane. Placement of the side-hill embankments over this natural drainage feature restricted the groundwater movement, resulting in a buildup of head which was relieved when the saturated embankments failed and began to move downslope.

Correction of the two failures consisted of stripping and removal of all failed debris, placement of permeable blankets over the foundations, replacement of the compacted embankments and the installation of horizontal drains.

By November 1, 1963, a total of 21,251 linear feet of horizontal drains had been installed at the two sites. These 103 drains averaged 206 feet in length with initial flows ranging from 300 to 500,000 gpd. The drains are highly responsive to precipitation. Within 24 hours after rain has fallen, the flow quantity increases considerably.

All drains were cased with 2-inch perforated metal pipe. During an inspection in July of 1979 and January of 1980, 91 percent of the drains were located. The drains which could not be found were drilled between the east and westbound lanes at the toe of the eastbound embankment. Slope wash and dense vegetation have either buried or concealed these drains. The remaining drains appear to be in excellent condition after serving for 17 years. A few of



IDEALIZED GEOLOGIC CROSS SECTION AT WHITEMORE MAINTENANCE STATION

FIGURE 6

the outlet pipes which connect to the collector systems have been bent by snow plows and straying vehicles. These should be replaced where torn from the collector.

A review of the service records indicate that the drains have been cleaned about every three to four years. Small amounts of silt and rust have been encountered from time to time, but heavy root growth from willows has been found and removed each time from several of the drains. Since the cleaning is usually done in the late fall, little increase in flow was noted except in those drains clogged with roots.

No distress of the roadway or embankments has been noted since their reconstruction and installation of the horizontal drains. Astounding amounts of water are observed flowing from the drains each winter (Figures 7 and 8). Total flows from the drains during the wet season are well in excess of one million gpd.

The effectiveness of horizontal drains in dewatering the volcanic agglomerate and loose volcanic ash of this installation is outstanding.

2. San Andreas

During late winter of 1964, two landslides developed in newly constructed cut slopes just north of the historically interesting gold mining community of San Andreas. The site is located in the Sierra Nevada foothills on State Highway 49 at an elevation of just over 800 feet. The climate is characterized by long, hot, dry summers and relatively mild winters with an average rainfall of about 33 inches.

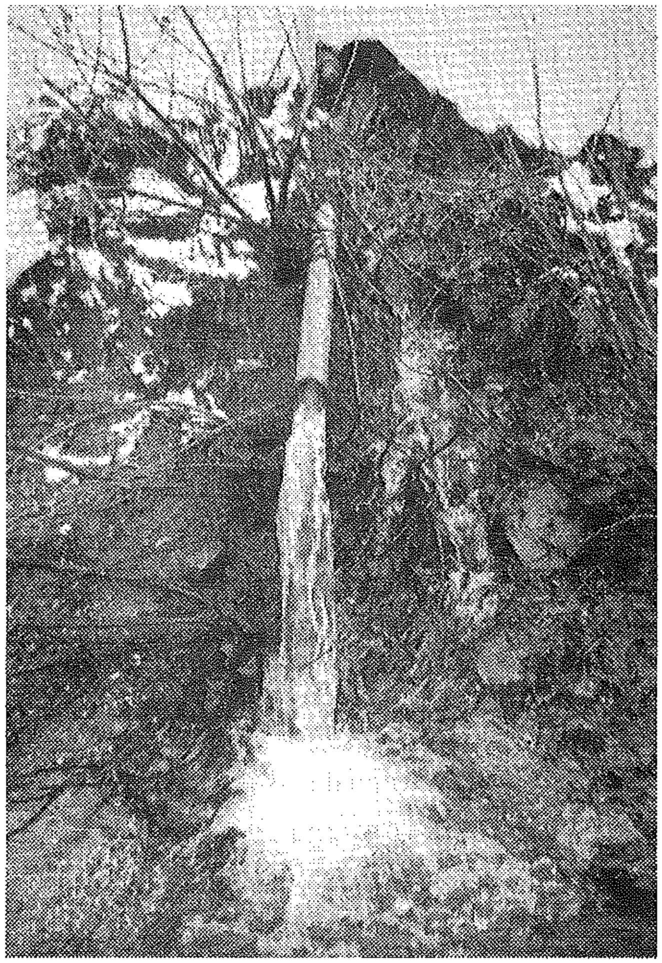


Figure 7. Whitmore drain flowing at capacity after 15 years service (photo 1978).

Figure 8. Typical winter flow of 17 year old drains at Whitmore Maintenance Station.

A 1,200 foot long section of an 80 foot high 1-1/2:1 cut slope failed in sheared and broken serpentine. A few days later a second slope 3,000 feet north of the first failed. This cut slope was also newly constructed in serpentine on a 1-1/2:1 slope and was approximately 90 feet high. Abundant free water was evident at the toe of both failures and the lower portions of each cut were wet before movement occurred.

The site has been mapped as Mesozoic ultrabasic intrusive rocks. Specifically, it consists of very sheared and broken serpentine. Both the antigorite and chrysotile varieties are present. Colors range from apple green to dark green with the typical greasy, waxlike luster in the massive varieties and silky luster when fibrous. Associated with the serpentine is a small amount of soapstone. Pyrite and chromite crystals are disseminated throughout the serpentine.

Because of the extremely sheared, foliated and broken nature of the rock, the surface of the cut slopes are covered by loose cobble and pebble size pieces of weathered serpentine (Figure 9). In-place outcrops suggest a general north-south orientation of the foliation.

Slide corrections consisted of stripping and removal of the failed debris, laying back the slopes on a 2:1 ratio in the areas of movement and installing horizontal drains.

Horizontal drilling operations began in November of 1964 and were completed in February of 1965. Thirty-three drains, largely from 150 to 200 feet in length, were installed from the toe of the cut slopes. Grades ranged from 5 to 20 percent and all 5,189 lineal feet of drain were drilled normal

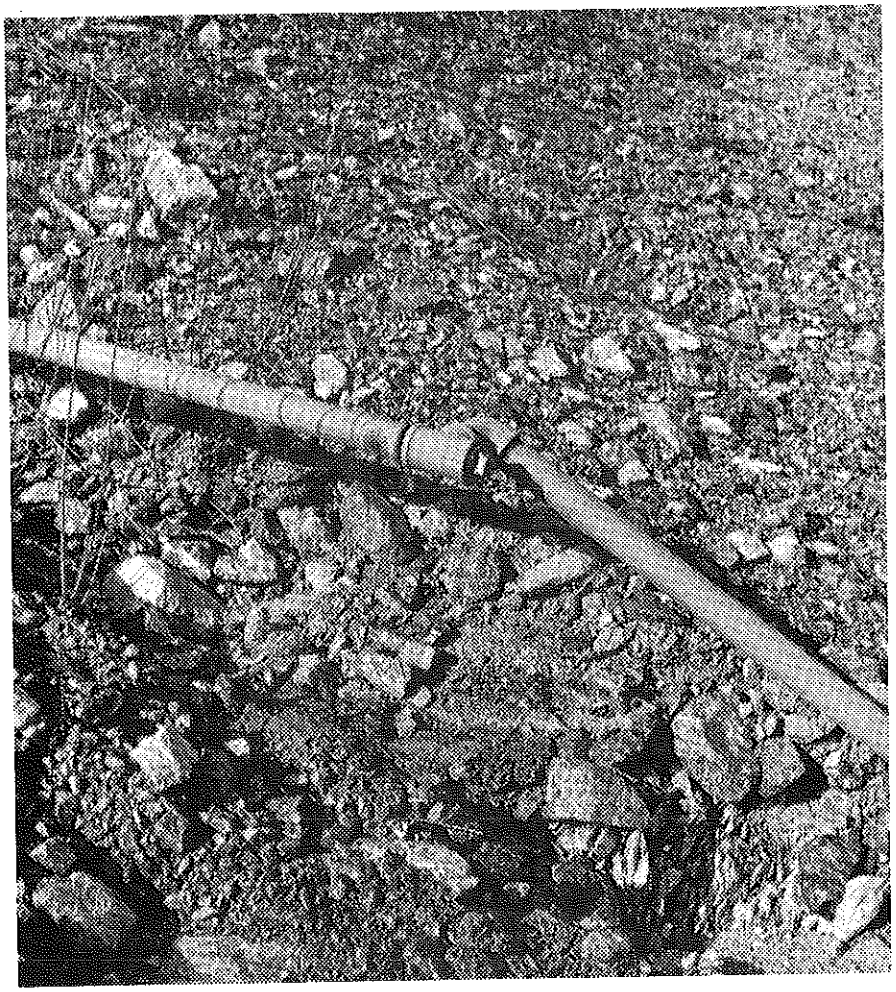


Figure 9. Serpentine cut slope of San Andreas installation.

to the roadway. Spacing between drains ranged from 20 to 150 feet. Locations for drains were selected by an engineering geologist and were based on the surface geology, evidence of free water on the slopes and subsurface information obtained during the drilling program.

The combined initial flow was 119,486 gpd. Two months after completion of the drilling project, the combined flow had dropped to 65,504 gpd or approximately one-half the initial flow. Examination of the installation in January of 1966, approximately one year after completion revealed a combined flow of 5,710 gpd. It should be noted, however, that the flows are very responsive to rainfall and increase rapidly after a heavy rain since the water is transported from the surface by means of fractures and inclined planes of foliation.

Two-inch perforated black metal pipe was used as casing for all the borings, while 2-inch galvanized metal pipe was used for the exposed outlets and for connecting to the buried 8-inch corrugated metal pipe collector system.

Cleaning records for this installation are not complete. It appears that they have been cleaned three times during their 15 years of service, for an average of about once every 5 years. The last cleaning was done on November 24, 1975. Minor amounts of silt and rust were removed from all the drains, and heavy root growth was removed from four of them. Little increase in flow was noted after cleaning except for the drains clogged by roots.

The installation was last inspected on January 30, 1980. The drains are in excellent condition and show little sign of rusting or damage. The four drains previously plugged with roots during the 1975 inspection and cleaning are again clogged and should be serviced. The remaining 29 drains could easily go another 2 or 3 years without cleaning. With the exception of the four drains, this installation should only need cleaning about every 8 years.

No distress of the cut slopes or pavement was noted after 15 years of service. The horizontal drains have effectively dewatered the unstable slopes and should perform well for at least another 15 to 20 years. maybe laying back the slope was all that was needed

3. Pacific House

A field review of an unstable cut slope at Pacific House, located on Trans-Sierra Highway 50 was made in August of 1969. The site, located at an elevation of 3,600 feet on the western slopes of the Sierra Nevada mountains has an annual precipitation of 51 inches.

