GRAHAM

AN INVESTIGATION OF THE FAILURE OF LAWN LAKE DAM LARIMER COUNTY, COLORADO

Conducted by The
Office Of The State Engineer

JERIS A. DANIELSON
STATE ENGINEER

February 14, 1983

Division of Water Resources
DEPARTMENT OF NATURAL RESOURCES
1313 SHERMAN STREET
DENVER, COLORADO 80203

ALAN E. PEARSON, P.E.
CHIEF, DAM SAFETY BRANCH

866
303 -~~830~~-3581

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INTRODUCTION

This report covers a history of the development and use of the Lawn Lake Reservoir Dam and the details of the State Engineer's investigation of the cause of the failure which occurred on July 15, 1982.

Lawn Lake Dam was a 24-foot high structure with a capacity of about 817 acre-feet of water, located in Rocky Mountain National Park, in Section 25, Township 6 North, Range 74 West, Sixth Principal Meridian. The site is on the Roaring River, tributary to the Fall River, ten miles upstream from Estes Park in Larimer County. The site is at an elevation of approximately 11,000 feet in a subalpine (Spruce-Fir) zone about 100 feet below timberline. The area is underlain by Precambrian igneous, plutonic and metamorphic bedrock that hold up steep slopes and produce thin, immature soils. The region was intensely glaciated during the Pleistocene leaving behind typical alpine glacial land-forms and materials including deposits of till and glaciofluvial sediments. The original Lawn Lake was created by a recessional moraine.

The investigation was conducted, under the direction of the State Engineer, by the Dam Safety Branch of the Division of Water Resources with the assistance of the Geotechnical Unit and the Water Supply Branch and with assistance by the Colorado Department of Highways, Dr. Wayne Charlie of Colorado State University, and Ralph Mangone, a metallurgical expert.

The members of the Dam Safety Branch, the Geotechnical Unit, and the Water Supply Branch, who contributed to the investigation and analytical tasks were Alan Pearson, Chief, Dam Safety Branch, Steve Spann, Supervising Water Resource Engineer, John Van Sciver, Senior Water Resource Engineer, Jim Norfleet, Senior Water Resource Engineer, Louis DeGrave, Senior Water Resource

Engineer, George Van Slyke, Supervising Water Resource Geologist, George Moravec, Senior Water Resource Geologist, Alan Berryman, Senior Water Resource Engineer, and Larry Dezman, Senior Water Resource Engineer. The members of the Department of Highways who conducted the geotechnical work were Frank Abel, Ken Geisert, Keith Berry, George Pavlik, and Steve Bignal. The State Engineer appreciates the significant contributions made by these persons to the investigations.

Whenever a failure or incident at a dam occurs, both the professional and private community seek to find an answer or a reason for the failure. The former are interested in learning from the event to prevent future occurrences, and the others for various reasons, including liability for the failure. Colorado law places sole liability for damages due to dam failure on the dam owner, regardless of the cause; however, the State Engineer's duty is to determine, if possible, the cause of failure in order to mitigate future events.

Investigation of the incident began immediately upon receipt of notice of the failure. The problem of access was a major problem during the investigation since there are no roads to the dam and the National Park Service prohibits vehicular access. The most practical means of getting to the dam with manpower and equipment is by helicopter. Coordination and dissemination of information among the several agencies investigating the failure was provided by the FEMA, Region VIII office, which proved to be very helpful in our investigation.

Several on-site investigations took place based on the findings of the initial inspection made on the day of failure. The investigations were prompted by various pieces of evidence and information that surfaced as the investigation continued. The investigations, evidence, and information will be covered in this report. Knowledge of the history and performance of the dam is an important part of understanding the causes for failure of the dam. The first part of this report includes a description of the dam and reservoir's development and use. The investigation, as well as the analysis conducted, will be described and a hypothesis for failure formulated from the findings.

A difficult problem in the investigation of this dam failure is the absence of eyewitness accounts. Although persons reported hearing sounds in the night, there was no visible distress to the dam as recent as a day before the failure, and the deficiency that caused the failure became obliterated by the failure itself.

This report is written in a narrative form in order to minimize the number of pictures and diagrams that would need to be designed for reproduction. References are made to the bibliography where the studies, reports, maps, and pictures are contained. These are located in the State Engineer's files.

HISTORY

1902 - 1931 Construction of the Dam and Enlargements

In June of 1902, the stock holders of the Farmers Irrigation Ditch and Reservoir Company (FIDRC) elected to complete the Lawn Reservoir by making a cut to draw off 12 feet of water from the existing mountain lake, and to construct a dam to impound a total of 24 feet of water. The company duly filed a map and statement on June 30, 1902[1]* in the State Engineer's Office showing the existing lake to be 16.4 acres in surface area and the dam to be 24 feet high to the spillway, creating a reservoir having 47.1 acres of surface area and 810.6 acre-feet of usable storage. The company also filed construction plans with the State Engineer which were approved by him on August 19, 1902. The design engineer was Mr. E. C. McAnelly of Fort Collins. The State Engineer designated the plans and specifications as OC-39[3]. The following year the company filed for a permit from the United States Land Office to obtain right of way for the dam and reservoir[24]. This filing showed the existing lake to be 14.4 acres in area, and the dam 19.4 feet high creating a reservoir 42.6 acres in area and having 498 acre-feet of usable storage (BLM 89583). The reservoir was ultimately decreed in the District Court for Larimer County for a capacity of 759.6 acre-feet, including a refill[2].

During this period (1902-1903), the company engaged Mr. Hugh Ramsey to construct a wagon road to Lawn Lake from Fall River in Horseshoe Park, and to make a cut to draw off 12 feet of water from the lake. He subsequently bid to make the cut two feet deeper. This was confirmed by Mr. T. W. Jaycox's letter

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* Superscripts refer to references in the Bibliography at the back of this report.

report from his on-site inspection on September 9th and 10th, 1903[5]. Mr. Ramsey was hired to haul the outlet pipe and headgate to the dam, and to install the outlet pipe, excluding construction of the access well.

A record of an agreement to construct the outlet ditch specified that it shall "begin 150 feet below the reservoir and then northwest to about 300 feet into the reservoir...". The ditch and pipe, however, were constructed on a bearing nearly due west as surveyed by the United States Geological Survey after the failure, which made it more perpendicular to the dam.

The greatest detail on the construction of the dam is contained in Mr. T. W. Jaycox's letter report dated September 22, 1903[5]. He does state, however, that the pipe and valve were in place, the concrete foundation and sides were completed, and the lead poured around the pipe before his inspection. A copy of his letter report is in Appendix D.

The notable statements in his report relate to the amount of pipe installed upstream and downstream of the valve; the valve rests on a stone foundation; the pipe was leaded into the valve using hot lead, and caulked; and the loose rock fill had a slope of 1:1 (on the downstream side) and a top width of five feet.