Saturated clayey soil and decomposed coarse-grained granitic debris were encroaching on the eastbound lanes from a 30 foot high 3/4:1 slope, causing a traffic hazard. The slide mass was fed by springs which may be partially sustained through irrigation of a large apple orchard located upslope from the top of the cut.

Ten horizontal drains were installed in late October and early November of 1969 (Figure 10). The drains ranged in length from 156 feet to 213 feet. Grades varied from 2 to 4 percent. Schedule 80, 1-1/2 inch diameter PVC casing

Figure 10. Pacific House. Examination of the first PVC drain casing installed in California. Photo March 1980.

was used in four of the ten drains, while the conventional 2-inch perforated steel casing was used in the remaining six drains.

The combined initial flow was 26,285 gpd. Upon completion of the project, the flows totaled 15,438 gpd.

On November 1, 1978 the site was again inspected. Although the cut slope has remained stable for the past 10 years, wet spots are common around the drains and two of the drains showed more water coming from around the casings than through them. Heavy root growth from a dense stand of willows has plugged most of the drains. Approximately 3,000 gpd was measured during the review. The slope appeared to be stable and no distress was evident on the pavement.

4. Cloverdale

During extremely heavy rainstorms in February of 1941, a large landslide occurred on Highway 101, near Cloverdale, 90 miles north of San Francisco. Portions of a high cut slope and side-hill embankment in poorly bedded, sheared shale with minor lenses and beds of sandstone slid into the Russian River, severing approximately 1,100 feet of the roadway (Figure 11). Large quantities of water in the form of springs and saturated slide debris were associated with the failure.

Corrective measures included a benched 1-1/2:1 cut slope and a reconstructed 2:1 embankment slope. Between March and June of 1941, 97 horizontal drains were installed using the "Hydrauger" equipment with 2-inch perforated steel casing placed in 4-inch drilled holes. The loose, broken

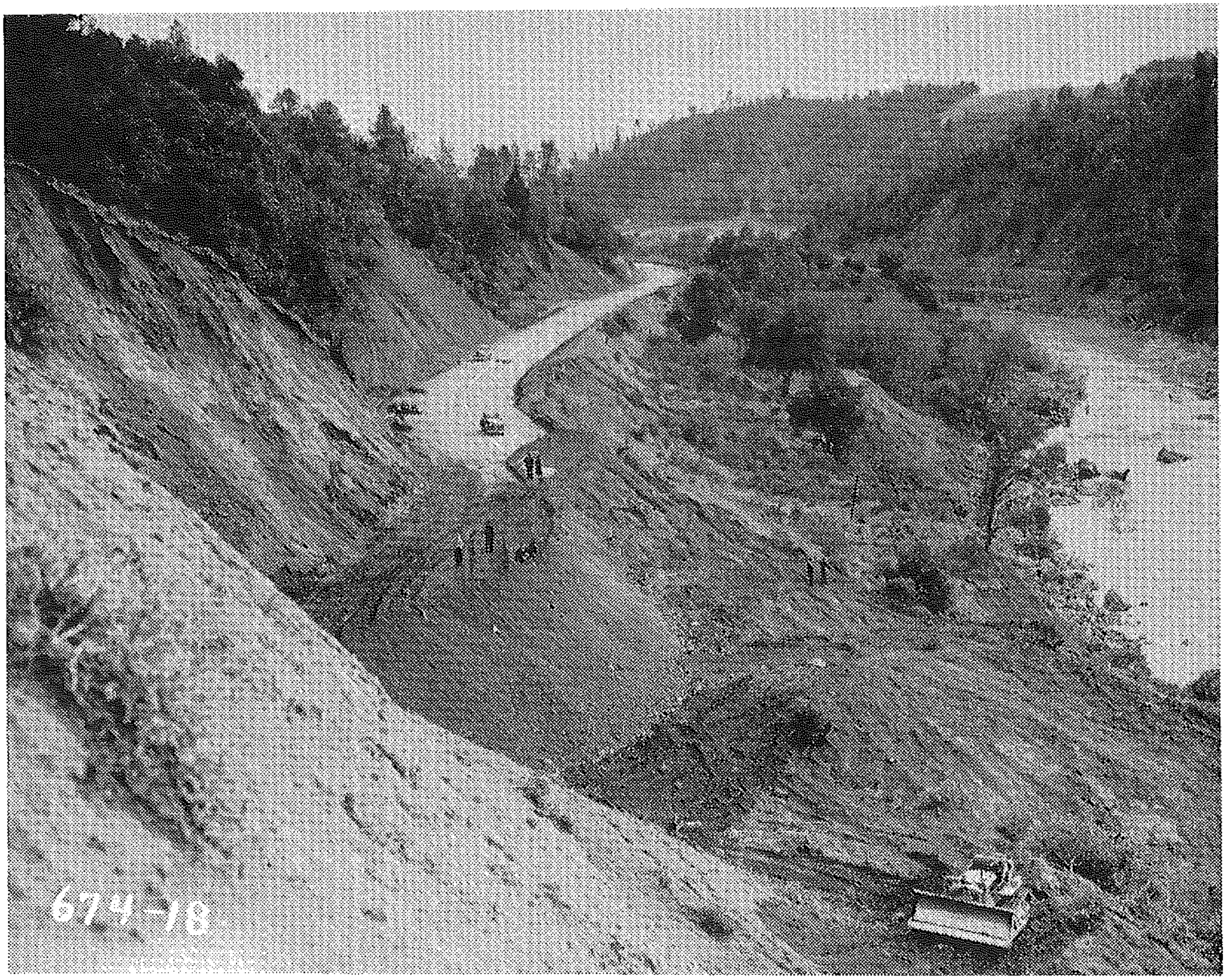


Figure 11. Cloverdale Landslide, February 1941.

shale caused a great deal of difficulty during the installation. The average drain length was only 55 feet. Several holes were abandoned because of caving and the lack of a workable method to case the holes under these conditions. A complete record of initial flows is missing from the original report although some of the individual drains were known to have produced between 150,000 gpd and 200,000 gpd.

Drain outlets and downpipes were connected to corrugated metal pipe which was buried below the shoulder thus preventing periodic inspection of the drains. Heavy rains during the winter of 1955-1956 produced appreciable quantities of water which appeared in various places along the toe of the cut slope. Investigation of the 15 year old installation showed this water to be coming from around the horizontal drains which had ceased to function properly because of heavy deposits of rust, gypsum and root growth.

As a result of the inspection, a drain cleaning and restoration program was recommended and completed in the summer of 1956. Forty-nine drains were located. Prior to cleaning, the drains produced a combined flow of 184,250 gpd with one drain producing 143,000 gpd of this total. Immediately after cleaning, they produced a cumulative total flow of 284,440 gpd. This flow increase clearly illustrates the value of the work performed (Table 1).

In addition to the cleaning and reconditioning of the collector system with easily accessible cleanouts, three new drains were installed in the most critical areas. A fourth drain was attempted but was abandoned without casing. Although considerable difficulty was still encountered during the installation of the three new drains an average length of 114 feet was obtained. These three drains produced initial flows totaling approximately 28,000 gpd.

TABLE 1

EFFECT OF DRAIN CLEANING
ON FLOW AT CLOVERDALE - 1956

Drain No.	Hole Depth	Depth Cleaned	Flow Before Cleaning GPD	Flow After Cleaning GPD	Remarks
3	65	65	830	1,080	Heavy root growth & rust
6	60	60	143,800	143,800	Gypsum & heavy rust
9	50	50	2,460	4,320	Gypsum & heavy rust
11	75	75	300	43,000	Very heavy root growth
13	80	80	1,440	7,200	Heavy rust
18	45	45	100+	10,790	Heavy root growth & silt
19	30	11	2,880	7,200	Heavy root growth & rust
21	26	26	100+	4,320	Heavy root growth
22	35	6	360	1,080	Heavy root growth
23	35	8	6,640	10,790	Heavy root growth & rust
24	37	37	200+	12,340	Heavy root growth & rust
27	57	57	720	1,540	Heavy rust
29	45	45	300	17,280	Root growth first 20', sand & rust

During October of 1956, 11 additional horizontal drains with an average length of 125 feet were installed in a slipout immediately south of the original failure. Initial flows totaled 261,989 gpd. More drains were recommended at that time to stabilize the large cut area. In 1959 these drains were installed by contract. Unfortunately, there is no record of the number of drains in this installation or their performance (Figure 12).

In 1974 the installation was again evaluated. Of the 147 drains examined, approximately 40 percent had flows. Many of the original drains installed 39 years ago were still functioning, one of which had a flow of 36,000 gpd. Most of the steel casings were severely rusted (Figure 13). Root growth from willows and other native plants had clogged many of the drains and the 8-inch collector system. Sloughing of the weathered slopes has buried many of the drain outlets on both the bench and at grade (Figure 14).

5. Nojoqui Grade

In December of 1940 approximately 200 feet of the northbound lanes of Coastal Highway 101 was lost or endangered by the slipout of a portion of a sidehill embankment. Vertical borings in the foundation area indicated the presence of a high water table in soft, poorly bedded claystone and siltstone. A smaller slipout of a similar nature occurred some 800 feet north of this site at approximately the same time.