The remainder of the construction and enlargement details are sketchy with only occasional statements in the minutes of the company's annual meetings. From these minutes, from correspondence in the National Park Service files[24], and data shown on several capacity surveys[32,33], it appears that the height of the dam was 20.35 feet to the spillway, with a reservoir capacity of 611.96 acre-feet in September 1907[32]. An enlargement of the dam to 24 feet at the spillway and the reservoir to 817.18 acre-feet took place on September 23, 1931[33]. There are no records of these enlargements being approved by the State Engineer. Surveys by the National Park Service in October of 1959 indicate the dam was 24.4 feet high at the spillway, and 27.9 feet to the crest of the dam. The following table summarizes the several referenced data:

TABLE 1

Reference	Date	Height of Dam in feet (to spillway)	Res. Surface area in acres		Res. Capacity in acre-feet	
			Low	HWL	Low	HWL
Water Filing 91	1/23/02	-	-	-	-	803.5
Decree	6/10/01	(24.0)	(16.4)	(47.1)	-	(759.6)
Water Filing 98	6/30/02	24.0	16.4	47.1	-	810.6
BLM #89583	5/14/03	19.4	14.4	42.6	-	498.0
Capacity Survey	9/--/07	20.35	-	45.29	-	611.96
Decree	8/01/31	Refill			-	(759.6)
Capacity Survey	9/23/31	24.0	-	49.4	-	817.18
NPS Survey	10/23/59	24.4	-	49.5	-	-

It should be noted that the spillway had only 3.5 feet of freeboard in 1959, according to the National Park Service survey, whereas the State Engineer's orders in 1951[5], and Mr. Spreng's accounting of the work he did in 1954[21,28], should have provided six feet of freeboard.

The plans OC-39, which were approved by the State Engineer, were not followed, for the completed dam resembles the plan in concept only. Except for the outlet works, the records indicate the dam was constructed by the company's own forces, under the direction of the President of the Board of Directors.

1951 - 1955 Repairs and Alterations of the Dam and Spillway

In 1951, due to an inspection and report by Special Deputy State Engineer, Clark Schnurr, State Engineer Hinderlider directed that the bottom width of the spillway be increased to 30 feet; the downstream slope of the dam be increased from 1 1/2:1 to 2:1, the dam height increased to provide at least six feet of freeboard for the spillway, and other actions be performed related to keeping the spillway clear of obstructions[5]. This directive was modified the same year, however, to lowering the spillway at least two feet to provide six feet of spillway freeboard, and to increase the bottom width to 30 feet[5].

The details of the work during this period are based on a telephone conversation[21] and an interview with Mr. Edward Spreng of Johnstown, Colorado[28]. As a young man, Mr. Spreng and the company's ditch superintendent, Mr. Tim Wright, during the months of September and October, 1954, worked on the dam and outlet. The two of them, with the aid of horses and slip, hand tools, and logistical support from the president of the board of directors, Tom McKee, excavated the spillway, removed timber from the reservoir, and repaired the outlet gate.

It does not appear that the spillway was lowered materially, but was widened to about 30 feet in 1954. If the spillway was lowered two feet, the usable capacity of the reservoir would have been approximately 721 acre-feet according to the capacity survey made in 1931 (CS-51)[33]. Storage records maintained by the Division Engineer show the gage as 24 feet, and the capacity as 824 acre-feet (later changed to 817 acre-feet) for the period 1954 to 1974, the length of the record.

Mr. Spreng's account of the work done to the outlet provides an explanation of the configuration of the outlet "dry well" at the time of failure. As Mr. Spreng describes it, "Mr. McKee wanted Tim and me to see if we could discover why the outlet gate wasn't working properly". They began to dig around the operating stem, which stuck up through the embankment fill at the crest of the dam (there was no well per plans and specifications OC-39). After digging a hole around the stem as far as they could, and not finding any problem, they returned to Loveland to relate the situation to Mr. McKee. They returned the following week, and with the aid of Mr. McKee, who had timber transported to the dam by horse, shored the excavation and completed a 4x4 foot well down to the valve bonnet. Mr. Spreng related how the digging was relatively easy and they had no water problems. (Storage records show the reservoir empty for two seasons prior to the excavation). He removed the bonnet from the valve and found the screw on which the gate leaf moved was stripped. The screw was removed, taken to Loveland for repair, and reinstalled.

A 30-inch diameter corrugated metal pipe (CMP) was transported to the site in pieces by horses, and reassembled using an acytelene torch. It was placed inside the cribbed excavation, the bottom being level with the bottom of the bonnet. The excavation was then backfilled with earth to the bottom of the nut on the top of the bonnet. The cribbing was removed and the outside of the CMP backfilled to the crest of the dam. On January 8, 1955, the ditch superintendent reported to the Board of Directors that conditions at Lawn Lake were in good shape.

1982 Post-Failure Surveys

The United States Geological Survey's field investigations after the failure show that the dam's crest was eight to ten feet wide, sloping towards the reservoir, the height from the invert of the entrance to the outlet to the crest of the spillway was approximately 24 feet, the upstream slope varied from 1.25 to 1.67:1, the downstream slope averaged 1.25:1, the spillway was 25 to 30 feet wide, and had a minimum freeboard of about three feet[34]. The United States Geological Survey is preparing a capacity survey map, which was not available at the writing of this report.

The preceding establishes the history of construction and alteration of the dam as can reasonably be determined.

EVENTS IMMEDIATELY PRIOR TO FAILURE

According to Henry Schmidt, ditch superintendent for the company, the reservoir was filled during the 1978 irrigation season, remained full through 1979, and was drained in the Fall of 1980. The reservoir remained empty during the 1981 season, and began to fill during the 1982 season. On September 21, 1980, the gate was closed an amount equal to one-half of the previous opening on August 14, 1980. No adjustments were made in 1981. On July 8, 1982, Mr. Schmidt and two other men went to the dam to close the valve. One of the men descended the well to oil the operating nut and reported that the well was dry. Mr. Schmidt said there was no sign or sound of running water. He also went to the discharge end of the outlet and observed that a small amount of water was still running. He attributed this to something being stuck in the gate leaf, preventing total closure. There is an eyewitness report in the NPS file about the men "cussing" the operation of the valve. (See Appendix E)

He spoke of, and had photographed, the snow cover below the dam as well as the drainage area. He remembered that the gage rod in the reservoir was damaged but that the reservoir was 2 to 2.5 feet below the high water line as observed on a large rock on the dam. He estimated the reservoir was two-thirds full, about 450 acre-feet. (Note: Capacity Survey 51 indicates that 450 acre-feet is equivalent to about gage 16, which would be eight feet below the spillway, two feet below the spillway at gage 22 is equivalent to 721 acre-feet). He left the dam feeling everything was in good shape.

In spite of several people having been on or near the dam, as recently as the day before the failure, no one observed anything which would have aroused their suspicions[25]. The only unusual event spoken of by the visitors camped near the dam were sounds described as wind, or a distant waterfall, during the morning of July 15, 1982 from about 2:00 a.m. to 4:00 a.m. They were awakened in the night and were concious of the sound. One wondered why the tent was not flapping from such a strong wind. Another camper was fishing in the spillway until about 8:45 p.m., July 14, and related that the wind was causing two foot high waves, and water was running over the spillway. He felt the dam was okay. Another camper relates discussing the noise with fellow campers about 9:30 p.m. on July 14th, and waking up periodically during the night noting that the noise had increased. Several campers who were located downstream from the dam, related how they were awakened about 6:00 a.m. on July 15th by loud thundering noises. When they looked to see what was happening, they saw 25 to 30 foot waves of muddy water carrying trees and rocks down the stream valley. (See Appendix E).

DESCRIPTION OF FAILURE AND DAMAGES

The first indication that something unusual was occurring in Horseshoe Park was reported by an A-1 Trash Service employee who was enroute to pick up trash in the Endovalley area[24,38]. He arrived at the Lawn Lake Trail head about 6:18 a.m., July 15, 1982, and heard a deafening noise and saw dirt in the air. At first, he thought a plane was crashing, but when he traveled up the road to investigate, he observed flooding and debris in the Roaring River. He then looked up the drainage and saw trees and rocks being thrown into the air. He quickly went to the trail head emergency phone and called the National Park Service dispatcher who received the call at 6:22 a.m. Park Rangers responded to the situation and notified the Estes Park Police Department at 6:43 a.m. (See Appendix E for copies of statements obtained by the National Park Service from witnesses.)

Estimates of the peak discharge from the dam breach as determined by the United States Geological Survey "dam break" investigation at Lawn Lake Dam, are about 20,000 cfs, reducing to about 7700 cfs at Cascade Reservoir in Horseshoe Park, and 5400 cfs at Lake Olympus[37]. The Cascade Reservoir, owned by the City of Estes Park, in Horseshoe Park began to overtop about 7:15 a.m. and failed at 7:42 a.m., sending an intermediate surge of about 14,000 cfs down the Fall River. The head of the flood entered Estes Park about 8:30 a.m.[38]. The flooding washed away bridges, destroyed road systems, inundated business and residences, destroyed a hydroelectric plant, fish hatchery, and caused three confirmed deaths. Damages have been claimed to exceed $31,000,000[35].

The Governor declared a state-of-emergency on July 15, and requested a Presidential declaration for Larimer County, which was made on July 22, allowing numerous recovery programs to begin[35].

Field Investigations

As a result of the initial inspection of the failure on July 15, it was concluded from physical evidence that the dam could not have failed due to overtopping, but could have failed by piping due to several possible causes, or from embankment instability. Further investigation and analyses were recommended by staff members[7].

A second investigation trip was planned and completed on July 22, 1982 where geotechnical and geologic information were gathered from the dam and foundation, the extent of rodent activity was investigated, the remains of the outlet works were examined, the spillway was surveyed for further hydraulic analysis, and extensive surface and air photography were obtained[11,13].

The soil samples obtained were transported to the Colorado Department of Highways' Staff Materials Laboratory for standard soil property testing, permeability, and triaxial shear strength determinations. The data gathered were analyzed and recorded in several memoranda/reports by the several engineers and geologists taking part in the investigation[11,15,29,34,36]. These data were used to develop a model of the dam for stability analysis. The reports on these investigations are contained in Appendices A, B, and C.

After examining the remains of the outlet works, the possibility that the gate-valve failed due to cracking because of rocks being jammed between the gate leaf and the seat was raised. In order to pursue this possibility, Mr. Ralph Mangone, an expert metallurgist, examined the pictures of the valve to determine if there was any reason to believe that the valve failed because of the rocks being jammed in the gate leaf. Mr. Mangone concluded that the breaks were fresh and probably caused by impact during the failure. Subsequent investigation of the valve on September 2, 1982 did not reveal any additional evidence that the valve was cracked before the failure.

Shortly after consulting with Mr. Mangone, it was revealed that a piece of lead caulking was found at the site. After obtaining this evidence, it was decided to retrieve more of the lead caulking since it appeared that the condition of the caulking was instrumental in understanding the possible reason for failure. A third inspection trip was planned and completed on September 2, 1982, which resulted in the finding of a significant amount of the lead caulking and other metal parts of the outlet works. The remains of the outlet were also examined more closely and photographed to assist in the interpretation of the evidence[17,20,23].

POSSIBLE CAUSES OF FAILURE

Following is a brief description of possible causes of failure and the conclusions reached.

Overtopping

It was concluded from the first investigation on July 15, 1982, that overtopping was not a reason for failure. The high water line in the reservoir was found to be about three feet below the crest of the dam[7]. This was corroborated by the findings of the United States Geological Survey from their surveys of the dam and reservoir[34].

The National Weather Service provided meteorological information in the vicinity of Estes Park, and it is concluded that weather was not a factor in the failure. Rainfall during the period from July 10-15, 1982 totaled 0.11 inch at Estes Park, and no large rainfall amounts were received in the area during this period. Precipitation at Estes Park from October 1, 1981 through June 1982 totaled 10.88 inches, which was 1.06 inches above normal for the period. Snowpack for the winter of 1981-82 in the mountains surrounding Estes Park was approximately 125 percent of normal.

Rodent Damage

Marmot burrows are located in the crest of the remaining dam and downstream slope, as well as in the sides of the spillway banks downstream from the control section. They are also located throughout the immediate area of the dam. No burrows were observed on the upstream slope of the dam[11].

Each burrow found on the remaining portion of the dam was excavated to determine its extent. The maximum distance of any of the burrows was three feet below the crest of the dam, and the maximum length was about four feet. None of the burrows extended below what would be considered the phreatic surface of the dam. There is no reason to believe that the dam's interior was extensively burrowed to cause the failure of the dam, although it cannot be totally ruled out, since a major section of the dam was washed away during the failure which may have contained the critical burrowing activity. The inspections and photographs made in prior years, however, do not indicate that there was abnormal rodent activity in the dam. It is concluded that rodent activity was probably not the cause of failure.

Frost Penetration

It was speculated by Dr. Wayne Charlie of Colorado State University, who was a member of the second investigation team on July 22, 1982, that soil property changes induced by freeze-thaw cycles of the soils and/or ice lense development could be a possible cause of failure. He stated the soils in the dam were frost susceptible and that the conditions at the site due to climate, frost penetration in excess of ten feet, and melting of snow, could have affected the strength and permeability of the dam[15]. Although these conditions are evident, it doesn't explain why the conditions, which existed during the 80-year life of the dam, became critical this year. It could be assumed that the strengths and permeabilities found during the investigation reflect the changed soil property characteristics and were included in the stability analysis. No ice lenses or frozen ground were found during the investigation, however, they could have thawed prior to the failure, particularly if they were a causitive factor. Investigation of this cause was limited due to resources and expertise in the specialized area. An expert on the subject of frozen soil would need to be engaged to conduct an analysis of the phenomenon. It is concluded, however, that the effects of frost penetration were reflected by the soil parameters used in the stability/permeability analysis.

Earthquake

Mr. Waverly Person of the United States Geological Survey's National Earthquake Information Center, was interviewed to see if any earthquake activity occurred in the vicinity of the dam at the time of the failure. He reported that no activity occurred during that time and, further, that no activity has ever been measured in that area.

Mr. Person said that the records were available at the center for review, and they were at a scale which could be analyzed for blasting activity if desired.

Embankment Stability

The details of the stability analyses are contained in references 14 and 15 and Appendices A, B, and C.

The initial analysis assumed that the embankment section through the outlet (maximum section) was undrained, similar to a homogeneous dam, which resulted in a factor of safety of less than one. This condition would cause an unstable slope and probable slip failure. It was concluded from the evaluation of the records of storage and the permeabilities obtained from the laboratory testing, however, that steady-state seepage must have existed at the time of failure and the assumption of no drainage was not likely. Some type of drainage probably existed within the dam section which kept the seepage from reducing the strength of the materials to a state of stress which would cause the materials to fail under normal conditions. Some other abnormal condition existed which caused the failure.

Lead Caulked Seal Between the Gate Valve and Outlet Pipe

During the investigation, it was learned that a piece of lead was found at the dam[17]. Lead caulk was used to form the seal between the outlet pipe and the gate valve[5]. This was contrary to the plans and specifications, OC-39, which required that the valve be encased in "concrete for three feet above the pipe and two feet below the pipe and one foot thick".[4] No evidence of any concrete around the gate valve was found during the investigation.

Examination of the piece of lead indicated it was in poor condition, being corroded and deteriorated to the point it would make a poor water tight seal[20]. This evidence prompted a third trip to the dam on September 2, 1982 with a metal detector, with the object of finding the rest of the lead caulking and other metal parts of the outlet, and close examination and photographing of the gate valve and outlet pipe[23].