Forty-two horizontal drains were installed using the "Hydrauger" during the summer of 1941 after the embankments had been reconstructed. They were placed into the hillside from locations immediately below the toe of slope in the saturated foundation

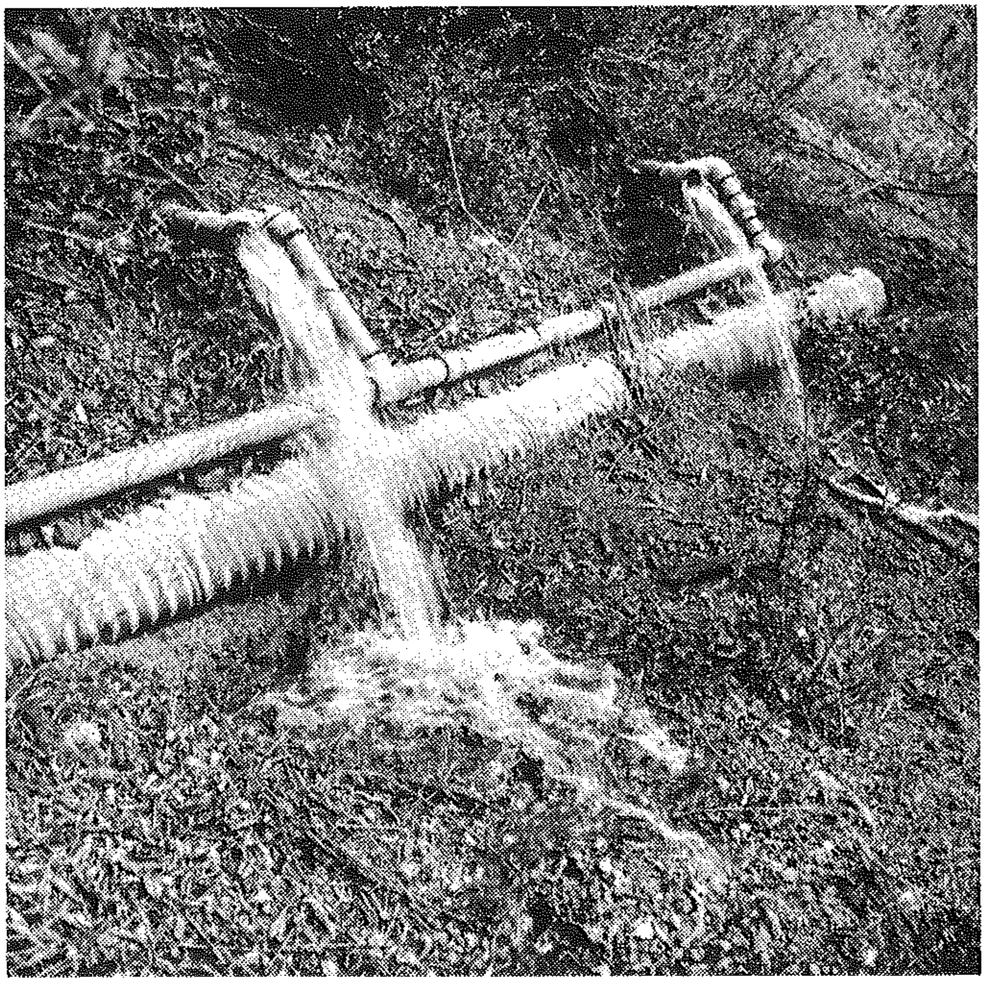


Figure 12. Cloverdale drains and collector system installed in 1959. Photo taken in March 1980.

Figure 13. Rusted outlet of drain installed at Cloverdale in 1941. Photo taken in March of 1980.

Figure 14. Buried drain at Cloverdale which was uncovered in 1974. Photo taken in March of 1980.

area. These drains ranged in length from 72 feet to 191 feet, a record for its day. Perforated 2-inch steel casing was used in 4-inch holes using auger bits and diamond "A" rod. Grades ranged from 2 to 10 percent. Records showing initial flows are not available and may not have been made.

Although the drains may have been cleaned from time to time, the first record of cleaning was in December of 1962, some 21 years after they were installed. Only 27 of the original 42 drains were found. The others had been buried by end dumping of slide material from a cut slope immediately south of the embankment. A heavy accumulation of roots, rust, and silt was evident in most of the drains cleaned. No appreciable increase in flow was noted after cleaning (Table 2), probably due to cleaning at the end of a hot, dry summer. Flows increased considerably during the wet season.

In late 1974 a contract was let to widen the embankment and construct two additional lanes for traffic. Shortly after commencement of the contract, it became evident to the resident engineer that additional subdrainage facilities would be necessary to assure construction and maintenance of a stable roadway. Boggy conditions, especially along the toe of the existing embankments in the area of buried drains, caused very slow and difficult operation of the contractor's excavation equipment. Several of the buried drains were uncovered by the contractor's equipment and were still functioning. The casings were largely rusted through. Those drains that had exposed outlets had large accumulations of iron oxide and algae on the ground below the casing (Figure 15).

TABLE 2

EFFECT OF DRAIN CLEANING
ON FLOW AT NOJOQUI GRADE - 1962

Drain No.	Depth Cleaned	Flow Before Cleaning GPD	Flow After Cleaning GPD	Remarks
2	115	Dry	Dry	Rust & silt
3	55	Dry	Dry	Rust & silt, pipe broken
8	120	Damp	Drip	Bit went through pipe at 110'
9	22	Damp	Damp	Rust, roots, silt; pipe broken at 22'
11	6	Slow Drip	Drip	Pipe bent at 6'
12	32	Damp	Damp	Roots, rust, silt; pipe bent or broken at 32'
13	180	Damp	Damp	Roots, rust & silt
14	155	Dry	Dry	Heavy rust, roots & silt
16	190	Dry	Dry	Roots, rust & silt
17	175	Drip	Fast Drip	Roots, rust & silt
19	190	Drip	Drip	Roots, rust & silt
21	175	Dry	Dry	Roots, rust & silt

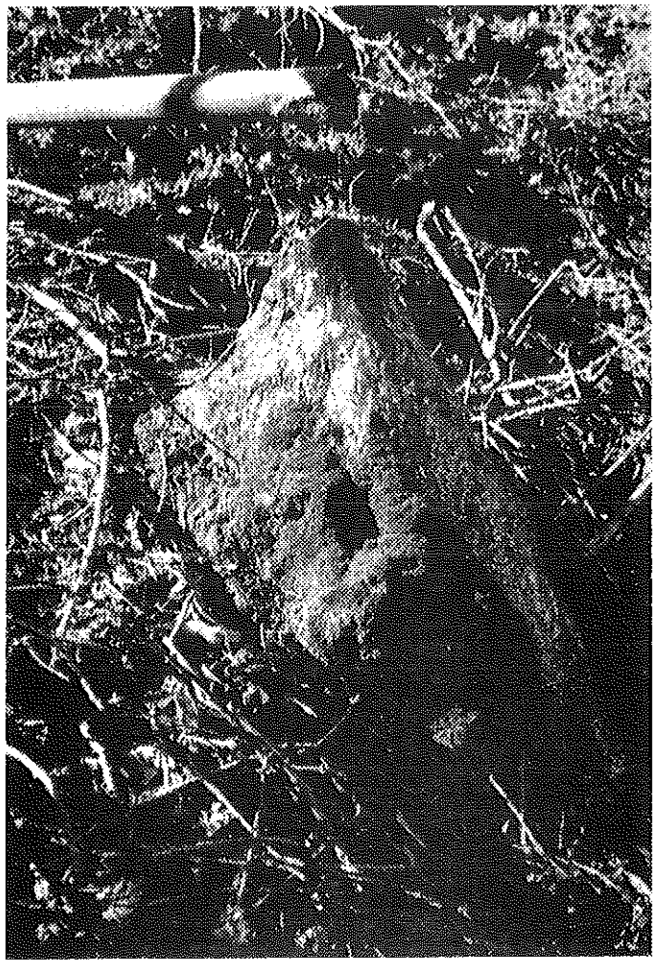


Figure 15. Rust and algae accumulation from drain installed at Nojoqui Grade in 1941.

Thirty-two new drains were installed in the spring of 1975, all of which showed some flow at the time of installation. The combined maximum initial flow was approximately 157,480 gpd. The combined flow at the completion of the job was approximately 11,350 gpd. The drains ranged in length from 150 feet to 450 feet. Twenty-five are 300 feet long.

A very successful horizontal drain installation, in terms of drilling progress and quantities of water produced, was completed at Nojoqui Grade in 1975. An average of 275 linear feet of drilled and cased drain was accomplished per 8 hour shift. There were several days when the footage was 350 linear feet per 8 hour shift using modern equipment.

In March of 1978, the installation was again inspected. Of the original 42 drains installed in 1941, all but eight were destroyed or replaced during the widening project of 1975. Of the eight remaining drains, two were dry, one had a drip, two displayed a trickle, two produced 90 gpd and one had a flow of 720 gpd. The steel casings of the 38 year old drains were severely rusted and would probably be totally destroyed if disturbed by a cleaning operation.

6. La Selva Beach

On August 18, 1973, cracking developed during construction of a 120 foot high, 1,200 foot long 2:1 cut slope near La Selva Beach. The project is located on the coastal highway south of Santa Cruz.

Massive, faintly cross-bedded very friable and loosely compacted buff-colored medium-grained silty sand of the Aromas formation is exposed on the slopes. These Pleistocene sand dune and lagoonal sediments are occasionally interbedded with 6-inch to 2-foot thick beds of gray to brown silty clay. Measurements taken on the clay beds suggest a slight tilting by as much as six degrees toward the west.

The Aromas deposits are so poorly cemented that when exposed to rainwater or surface runoff, the structure disintegrates and washes easily, forming gullies and miniature badlands.

During clearing and grubbing operations, just prior to excavation, a large grove of mature eucalyptus trees were cut down near the top of the planned cut. Elimination of transpiration by the trees caused a rapid rise in the groundwater table. This resulted in a saturation of the poorly cemented sand and a sudden loss of strength. Lateral support of the weak material was greatly reduced by the excavation, resulting in cracking of the new slope near the top and followed shortly afterward by an overall slope failure and flow of saturated sand near grade.

On October 6, 1973, corrective grading was started. The work consisted of removal of the failed debris and excavation of a new 2:1 slope down to the grade of an upper 50 foot wide bench. This was completed on November 5, 1973. On November 19, 1973, the contractor installed a 30-inch vertical well on the bench to a depth of 51.5 feet. State forces then installed five observation wells spaced at 200 feet on centers along the upper bench. These wells were drilled through 45 to 50 feet of sandy material to the top of the major clay layer along which movement and groundwater flow was taking place. The lower 2 to 12 feet of sandy material in the wells was saturated.

The 30-inch well was pumped 24 hours per day from December 11, 1973 to March 4, 1974. Average daily discharge was 1,900 gallons. During this period no appreciable drawdown was noted at the observation wells, and the pumping well was abandoned.

On March 26, 1974, horizontal drilling began. The original plan was to install several 300 foot holes on 2 percent grades from each of three areas for good coverage. After several attempts, the best results were obtained by drilling on 6 to 8 percent slopes with most borings limited to 150 to 200 feet in length. Sixty-nine horizontal drains were installed with a combined maximum initial flow of 169,500 gpd.

Drilling was very difficult. Initial attempts were totally unsuccessful for two major reasons. First, when the Aromas sands become wet, the original structure collapses and the sand "melts" and begins to flow (Figure 16). When drill rotation was stopped in this material, the pump shut off and the stem broken for the purpose of adding an additional section of new drill rod, the sand slurry would flow into the drill rod through the open drill bit, packing the entire string of drill rod. When drilling resumed, it was impossible to force the packed sand out of the drill rod and regain circulation of drill fluid.