About 144 inches of lead caulking were found and the locations plotted on a map, as well as photographed. The lead caulking was brought to Denver for further examination and is in the State Engineer's possession. These additional pieces of lead are also in poor condition and of differential thicknesses. The ends of the pieces are deformed in some cases and have cold joints in others. The thicknesses of the lead found would also be inadequate to fill the annular space between the pipe and valve flange, according to measurements made in the field[23].

Examination of the valve revealed that there were signs of leakage from the joint between the flange and the pipe located at the top, due to the presence of tuberculated orange-colored stain similar to the upstream face of the gate leaf and other parts of the outlet which were exposed to the water. This is in contrast to the blackened surfaces of the rest of the upstream flange, where the lead caulking was in contact with it.

Outlet Pipe Bedding

In order to determine the condition of the bedding of the remaining outlet pipe, and if there is any evidence that a void existed under it, the outflow from the reservoir should be diverted and the pipe carefully excavated and examined.

MODE OF FAILURE

The following description of the manner in which the embankment was breached is hypothesized from the remains of the dam, and the location of the evidence found during the investigation. The facts that were observed are:

1. The breach occurred at the maximum section of the dam where the outlet works were located. The dimensions of the breach are about 27 feet deep, the top width is 91.5 feet, and the bottom width is 58 feet.
2. There were discernible sounds heard by nearby campers in the night and early morning hours that sounded like strong winds, or a distant water fall. These were heard as early as 9:30 p.m. on July 14th, and from 2:00 a.m. to 4:00 a.m. on July 15th. A wall of water was cascading down the Roaring River at 6:00 a.m. on July 15th. (See Appendix E)
3. There are sand plumes on the natural ground (moraine) on each side of the scoured streambed below the dam.
4. The corrugated metal pipe that was installed as the dry well for the operating stem in 1954 was found on the natural ground downstream from the dam. The top 15 1/2 feet was intact, the bottom 7-8 feet is missing. The hinged hatch cover is missing.
5. The valve stem, which was attached to the operating nut on the valve by gravity, has a nearly 90 degree bend at the lower end, just above the socket. It was found about 100 feet downstream from its origin. See reference 23.

6. Parts of the downstream outlet pipe were found downstream from the dam in a battered and broken condition. Several feet of the outlet were not found. The pieces found were scattered from the dam to about one mile downstream.
7. The gate valve and several of the broken pieces were found within 200 feet from their original location in a line with the axis of the outlet pipe. They were found on the bedrock surface which was scoured clean by the large flows during the full breach.
8. The lead caulking for the gate valve was found within fifty feet of its original location on the bedrock surface.
9. The geotechnical investigations and stability analyses indicate that the state of stress in the dam was near failure condition.

These facts indicate that the dam failure probably began as a small hole or void caused by piping at the level of the outlet conduit. As the hole was enlarged by the internal erosion of the embankment materials from the escaping water, the increased flows exceeded the capacity of the outlet channel, spreading out over the moraine below the dam. The materials being eroded were deposited along the fringes of the flow, subsequently being partially removed as the larger flows began to scour the moraine upon which they were deposited.

The reservoir must have been discharging through the hole for many hours, and at a sufficiently large rate to be heard during the night by the campers at the site. The hole enlarged sufficiently around 5:00 a.m. to 5:30 a.m. to cause the overlying material to collapse into the hole and flowing water, resulting in the total breach of the dam. The outflow increased to its maximum amount very quickly, carrying the corrugated metal dry well downstream on its crest and depositing it in the brush on the left side of the flooded area where it escaped being dislodged during the scouring by the rest of the outflow. The toppling of the corrugated metal dry well bent the operating stem over, but did not dislodge it from the valve. The erosive force of the waters gradually eroded the foundation of the downstream portion of the outlet pipe and dislodged it from its place. It is not certain whether the pipe was removed in pieces or in one piece ultimately becoming broken and scattered downstream. With its downstream support removed, the valve was dislodged from its connection to the upstream portion of the outlet pipe, the lead caulking being deposited within 50 feet of its origin, probably due to its small size and heavy weight, and the gate valve transported over the bedrock surface to its resting place. It appears that the valve housing was hit by a large boulder, at its resting place, which knocked the large piece of the lower right hand quadrant off the valve and washed it further downstream[23].

It does not appear, by the evidence found, that a massive slope failure occurred as the primary cause of the breach of the dam resulting in the erosion of the dam from the top down. This conclusion is based on the existence of the sand plumes, which indicate that the initial failure was gradual with the sand being deposited on the existing morainal surfaces by lesser flows before the total breach flows began, scouring the moraine down to bedrock.

FINDINGS AND CONCLUSIONS

Findings

The evidence found in this investigation leads to the conclusion that the failure was caused by the deflection and/or deterioration of the lead caulking at the connection between the outlet pipe and the gate-valve, resulting in a situation which increased the potential for piping of dam material and/or affected the pore pressure distribution in the embankment, which could reduce the strength of the materials in the dam to a state of stress which could cause a portion of the slope of the dam to slough.

Piping is the backward erosion of earthen materials due to the velocity of the leaking water being sufficient to dislodge the individual soil particles from their matrix and transporting them from the dam. A hole is developed from the downstream exit point back towards the source of leakage. A path for the concentration of the leakage sometimes exists due to improper backfilling and resulting voids along an outlet conduit.

A credible explanation for the situation to develop into a failure after nearly 80 years of use is based on the leakage not becoming pressurized unless the gate was in some stage of total, or nearly total, closure and the reservoir close to full or having sufficient potential energy to influence the leakage from the joint.

Storage records for the reservoir for the periods from 1938 to 1973 and from 1978 to 1981 are available, but not the discharge records. During the early years, the reservoir was operated on a fill during the runoff and empty in the fall basis, but, during the period from 1960 through 1973, the reservoir was full during all the months of the year. Unfortunately, it is not possible to determine whether the gate was totally or partially closed during these periods. It was assumed it was closed sufficiently to maintain the level of the reservoir at the spillway.

Another reason for the progressive nature of the deterioration would be the slow deterioration of the lead caulking itself during the periods of high pressure leakage. In accordance with Mr. Mangone's consultation, the lead could erode due to high pressure leakage.

Discussion

Whether or not the leakage from the valve connection had a path or void to flow through, would determine how it affected the dam.

If there were no void, the pressure from the leak could create a local "bulge" in the steady-state phreatic condition within the dam. This could cause a slough in the downstream slope which would expose the seepage from the reservoir within the dam (steady-state phreatic condition). The seepage within the dam has a higher potential energy, and could cause the dam materials to be washed from their place. This condition, and the leaking water from the deteriorated seal, could readily erode a hole back to the valve. With a flow path existing from the downstream face of the dam back to the valve, the potential energy existing within the dam under steady-state seepage could be sufficient to pipe the easily erodible materials of the dam lengthening the piping path to the upstream face of the reservoir. Once the void was through the dam, it would only be a matter of time before a total breach would occur due to the water flowing through the hole.

If there were a void, even of a small size, existing along the pipe, the leakage would have followed this path of least resistance. The possibility of a void existing beneath or along an outlet is great, unless care is taken during backfilling of an outlet. Modern practice requires the use of shaped beddings, and sometimes fresh concrete placed under and around the pipe to assure a positive cutoff. Cut-off collars are also placed around outlet pipes to increase the seepage path length along the pipe. In the case of Lawn Lake's outlet, the cut-off collars were not constructed, and the outlet pipe was bedded and nearly backfilled before the State Engineer's representative inspected it in 1903. In addition, the valve and pipe were not encased in concrete as specified by the engineer. Finally, according to our investigation, it appears that the source of the materials for the backfilling of the outlet pipe were the finer glacial materials from the surface of the moraine to the left of the outlet ditch. Investigations showed that these materials were nonplastic and would offer little resistance to erosion. Resistance to piping, however, may have been improved by the addition of the cement to the fill as described in T. W. Jaycox's report[5].