Figure 16. Flow of Aromas sand across frontage road at La Selva Beach.

Secondly, even where a reasonable length of hole was successfully drilled, it was not possible to case the drain through the wire line drill rod because of the presence of sand. Caving of the saturated sand prevented a successful casing operation once the drill rod was removed from the hole.

In an attempt to overcome these difficulties, a foot valve was welded to the shank of a "drop-off" tri-cone roller rock bit. This prevented the inflow of the sand slurry when the pump was shut off. In addition, a floating piston device was inserted in the drill rod adjacent to the rig by the drilling contractor to retain drill fluid in the rod while adding new sections of rod and to prevent sand from entering the drill rod during the casing operation after the bit had been dropped off. This combination of valves worked well.

Mechanical analysis of the material suggested that the conventional .020-inch slotted PVC casing would allow too much sand to enter the casing. A .010-inch slot was selected and used throughout the job.

Observation well water data indicated a slow steady drawdown during and following completion of the horizontal drain installation. Based on these positive results, the contractor began excavation on May 10, 1974 from the upper bench to the lower bench level.

On May 23, 1974, an 8-inch slotted plastic pipe underdrain was placed in an 8 to 12 foot deep trench on the lower bench. The flowline grade of the underdrain was situtated approximately 1.5 feet below the top of the major clay layer.

During placement of the underdrain in the trench, a crack appeared in the slope above the lower bench. It was 350 feet long by up to 0.2 foot wide and extended up to the front of the upper bench. The contractor proceeded with the work at an accelerated rate until the system was backfilled. No more movement has been observed in this area.

On May 29, 1974 while excavating the slope below the lower bench, a small "blowout" of saturated sand occurred. It was repaired with heavy stone riprap.

Both bench surfaces were treated with SC-70 prime coat at 0.75 gal/yd^2 to stop rainwater from penetrating into the slip zone.

The installation is now nearly 6 years old and there is no distress of any consequence showing up. The prime coat on the benches has been damaged by foot traffic, however. The horizontal drains have performed extremely well and have been effective in keeping the groundwater at a safe level.

Maintenance forces have cleaned the drains every 2 to 3 years using a high water pressure system. Minor amounts of sand have been removed but the quantity is decreasing each time they are cleaned.

Slot size has been particularly important on this project. Two-inch metal pipe with 3/8-inch perforations were used on a job with similar materials during the early 1940s. This project was located three miles east of the present site. The casings were packed with the Aromas sands in a very short time and the drains lost their effectiveness almost immediately.

7. York Mountain

A 23-mile segment of totally new highway alignment was constructed between Paso Robles and Cambria on the central coast of California during the late 1960s and early 1970s. This portion of the California Coast Range has a history of instability and associated groundwater problems. In addition, the area is dissected by both ancient and historically active fault zones.

Failure of the 1-1/2:1, 750 foot long cut slope near York Mountain was first noted on November 5, 1970 during a period of heavy rainfall. The planned cut for this area was 140 feet in height. Excavation had been carried to within 50 feet of grade when the first movement was observed. Work was stopped at 37 feet above grade as the area of disturbance rapidly enlarged.

The initial failure occurred low on the cut as a shallow arcuate-shaped slump in highly sheared and broken black clayey gouge-like material. Extensive cracking then developed above the slump in thinly bedded shales and sandstone which dip steeply into the cut face. The cracks were roughly parallel to the roadway and occurred along the strike or trend of the sediments. As the lower portion of the slope was displaced toward the roadway, the overlying beds tilted toward the open cut. This movement developed along clayey bedding planes and was progressive in degree of displacement and distance from roadway (Figure 17). A significant reduction of lateral support by excavation, coupled with the introduction of surficial rainwater along clayey bedding planes greatly reduced the shear strength along these planes resulting in progressive cracking and

Figure 17. York Mountain failure during construction. November 1970.

block tilting. Groundwater was not evident at any time and did not appear to be a factor in the failure at that time.

A stability analysis was conducted using a conventional block configuration. The constructed 1-1/2:1 slope was assigned a safety factor of unity. Depth of failure of 30 feet and a unit weight of 150 lbs/cu.ft were used. Using these criteria, a safety factor of 1.24 was obtained for a 2:1 slope. Based on observations made during the field investigation, it was felt that a slope having a safety factor of unity may be somewhat flatter than 1-1/2:1. A 2:1 slope was, therefore, considered marginal for the high cut, and a 2-1/4:1 was recommended, with a 20 foot wide bench 50 feet above grade and a 10 foot debris bench at grade.

Cracks appeared at the top of the corrected slope by July 1971. With the advent of the wet season, the failure progressed throughout the cut with some tilting movement along individual clayey bedding planes, similar to the original failure. No distress was noted on the pavement, but free water was evident along the debris bench at grade on the lower portion of the slope, and for about 20 feet above the upper bench.

Five 360 foot long exploratory horizontal drains were installed at grade in mid September of 1972. All drains were placed normal to the roadway so that they would intercept as many bedding planes as possible. Grades were held to 5 percent, while the spacing between drains ranged from 45 to 100 feet.

The combined maximum initial flow was 72,830 gpd. A somewhat reduced movement along the clayey planes continued throughout the next winter. Several wet spots persisted on the slopes and near grade.

During April and May of 1973, an additional 18 horizontal drains were installed from grade and from the bench above grade in an effort to stop movement and dry up the slope. Lengths ranged from 245 to 360 feet while grades ranged from 5 to 15 percent. Orientation of each drain was normal to the steeply dipping shale beds.

Initial flows ranged from dry to 175,000 gpd, while the combined initial flow was over 332,940 gpd. A final reading on the last day of drilling, May 9, 1973, was 70,954 gpd.

The horizontal drains on this project are extremely responsive to rainfall. Figure 18 illustrates this relationship quite clearly, covering a period of time from their installation until April of 1975.

The seven year old project was inspected in March of 1980 (Figure 19). The drains and collector system appear to be in good condition but they have not been cleaned since their installation. All the drains were cased with 1-1/2-inch slotted PVC so there is no rust, but some silt and root growth was noted.

No more movement has been recorded since the last 18 drains were installed. It appears that the drains have been effective in dewatering the slope, producing an increased strength of materials resulting in a condition of equilibrium.

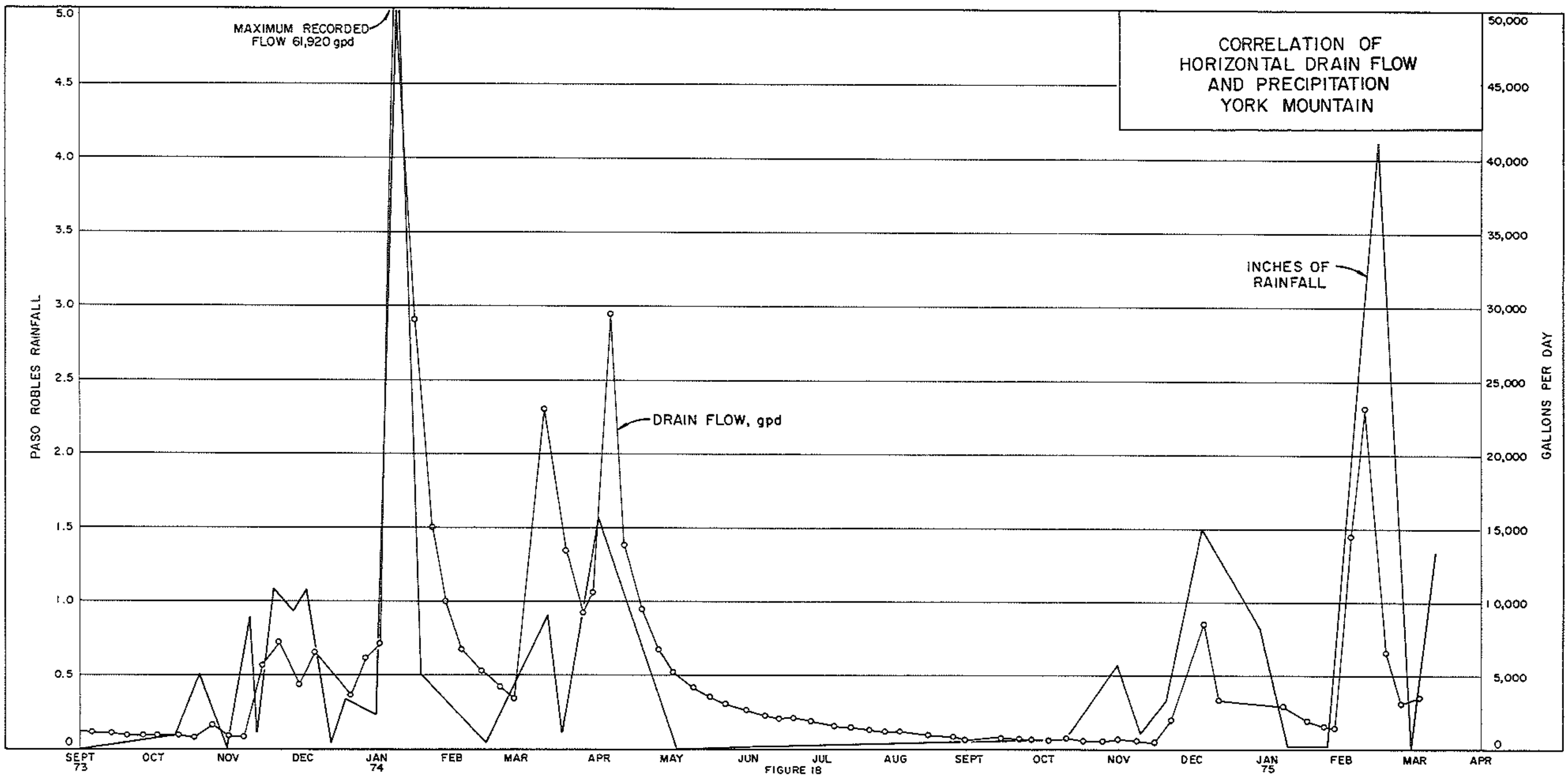

CORRELATION OF
HORIZONTAL DRAIN FLOW
AND PRECIPITATION
YORK MOUNTAIN
MAXIMUM RECORDED FLOW 61,920 gpd
DRAIN FLOW, gpd
INCHES OF RAINFALL
PASO ROBLES RAINFALL
GALLONS PER DAY
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
SEPT 73
OCT
NOV
DEC
JAN 74
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
NOV
DEC
JAN 75
FEB
MAR
APR

FIGURE 18

Figure 19. Progressive tilting of shale beds into roadway at York Mountain. Photo March 1980.

B. Major Factors Which Influence Drain Effectiveness

Through the seven case histories presented in this paper the effectiveness of horizontal drain installations in increasing soil strength through dewatering, arresting movement and stabilizing serious problem areas has been demonstrated.

Several factors influence the effectiveness of a drain system such as the lithology, location, orientation, spacing, casing, age, pH and mineral content.

1. Lithology

Most horizontal drains installed within the California Highway System are drilled in weathered rock covered by thin surficial layers of soil. Of the seven case histories cited, six are in weathered rock including serpentine, volcanic agglomerate, granite, phyllite, tuff, sandstone, shale and clayshale, while the seventh is in a poorly consolidated dune sand.

Movement of groundwater within rock is largely confined to discontinuities such as joints, fractures, bedding planes, faults and planes of foliation. These discontinuities must be open and continuous or must intersect each other in order to allow influent seepage and movement of groundwater. Closed discontinuities such as tight joints and bedding planes or the lack of discontinuities in the case of massive blocks of igneous rocks or massive beds of sedimentary rock will yield little if any water when penetrated with a horizontal drain.

Exceptions to the above are where the rock is permeable as in the volcanic agglomerate of the Whitmore Maintenance Station or where granular material is loose and poorly cemented as in the dune sands of the La Selva Beach project.

Cementation, fabric or structure, and grain size are important factors when attempting to dewater sedimentary material. As a general rule, the finer the grain size, the slower the sediments will drain. Clays yield little if any water to drains while sands which have an open structure with interconnected void space or little cementation such as the La Selva Beach sands can be effectively drained.

The geology of California is quite complex. Several changes in rock type as well as the associated discontinuities such as faulting or angular unconformities can take place within a few feet. An example of this is the Whitmore Maintenance Station project where a 50 foot high cut slope exposes volcanic agglomerate conformably overlying tuff which is in discordant contact with the underlying phyllite.

All three rock types have different water bearing and transmitting capacities. The volcanic agglomerate is permeable and readily allows percolation of surface water downward to the underlying tuff. The tuff, which is highly altered and contains a considerable amount of clay, is virtually impermeable. The phyllite which lies below the tuff is vertically foliated, parts easily along these planes, and where slightly weathered, allows water to move freely.

Horizontal drains drilled into the agglomerate yield large amounts of water during the wet season and are usually dry during the summer months. Drains placed solely in the clayey tuff do not yield water at any time of the year, while drains exclusively placed in the underlying phyllite generally yield moderate amounts of water all year long.

Lateral changes in lithology are also common within the installations studied and have a direct bearing on the effectiveness of the drains. This is particularly true at the York Mountain and Cloverdale installations where the largest producers of water are from drains located in fractured sandstone. Adjacent drains drilled in tight shale generally produce far less water.

2. Drain Location, Orientation and Spacing

The most effective horizontal drain installations in California are those which have been designed and drilled on the bases of the geology of the site. In order to achieve maximum effectiveness, a site must first be analyzed to determine the source and direction of groundwater movement into the area, the transporting agent such as a permeable stratum, brecciated zone or open joints sets, and the most desirable location to intercept the water before it reaches the area of instability.

Near-vertical groundwater barriers such as the clayey, gouge-like shear zones of the Cloverdale project must first be identified and then penetrated by horizontal drains to relieve the impounded water behind them.

Confining beds, such as the clayey tuff of the Whitmore Maintenance Station which impeded the downward percolation of water and produced a saturated slope of agglomerate above grade, must first be recognized and then penetrated with a drain having a suitable grade before stability can be obtained.

The York Mountain project was effective because each drain was aligned to intercept the maximum number of water bearing bedding planes. This was accomplished by drilling the drains normal to the strike or trend of the steeply dipping shale and sandstone beds.

Stability was achieved at the La Selva Beach project because good coverage of the saturated sands was obtained and because the drains were located low in the section, resulting in a maximum drawdown of the water table.

Spacing of drains in an installation should be based on the location of productive zones where the water occurs rather than an even spacing over a large area which is both productive and nonproductive. Spacings of joint sets or bedding plane thicknesses may vary widely over a short distance, therefore requiring a variable spacing of drains to accommodate change.

Drain length of the seven projects cited was governed by the water bearing strata intercepted rather than on a predetermined length. In most cases the initial drains are drilled to a greater length than is considered adequate. Volumes and points where the water was intercepted were recorded during drilling and subsequent drain lengths were determined from the drill data.

Location, orientation and spacing of drains are often adversely affected or controlled by right-of-way constraints, funding, topographic accessability or a combination of the above. These constraints must be held to a minimum if an efficient, productive installation is to be obtained.

3. Effect of Time on Casing and Productivity

Some of the first horizontal drains installed by the California Division of Highways in 1939 were cased with 2-inch, black perforated metal pipe. For the next 30 years, this type of casing was used in California.

In 1969, slotted 1-1/2-inch Schedule 80 PVC casing was used on an experimental basis at Pacific House. A total of ten drains were installed, four of which were cased with plastic while the remaining six were cased with perforated metal pipe. Both metal and plastic were used on the same project so that a meaningful comparison of performance could be made under identical conditions of age, maintenance and environment.

The Pacific House installation was selected for the research study because of this unique situation and because it is one of only a few that have been installed in granitic material. A field inspection of the 11 year old PVC showed that it is in excellent condition and should perform well for many more years. Slotted sections were used throughout the entire length of the drains allowing willow roots easy access near the outlet (Figure 20). The drains need cleaning, and a protective sleeve of galvanized pipe should be put over the outer 10 to 20 feet of drain to discourage root growth.

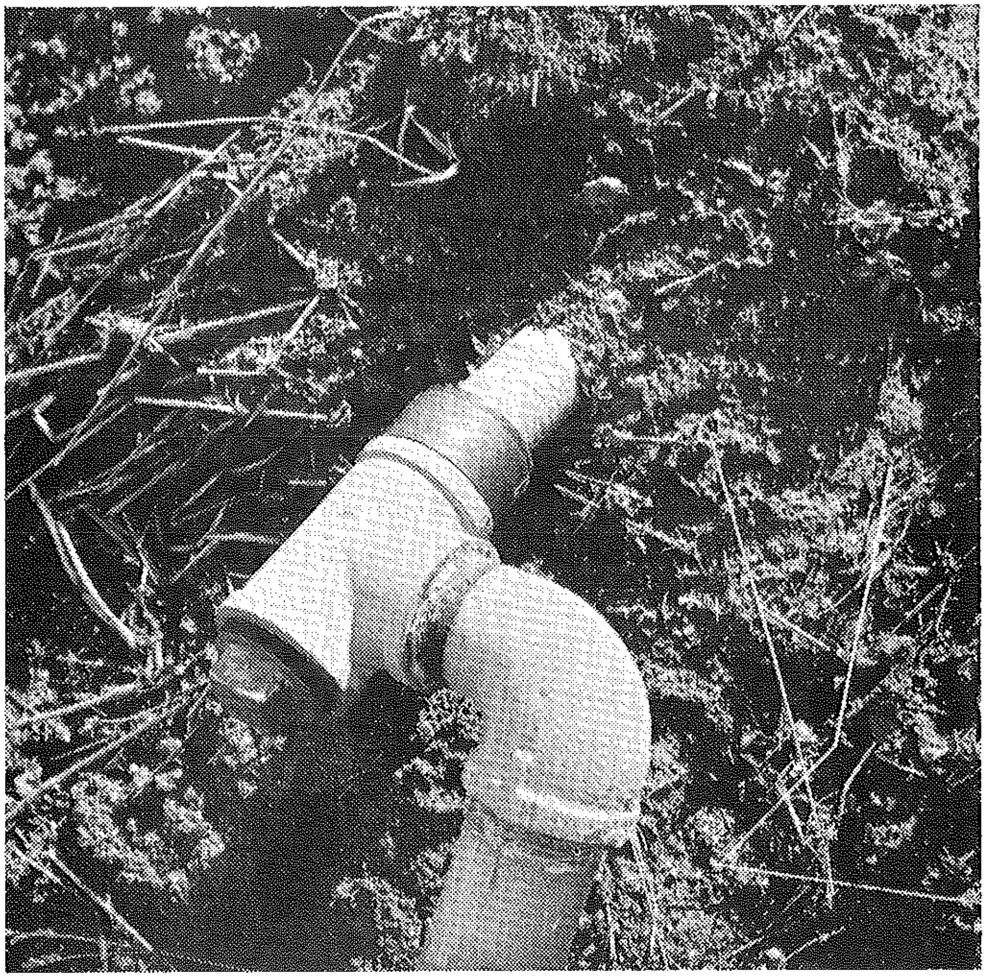


Figure 20. Slotted PVC casing installed at Pacific House in 1969. Photo taken in March 1980.

The metal casings, although somewhat rusted, were in good condition and should last an additional 20 to 30 years in this environment.

Because the 3/8-inch diameter perforations are so much larger than the 0.020-inch slots, they allow more of the fine-grained material to enter the casing. This does not appear to be critical at Pacific House, but would be at an installation like La Selva Beach where the material consists largely of fine to very fine-grained poorly cemented sand.

A 0.020-inch slotted PVC casing is used in the majority of all installations made in California today. When poorly cemented granular material is encountered, a mechanical analysis is run to determine the proper slot size. Three of these installations have required the use of .010-inch slotted casing, including the La Selva Beach installation, to prevent the fine-grained sand from entering the drain. The oldest of the three is now seven years of age and is performing well, but requires cleaning with a high pressure water system every second year.

Some metal drains, 40 years of age, are still producing large quantities of water although their casings have largely deteriorated to a thin shell of rust. In most cases an attempt to clean them at this stage would result in severe damage or total loss of their structural integrity.

Although the oldest installation using PVC is only 11 years of age, it is anticipated that through an effective maintenance and cleaning program, the 40 year life may be considerably extended, certainly well beyond the design life of the highway.

It has been very difficult to evaluate the effect of age on an installation in the area of productivity. Flows fluctuate widely from day to day during the wet season. Storms vary widely in intensity and duration.

To be meaningful, it therefore would be necessary to make flow measurements each year at the same time interval following a storm which was similar to the previous year's storm in size, intensity and duration.

Soil moisture also varies widely and would have to be reasonably similar in order for a yearly comparison to be meaningful.