The rockfill on the downstream slope, which existed at the outlet section, the rocky nature of the channel, and flows from the outlet pipe itself could conceal any piping condition occurring along the outlet. The fine material may have collected in the rockfill itself as it was piped from the embankment. Again, once a significant flow path was piped back to the valve, the potential energy within the embankment could readily pipe a hole to the upstream slope of the dam.

A couple of items that relate to the condition of the outlet are noted. One is a reference in the June 22, 1906 minutes of the company's annual meeting by its ditch superintendent of a "cave" that occurred where the reservoir discharges into the pipe, and the suggestion that the necessary stone and cement work be done as soon as possible. The other is that the water in the reservoir during the investigation of July 22, 1982 was noted to be running through cracks in the concrete headwall at the entrance to the pipe. It is assumed that the concrete headwall existing today was constructed at the suggestion of the superintendent in 1906.

Conclusions

It is concluded that the failure occurred due to leakage under high pressure from the leaded connection of the outlet pipe and valve, causing progressive piping of the dam embankment in the vicinity of the outlet pipe during periods of high reservoir levels and gate closure and sudden collapse of the embankment allowing rapid evacuation of the reservoir.

BIBLIOGRAPHY

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2. Findings and decrees for the Lawn Reservoir, claimant Farmers Irrigation Ditch and Reservoir Company, No. 4862, District Court, District No. 4, and No. 10077, District Court, District No. 4.

3. Plan and cross-section of dam and outlet of Lawn Reservoir, approved by State Engineer, Addison J. McCune, on August 19, 1902, file OC-39.

4. Contract and specifications for the dam and outlet of the Lawn Reservoir (undated, unsigned), State Engineer file OC-39.

5. State Engineer's correspondence file, Lawn Lake Dam, 3104.51, September 22, 1903 to August 12, 1980 (especially T. W. Jaycox's report of 9/22/03).

6. State Engineer's Preliminary Hazard Determination File, Lawn Reservoir Dam, 3104.51.

7. Inspection Report, Lawn Lake, OC-39, W. Div. 1, W. Dist. 4, July 15, 1982 by Jim Norfleet and John Van Sciver, Division of Water Resources, Dam Safety Branch (Failure Report).

8. Office memo, Jim Norfleet, Division of Water Resources, Dam Safety Branch, July 19, 1982. Telephone conversation with a Larry Ledwich, State Division of Disaster Emergency Services, who visited dam site on Saturday, July 15, 1982.

9. Inspection of Outlet System and Debris, July 22, 1982, by Jim Norfleet, Senior Water Resource Engineer, and Wayne Charlie, Colorado State University.

10. Memo of meeting, Lawn Lake investigation schedule, July 22, 1982, John Van Sciver, Division of Water Resources, Dam Safety Branch.

11. Inspection Report, Lawn Lake, OC-39, Division 1, District 4, July 22, 1982 (exploration trench of downstream slope @ Station 3+87, mapping and investigation of rodent activity, spillway profile, and cross-sections), Alan Pearson and John Van Sciver, Division of Water Resources, Dam Safety Branch.

12. Office memo, John Van Sciver, Division of Water Resources, Dam Safety Branch, July 22, 1982, telephone conversation with Bob Jarrett, USGS, Water Resources Division, about his findings/activities at the dam site on July 21, 1982.

13. Scope of Lawn Lake Dam Failure Investigation, Dam Safety Branch, July 26, 1982, by Alan Pearson, Division of Water Resources, Dam Safety Branch.

LAWN LAKE DAM
FAILURE INVESTIGATION

APPENDICES

A. Geologic/Geotechnical Notes
B. Laboratory Testing
C. Slope Stability Analysis

OFFICE OF THE STATE ENGINEER
February 14, 1983

Jeris A. Danielson
State Engineer

LAWN LAKE DAM
FAILURE INVESTIGATION

Geologic/Geotechnical Notes

Appendix A

by

George Van Slyke, Supervisor, Geologist
James Norfleet, Senior, Water Resources Engineer
John Van Sciver, Senior, Water Resources Engineer

LAWN LAKE DAM
GEOLOGIC/GEOTECHNICAL NOTES

APPENDIX A

GENERAL

On July 15, 1982, Lawn Lake Dam failed due to unknown causes. On July 22, several members of the Dam Safety Branch inspected the dam in an attempt to determine the cause of failure. We were taken to the site by helicopter.

GEOLOGIC SETTING

The dam is located on an old glacial moraine. The moraine material appea to be a maximum of 25 feet thick in the immediate vicinity of the dam and overlies pre-Cambrian igneous rocks. These igneous rocks range in composition from granite to diorite. They are fractured and jointed with a fracture spacing of about one foot. Three distinct joint sets are evident: (1) parallel to the dam axis, dipping about 45° downstream and 30° to 45° upstream; (2) normal to the dam axis, dipping 70° to 80° toward the right (south) abutment; (3) at about 45° to the dam axis, dipping about 60° downstream (See sketch A-1 and photos A-8 and A-9).

The granites appear relatively fresh with very little weathering. The rock is very hard and "rings" with a strong hammer blow.

It appears that the glacial moraine originally formed a dam across a natural depression in the valley.

OBSERVATIONS CONCERNING CONSTRUCTION

In the early 1900's, the lake was enlarged and controlled outlet installed. Fill was placed on top of the natural moraine dam and an area excavated through the moraine for placement of the outlet pipe. The cut was filled with material of unknown composition (this material was washed out at the time of failure). An additional 7 to 9 feet of sandy fill was placed on top of the moraine. At this height (approximately 5 feet below the crest), a layer of organic material appears to cover the entire dam.

The origin of this organic material is unknown; however, it appears that this layer may be the result of the growth of grass on the surface of a dam approximately five feet less in height than the present dam. (See photo A-5) Due to the appearance of this organic layer, the "shorte dam must have existed for a considerable time before an additional five feet of fill was placed.

OBSERVATIONS OF JULY 15, 1982 (Ref: Inspection Report dated July 15, 1982)

Geologic and Geotechnical Findings

The right side of the breach was carefully examined for signs of weakness which may have existed within the embankment. The following specific items were noted:

An organic clay/silt seam, 12 inches in thickness, was found running through the dam approximately five (5) feet below crest elevation. This organic seam was totally saturated and free water was released when a sample was squeezed. Soil temperature was between 35 and 40 degrees and the soil did display a slight degree of plasticity.

A relatively clean sand lense was found running through the dam above the foundation, approximately 10 feet below crest elevation. This sand seam was totally saturated and the soil formed a "mud flow" when agitated by foot.

A lense of peat was found running along the foundation of the dam approximately 12 feet below crest elevation. Tree roots were growing in this peat layer.

For a description of other features observed, refer to inspection report by John VanSciver and Jim Norfleet, dated July 15, 1982.

OBSERVATIONS OF 7-22-82

On the day of the inspection, both sides of the breach were logged, samples taken, the channel section around the outlet pipe was inspected, and photographs (both air and ground) were taken. (See photos A-1 through A-7)

Logging of both sides of the breach show very good correlation from side to side. Seven distinct layers are present on the right side and nine on the left. The two lowest layers on the left are not present on the right. These represent filling to bring the left side up to the approximate level of the right side. From that point up, all layers are generally similar on both sides. Although there are variations within layers, they were easily divided into the general classifications as shown in Figure A-1.

Visual classification done at the site appears to be in general agreement with laboratory results. Discrepancies seem to be due to individuals "seeing" more fines and less gravel than the lab.

The dam above the moraine is composed entirely of silty and poorly graded sands with varying amounts of fines and gravel. Also, as noted in the logs, considerable amounts of organic material were found. Distinct color changes probably resulted from various borrow areas. (See photos A-1 and A-5) Although there is some variation in material type within a layer, the environment from which they were taken was similar. Based on this, we estimate that there were between four and seven borrow areas. All the fill is in a semi-compact, friable state and is moist except layer seven which appears to be saturated.

The channel of the breach has a number of large granitic boulders near what remains of the outlet pipe (See sketch A-1 and photo A-7). One of the boulders has a black, sooty coating on the right (south) side. Also found near this boulder at the water surface was a black coarse sand. This sand is extremely friable and very weakly cemented. It is composed almost entirely of coarse sand and is very open (i.e., point to point contact of sand grains). On close examination, it was found that this sand is composed of granitic fragments and the black is a sooty surface coating similar to that on the boulders.

Based on observations and construction photos, it appears that the black soot may have come from a coal fire built in the area during construction for heating rivets and lead and for keeping warm.

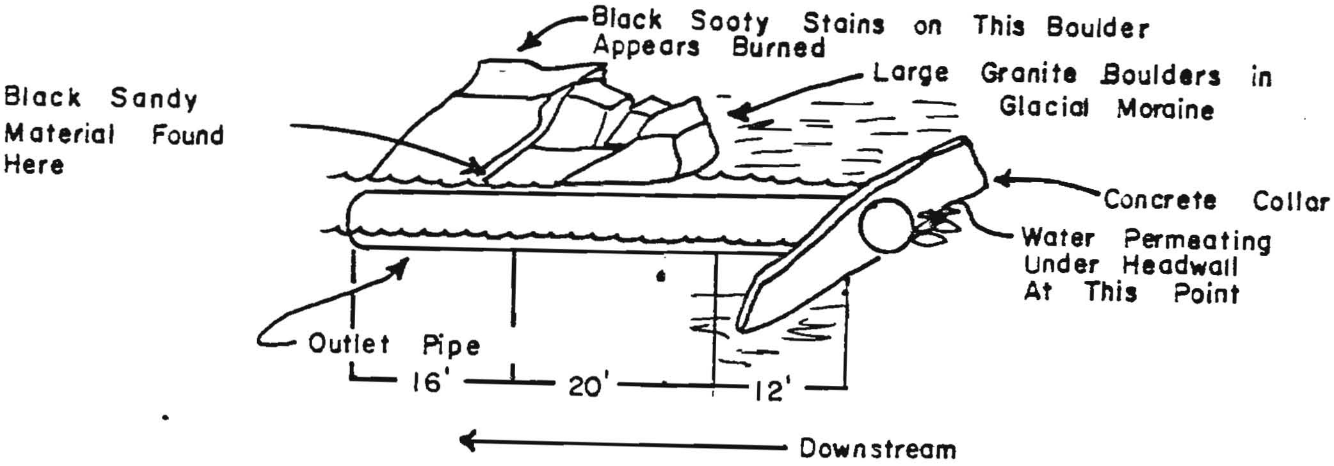
Photo A-1:	Right side of breach.
Photo A-2:	Downstream toe on right side of breach.
Photo A-3:	Foundation on right side of breach.
Photo A-4:	Close-up of trench excavation on right side of breach.
Photo A-5:	Left side of breach.
Photo A-6:	Trench excavation on left side of breach.
Photo A-7:	Foundation on left side of breach.
Photo A-8:	Rock in stream channel immediately downstream of dam.
Photo A-9:	Rock in stream channel 100 feet downstream and beyond.
Photo A-10:	Seep area downstream on left side of stream channel. Flowing water present.

Layer No.		GENERAL DESCRIPTIONS
1	Silty Sand (SM)	65% fine to coarse sand 20% non-plastic fines 15% subrounded gravel to 6" maximum Material is generally moist, tan to light br with occasional limonite stains. Contains m thinner layers with varying amounts of grave and fines. A 3" thick layer of GP-GM was lo on the right side between 10" and 1'1" below crest.
2	Silty Sand (SM) (Organic)	55% fine to coarse, mostly fine sand 20-25% slightly plastic, organic fines 20-25% subrounded gravel to $2\frac{1}{2}$" maximum Material is dark gray to black, contains abu pieces of wood. Moist. Due to the fineness the sand, this material appears to be an orga silt by visual classification.
3	Silty to Poorly Graded Sand (SM-SP)	65% fine to medium with occasional coarse san 10% non-plastic fines 25% subrounded gravel to 3" maximum Contains small layers which are skip-graded o ing medium sand size. Brown, moist. Contain some organic debris (wood chips).
4	Silty to Poorly Graded Sand (SM-SP)	75% mostly fine to medium sand 10% non-plastic fines 15% subrounded gravel to 1" maximum Occasional layers of very silty material. Da brown, moist.
5	Silty Sand (SM)	75% fine to medium sand 20% non-plastic to slightly plastic fines 5% fine subrounded gravel to 1" maximum Dark reddish brown to gray-brown, moist. Occa sional organic streaks.
6	Left side Silty to Poorly Graded Sand (SM-SP)	73% mostly fine sand 7% non-plastic fines 20% fine gravel to 5/8" maximum Brown, moist.
	Right side Gravel (GW)	55% gravel to 3" maximum 40% mostly fine sand 5% non-plastic fines Brown, moist.
7	Silty Sand (SM)	70% fine to coarse sand 20% non-plastic fines 10% subrounded gravel to 1" maximum Dark reddish brown with rust streaks and gray mottling, moist to saturated. Right side con less fines (dropping to 5%). Left side conta up to 40% fines.

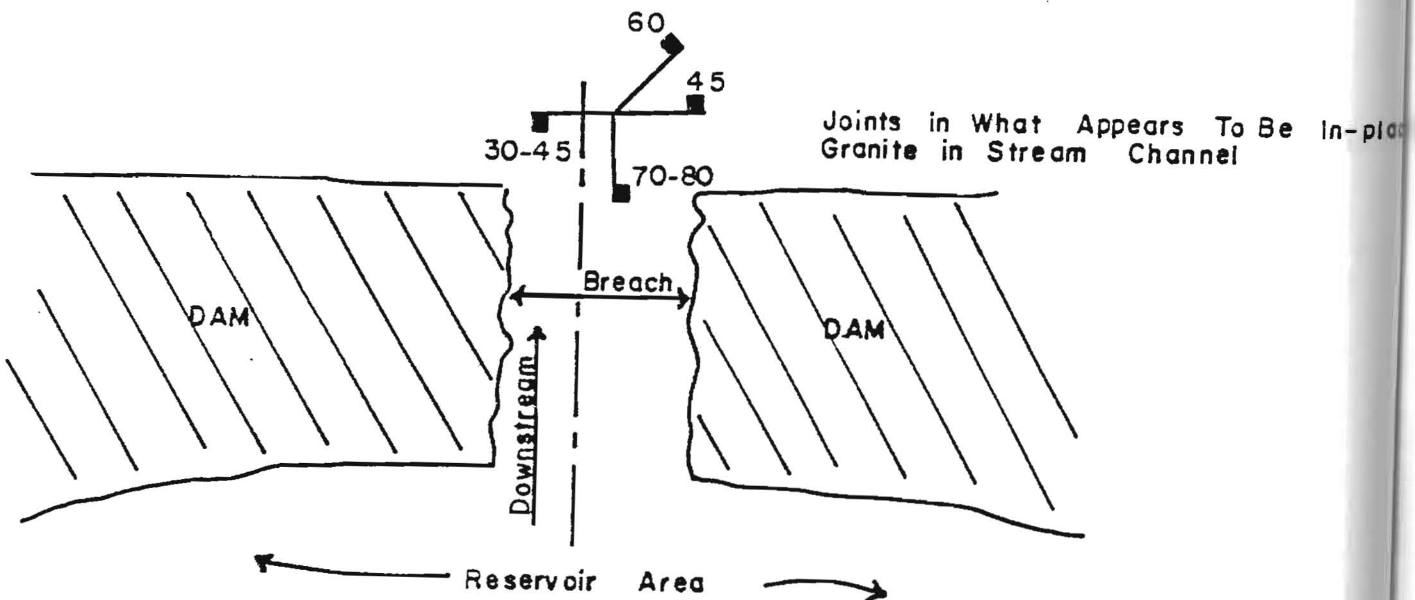
8*	Silty Sand (SM)	Similar to layer 6 except saturated.
9*	Silty Sand (SM)	65% mostly fine sand 15% non-plastic fines 20% subrounded gravel to 4" with occasional cobbles and boulders to 1' which have coating of organic silt. Wet to saturated, reddish brown with limonite satins and wood fragments.
Moraine		A mixture of large granite boulders, cobbles, sand and non-plastic fines. No apparent bedding.