Undoubtedly, there is a slight decrease in efficiency over a period of years. It is the author's opinion, however, based on observations made during this study and over a period of years prior to this study, that if proper cleaning and maintenance is performed on a regular basis, a drain installation will function effectively for at least as long as the expected life of the highway and in most cases longer.

4. Maintenance Programs

Perhaps the single most important factor in the long-term performance of horizontal drains is a well developed and executed program of inspection, repair and cleaning.

To begin with, a drain cannot be maintained if it cannot be located. Lack of good records, including plans which show the locations of the drains in relationship to survey monuments or permanent landmarks is common. These sites can be obscured or lost in time because of transfers, retirements or promotions of personnel who are only aware of the drains because they were present during the actual installation.

It would appear that the most effective method of maintaining continuity in a horizontal drain program is to permanently assign qualified personnel the full-time task of inspecting, cleaning, replacing or repairing horizontal drain installations on a state-wide or regional basis.

The establishment and maintenance of a central file on all drain installations as well as the placement of paddle markers (Figure 21) or other means of marking each drain in the field such as well marked steel posts or signs, is a good practice.

Drains located near the toes of embankments are sometimes lost through the practice of end-dumping waste material over the side of the fill, thereby covering the outlets. This practice, in addition to burying the drains, can reactivate movement in unstable areas particularly where the load is placed at or near the head of the slide mass.

Dense growth of water-seeking plants such as willows around the outlets not only tend to conceal the drains but also to curtail their performance by extensive root growth within the first 10 to 20 feet of the opening. Selective herbicides have been used successfully around the drain outlets to retard or eliminate undesired vegetation. Solid pipe is now used for the outer 20 feet of each drain to discourage roots from entering the drains.

Horizontal drains are also lost or damaged because they are not protected against rockfall, particularly in the case of exposed PVC casing, or because they are vulnerable to snowplows, rockplows, or straying vehicles near the edge of the

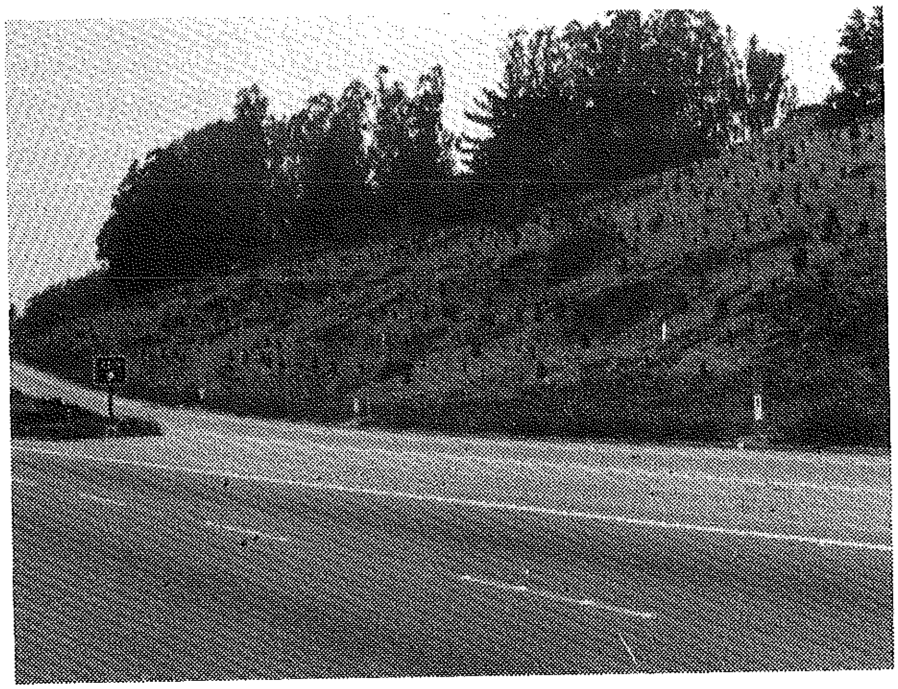


Figure 21. Paddle markers used to mark drain outlets at La Selva Beach.

traveled way. A good practice is to protect the PVC casing at the outlet with a galvanized pipe sleeve which slips over the PVC casing and is inserted into the drilled hole approximately 10 feet. The exposed end of the metal pipe is then connected to a cleanout plug with an elbow which allows the surface pipe to lie adjacent to and parallel with the slope (Figure 22). This pipe is then connected to a buried collector system located at the base of the slope. Cleanouts should also be provided for the collector system.

Drain cleaning and maintenance records should be kept for each installation. These records should include dates of cleaning and repairs, flows recorded for each drain prior to and after cleaning, depth of cleaning, shearing or damage of drains due to slide movement or external forces, the general condition of each drain, and the responsible party in charge of the operation. Figure 23 was designed during this study for field use by maintenance personnel. A minimum of writing is required to complete the form and it could be readily adapted to a computer program.

5. pH and Mineral Content

The effectiveness of a drain installation over a long period can be greatly altered by the pH and mineral content of groundwater. Although these factors were not examined in detail for this study, they appear to be more important than the type of environment such as coastal, valley or mountainous.

High acidity (low pH) or the presence of corrosive elements commonly found in fault zones or highly mineralized areas may significantly shorten the life of the drain by attacking the casing. This is particularly true where steel casing has been used.

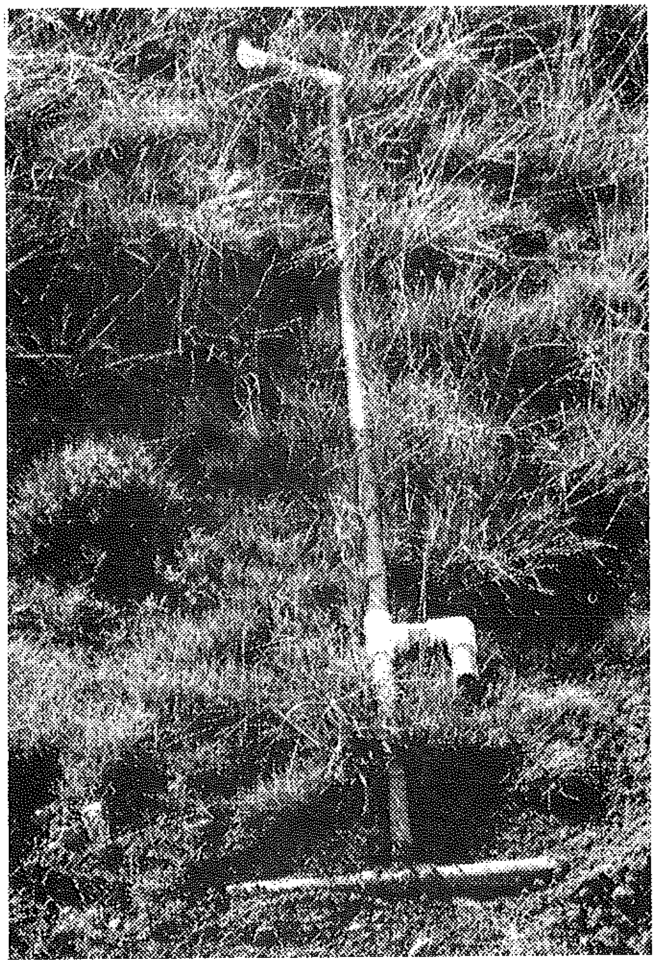


Figure 22. Drain outlet and collector system.

HORIZONTAL DRAIN

Inspection Cleaning Repair

District_____ County_______ Rte._______ P.M._____ Geographic Loc.____________

Inspected by__________ Date_________ Drain No._______

Drain Length________ Length Cleaned_________ General Condition ____________

FLOW DATA

	Before Cleaning	After Cleaning
1. Dry	☐	☐
2. Drip	☐	☐
3. Trickle	☐	☐
4. Flow	_______ gpd	_______ gpd

DRAIN CONDITION

	Slight	Moderate	Heavy
1. Root Growth	☐	☐	☐
2. Mineral Deposit	☐	☐	☐
3. Rust	☐	☐	☐
4. Silt	☐	☐	☐

MISCELLANEOUS

	Present	Needed
1. Paddle Marker	☐	☐
2. I.D. Tag	☐	☐
3. Outlet	☐ Visible	☐ Concealed
	☐ Intact	☐ Damaged
4. Collector System	☐ Buried	☐ Exposed
	☐ Intact	☐ Damaged

Comments:____

____

____

Field Form for Horizontal Drain
Inspection, Cleaning and Repair

Figure 23

Groundwater which is highly charged with calcium sulfate, or iron, for example, may also reduce the performance of the drain by plugging the slots or perforations. Mineral compounds are usually precipitated near the outlet where the ionic solutions are subjected to a change in temperature and pressure.

C. Drain Cleaning Equipment and Techniques

Since the first horizontal drain was installed in California in 1939, there has been a growing need for adequate tools and equipment to clean and maintain them. Early efforts consisted of a short steel rod with a sharpened blade welded to the end for cutting root growth near the outlet. Later a flexible steel cable used in cleaning sewer lines was tried. This equipment was not particularly suitable in that there is no flushing action, the length of cable is limited, and it frequently catches on the inside of the casing and twists off.

Eventually a cleaning system consisting of an air-driven motor, 5 foot sections of "E" rod, and a fishtail shaped cutting bit was developed (Figures 24 through 27). Power was supplied to the air motor by a small compressor with a capacity of about 125 psi. As the rod and bit were rotated, water was circulated through the rod by means of a small pump, usually the equivalent of a 2-inch trash pump.

Normal operational procedure was to insert the bit and rod into the outlet of the drain and then rotate the drill rod with the air motor as it was advanced into the drain by two men pushing on the apparatus. The drain was flushed at the same time by circulation of water through the drill rod.

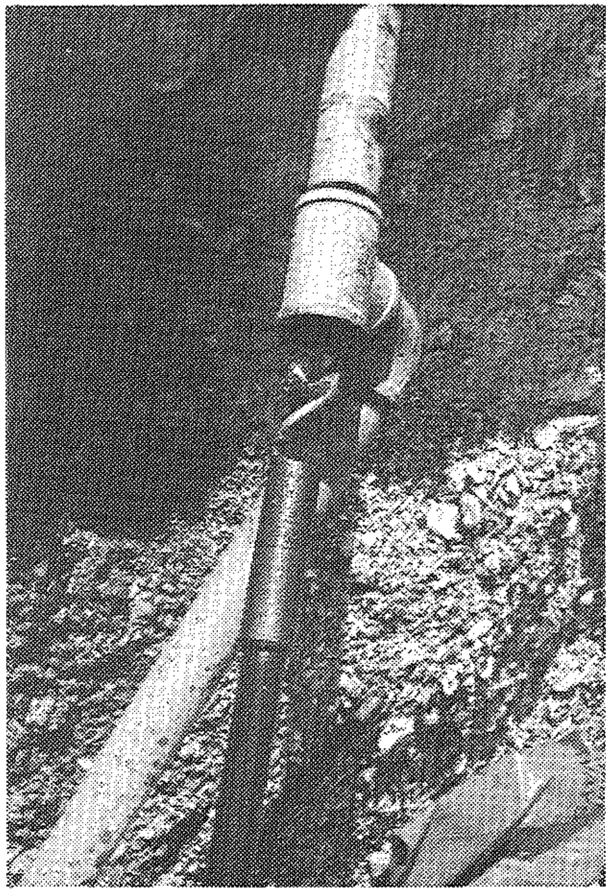


Figure 24. Bit and "E" rod formerly used to clean horizontal drains.

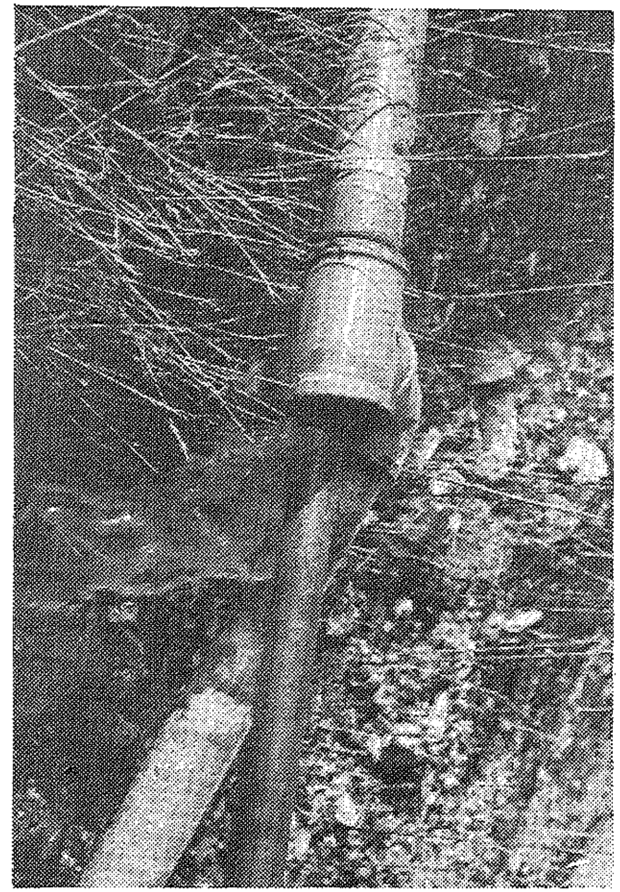


Figure 25. Cleaning system in operation. Note rust and silt encountered during flushing.

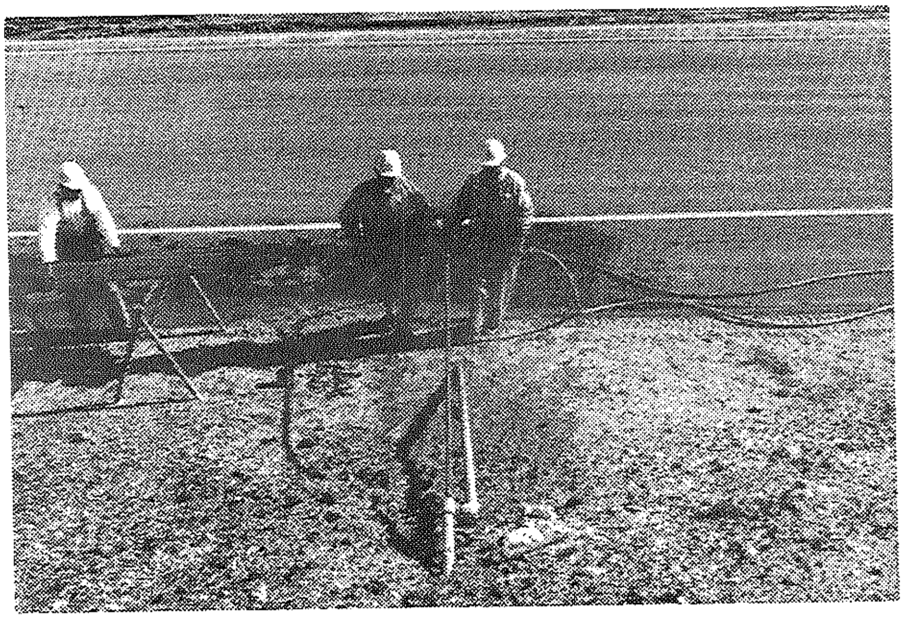


Figure 26. Drain cleaning operation at San Andreas, 1975.

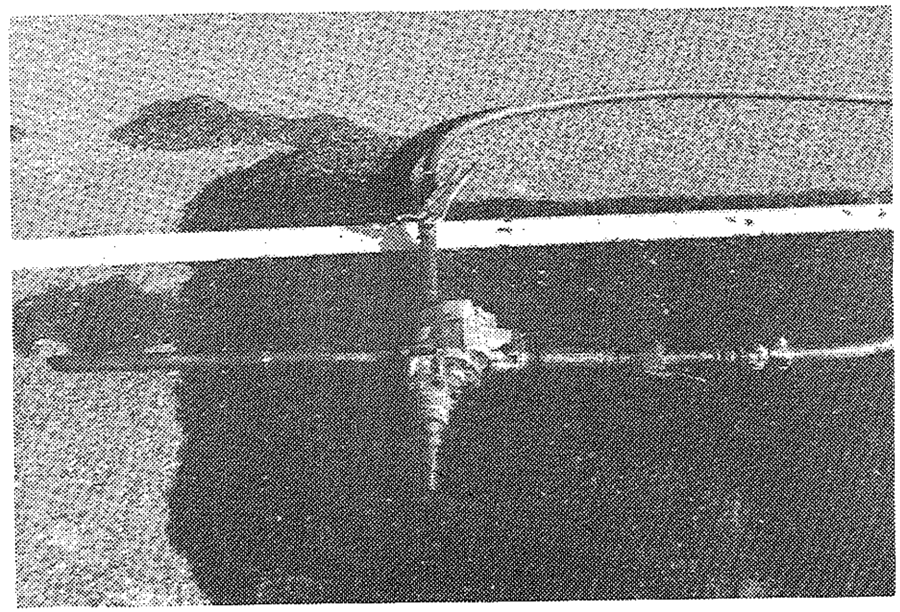


Figure 27. Close-up of air motor.

This equipment and cleaning technique is still widely used today. Cleaning of the first 100 feet or so is usually accomplished without too much difficulty, but as additional lengths of rod are attached, it becomes increasingly more difficult to work the rod back and forth and advance the bit in the casing.

Until the advent of PVC casing in 1969, most horizontal drains were cased with 21-foot lengths of 2-inch black perforated pipe which was butt-welded in the field. Frequently the drill bit would catch on these welded joints, resulting in a tendency to wrench the air motor out of the hands of the operators.

This drain cleaning system was examined in detail during the research project in an effort to improve or redesign the system for satisfactory use in both steel and PVC casing. As part of this effort, drain cleaning of the San Andreas project was conducted in November of 1975. The entire process was observed and photographed. It was concluded during this phase of the study, that the rotating, cutting blade should be eliminated because of the potential damage to the PVC casing. It was also concluded that the maximum effective depth of cleaning was about 200± feet which was approximately 100 feet short of the average length of newly installed drains. The cleaning procedure was also very demanding physically and the men were susceptible to injury.

During the course of the study it was learned that maintenance personnel in one of the highway districts had adapted a high pressure water cleaning system for use in cleaning drains. The truck-mounted system was originally designed and built for cleaning sewers and had been modified for use in unplugging culverts. Components included a high pressure pump with a capacity of 600 to 800 psi, a reel-mounted hose, a water tank and a vacuum system for retrieval of the water and debris. Initial modifications for drain cleaning consisted of reducing the hose size to one inch and the use of a smaller nozzle on the end of the hose (Figures 28 and 29).

The system did a reasonably good job of cleaning the perforated steel casing, however, the operators had to assist the system by pushing the hose into the drain because of insufficient pressure. Depth of cleaning was therefore limited to about 150 feet.

During the summer of 1976, arrangements were made for the demonstration of a high pressure water system at the Whitmore Maintenance Station. The truck-mounted system called the Vactor Jet-Rodder was designed and built by the Myers-Sherman Company of Streator, Illinois. This vacuum and jetting equipment was also designed for sewer and culvert cleaning and had a 1,500 gallon water tank for jetting, a 16 cubic yard tank for refuse collection and a variable pressure pump producing up to 1,650 psi with a patented pulsating or jack hammer action.

The demonstration was impressive. Several drains were cleaned within a two hour period. Because of the high pressure, the hose was self-feeding into the drains. A 300 foot drain could be cleaned with relative ease within about a 20 minute time period.

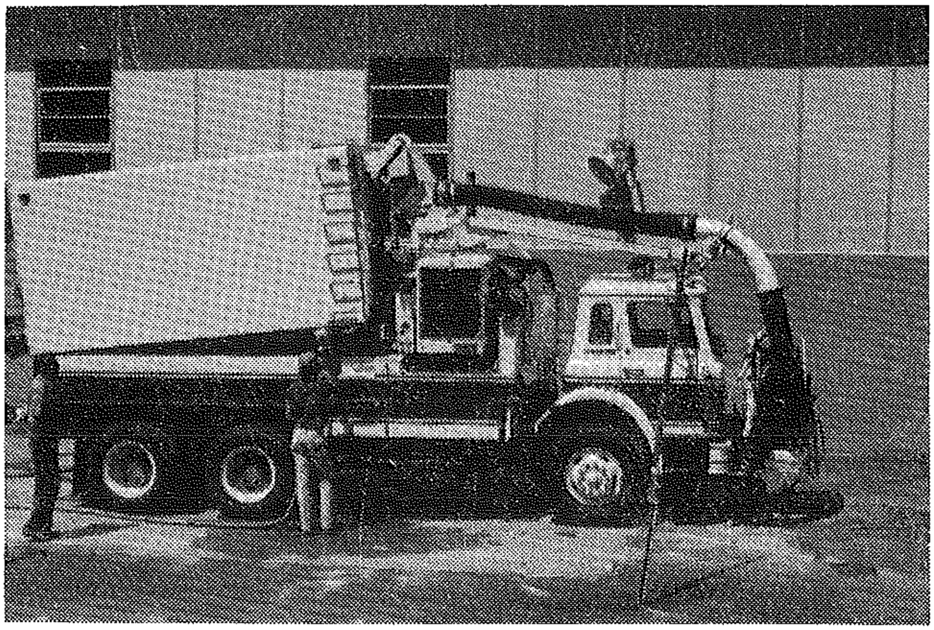


Figure 28. Vactor Jet-Rodder - truck, tank, pump and reel at Whitmore Maintenance Station.