* Layers 8 and 9 are not present on the right side of the breach.

LAWN LAKE DAM



SKETCH OF OUTLET AREA
LOOKING SOUTH 7-22-82
NOT TO SCALE

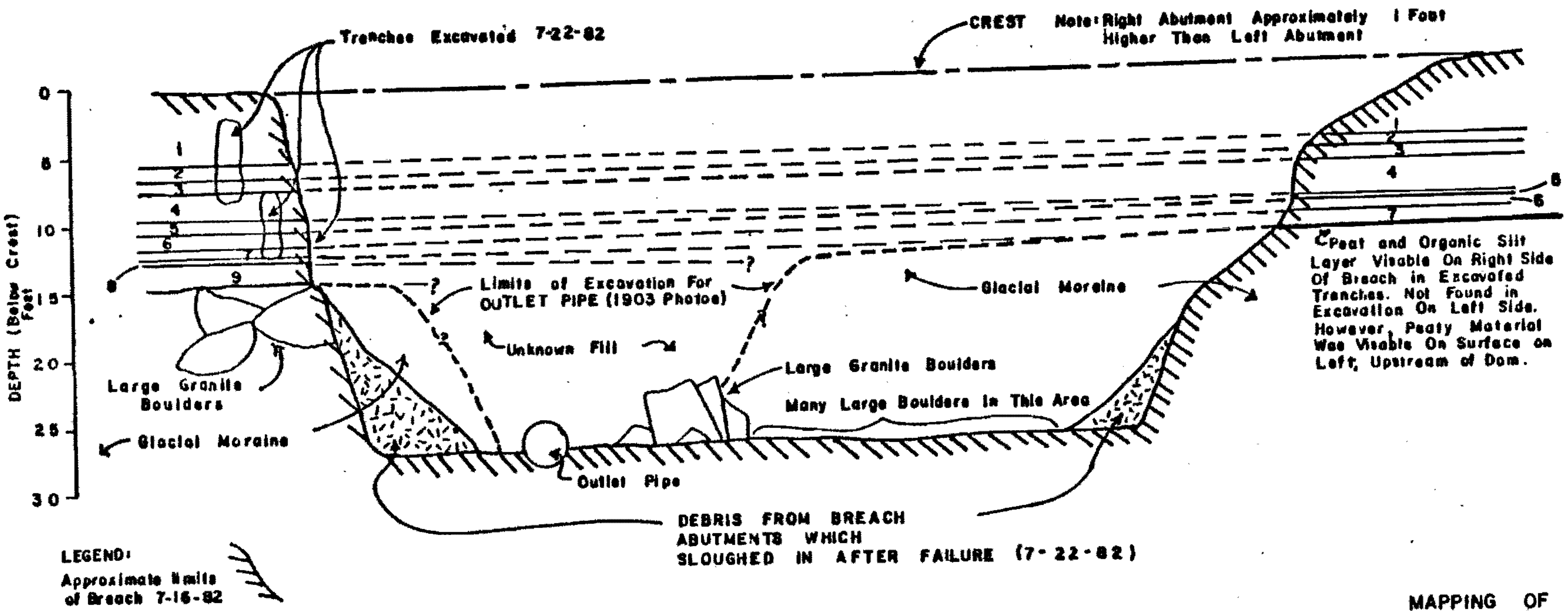


SKETCH SHOWING
JOINT ATTITUDES
See Photos A-8 and A-9

SKETCH A-

FIGURE A-1: See Attached Descriptions of Soil Layer 1 through 9.

LAWN LAKE DAM



MAPPING OF BREACH 7-22-82
by
GEORGE VAN SLYKE
JAMES NORFLEET

Scale: 1" = 10'