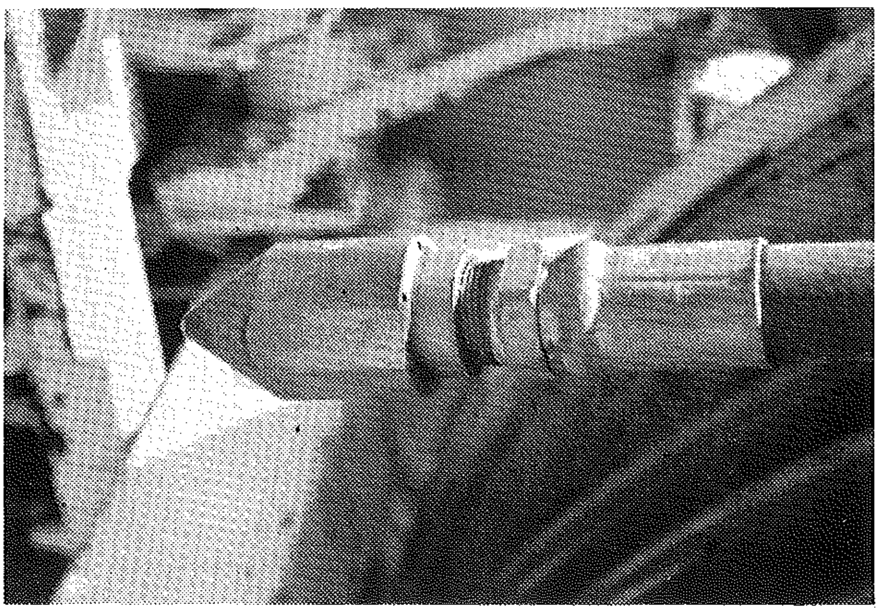


Figure 29. Close-up of Vactor Jet-Rodder hose and nozzle.

In January of 1978, the drain cleaning operation of Contra Costa County was observed. They had modified an early model high pressure water system manufactured by F. E. Myers Company of Ashland, Ohio for use in cleaning horizontal drains. The system was so impressive that a demonstration of the latest Myers equipment was set up for August 10, 1978 at the La Selva Beach drain installation.

This site was selected because slotted PVC casing had been used and because the accumulation of very fine sand passing the .010-inch slots would provide a good test of cleaning effectiveness.

The equipment consisted of a diesel powered Myers pump which can be varied in pressure from 100 to 2,000 psi, 1,000 feet of 1-inch hose mounted on a hydraulically operated reel located on the rear of the truck and a 2,000 gallon water tank (Figure 30). The hose nozzle was constructed with six equally spaced holes drilled on 15 degree angles with the axis of the base (Figure 31) and a single hole at the tip of the head. Water passing through the six holes propelled the hose into the drain and at the same time flushed the sand out of the casing. Water discharged from the center of the nozzle was designed to loosen and erode any blockage in front of the hose.

Cleaning time was somewhat faster than the Vactor Jet-Rodder because of a greater water pressure. A variety of hose sizes and associated volumes are available. Using 1/2-inch hose the volume is 20 gpm, with 3/4-inch hose the volume increases to 35 gpm and with a 1-inch hose the volume is 60 gpm.

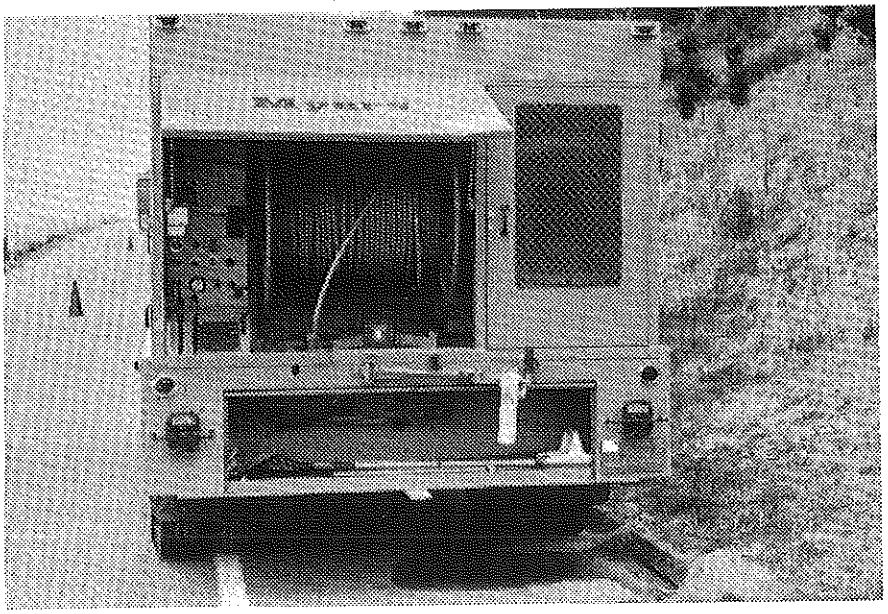


Figure 30. Myers drain cleaning equipment at La Selva Beach.

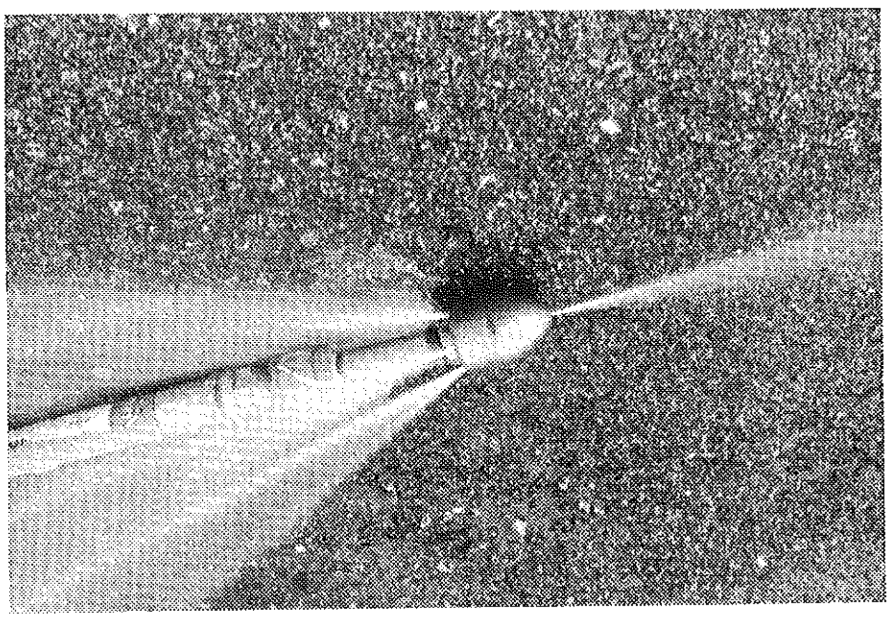


Figure 31. Myers hose and nozzle in operation.

This system appears to be very effective. During the demonstration, the outer galvanized pipe sleeve was removed from the slotted PVC casing of a drain. As the nozzle was passed through this section of pipe, the high pressure water could be observed spraying out of each slot, clearing any obstruction that may have been there.

Inquiries were made of several other companies which manufacture water cleaning systems. These included Dy-Namic Hydra Cleaners of Boerne, Texas, Partek Liqua-Blaster of Houston, Texas and Water Ram of Lamb Enterprises, Inc., Portland, Oregon. Brochures obtained from these companies suggest that they sell similar equipment, although the Water Ram and Partek Liqua-Blaster are smaller, trailer-mounted rigs.

It would appear after testing the various systems under actual field conditions and after discussing the equipment and operations with maintenance and manufacturing personnel that the best performance can be expected when pressures are maintained between 1,600 and 2,000 psi and when the water volume is 30 gpm or more.

Excellent cleaning results were obtained from both the Vactor Jet-Rodder and Myers equipment. No damage was noted from using the high pressure spray on the plastic pipe although prolonged exposure at a single location would probably cause some erosive damage.

Heavy root growth in the first 20 feet of a drain may have to be removed before the water cleaning system can be used effectively. This can usually be accomplished quite easily by hand rotation of a cutting blade on the end of a short steel rod.

The 15 degree angle used for the six orifices on the Myer nozzle appears superior to either greater or smaller angles. Elimination of sharp corners on the nozzles and hose adaptors would be helpful in preventing "hang ups" on welds or rough PVC joints.

The hydraulically operated hose reel saves time and is extremely helpful in winding up the heavy high pressure hose filled with water.

By changing the hose size and varying the pressure and volume, the truck-mounted equipment can be used for a number of different jobs such as cleaning culverts and pipe lines, removing dirt and grease from equipment, scrubbing spills from the travelled way, cleaning signs and preparing surfaces such as guardrails for paint.

D. Comparison of Steel and PVC Casing

Slotted PVC casing is widely used throughout the horizontal drain industry today. Some perforated black metal pipe is still used, however, particularly when PVC is not available or where a greater resistance to shearing is desired.

Black metal pipe is commonly supplied in 21 foot lengths that weigh about 52.5 pounds or 2.5 pounds per foot. These sections of pipe must be butt welded in the field to form a continuous casing. For a typical 300 foot drain, it takes two men approximately two hours to weld and install the casing.

The PVC casing weighs only about 0.5 pound per foot and is available in 10 foot lengths for ease of handling and transport. Male and female ends are milled at the same time the pipe is slotted. This process provides a good surface for application of the bonding cement, eliminates the need for couplings and provides a smooth exterior surface which can be easily inserted into the drilled hole. Casing of a drain with PVC usually takes two men about 15 to 20 minutes.

Cost per foot of the perforated metal pipe at the writing of this report is $2.10 while the slotted PVC pipe is approximately $1.00.

In general, slotted PVC pipe is preferable because it is less expensive, lighter in weight, easier to transport, faster to install and largely inert to elements commonly contained in groundwater (see Section B-5).

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