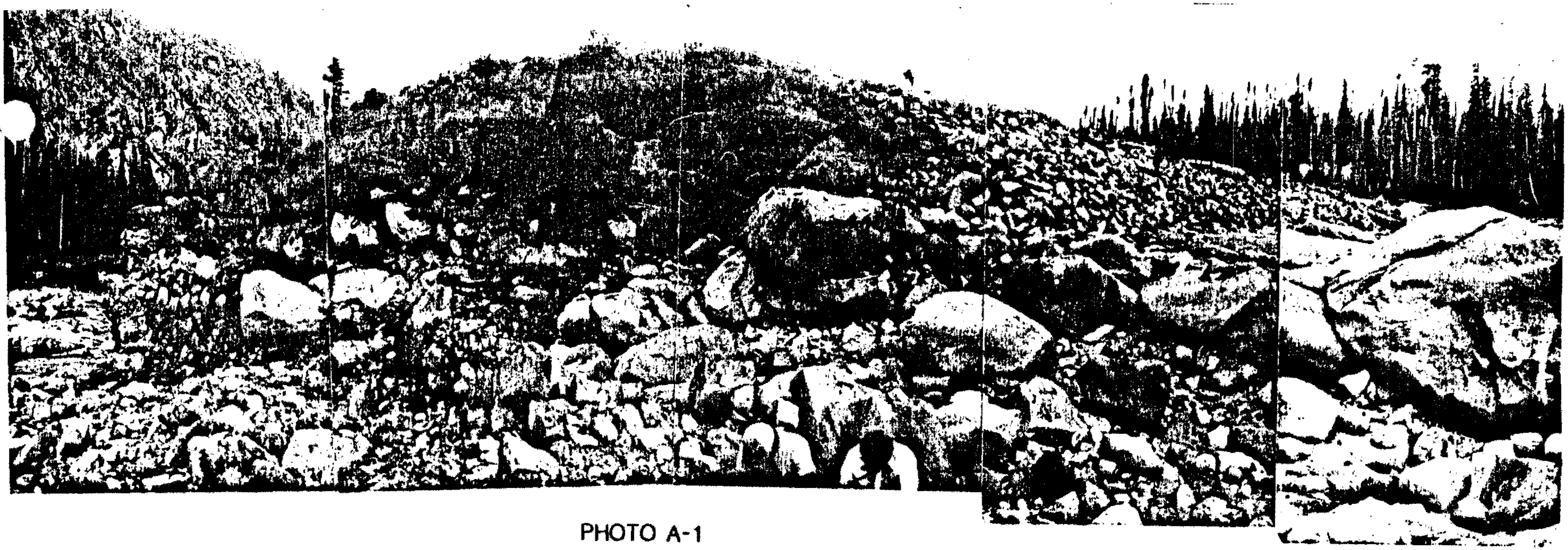


PHOTO A-1

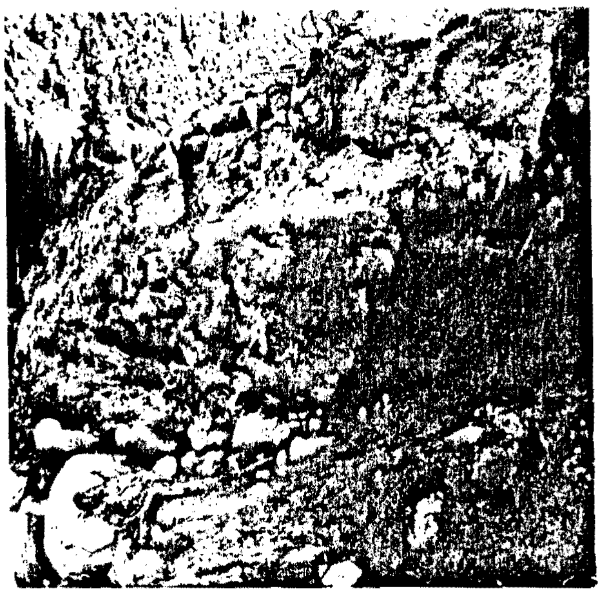


PHOTO A-4

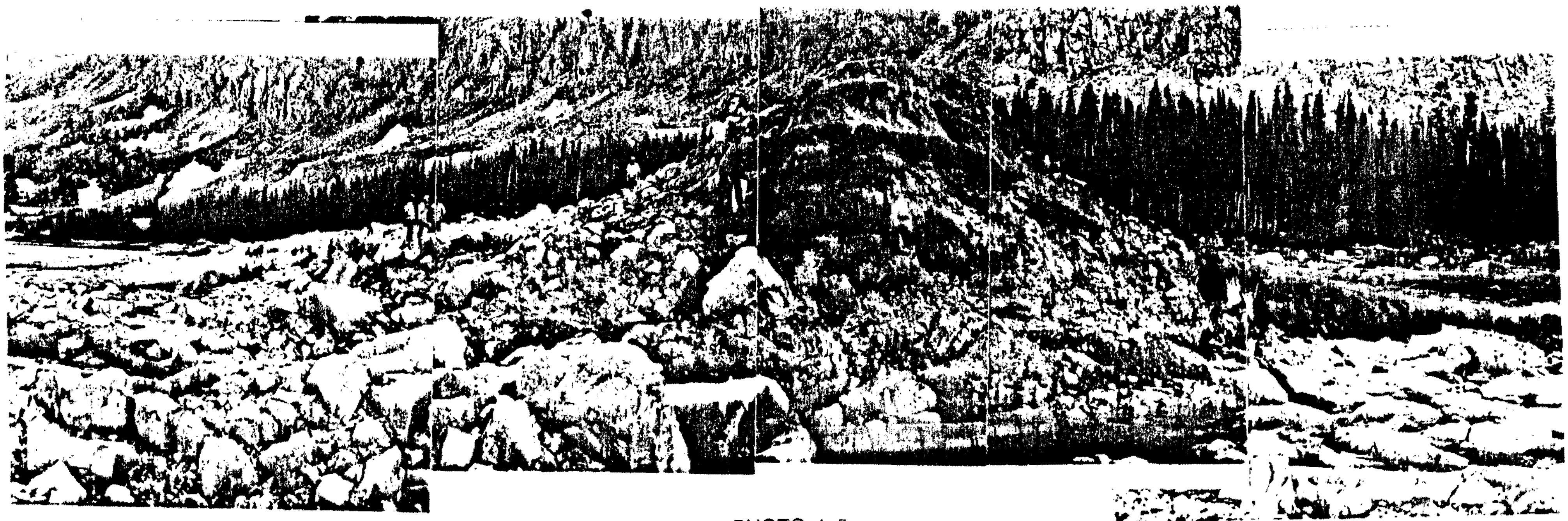


PHOTO A-5

PHOTO A-6

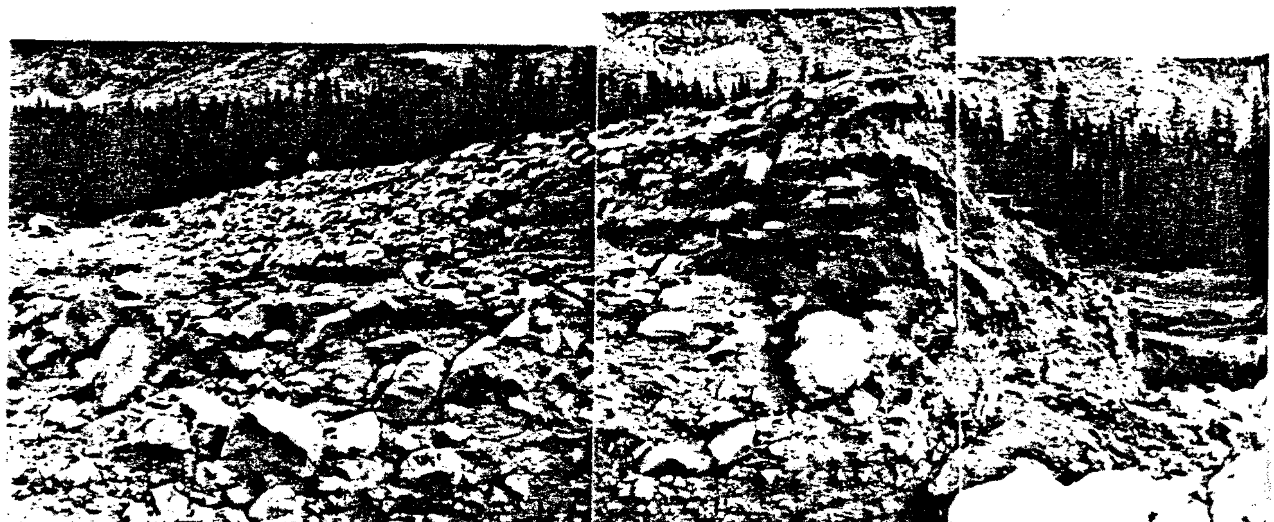


PHOTO A-7

PHOTO A-8

PHOTO A-9

PHOTO A-10

LAWN LAKE DAM
FAILURE INVESTIGATION
LABORATORY TESTING

APPENDIX B

by

James Norfleet, Senior, Water Resources Engineer
George Van Slyke, Supervisor, Geologist

LAWN LAKE DAM
FAILURE INVESTIGATION
LABORATORY TESTING

APPENDIX B B

LABORATORY TESTING

As stated in Appendix A (Geologic/Geotechnical Notes), seven sack samples were obtained from various strata on the left side of the breach. The left side samples were numbered 1L through 7L, and a nuclear test was performed to determine the density and moisture content of the material below the nuclear test gage. The percent gravel was used to correct the field density for placement density of the minus #4 in laboratory triaxial shear tests. The results of field density and moisture tests are presented on Figures B-1 through B-7.

A small moisture sample was obtained from each of the seven sack samples for a laboratory moisture determination. The moisture content as determined in the laboratory was within three percent of the field moisture for four of the seven samples, no. 1L, 2L, 5L, and 7L. The difference in moisture content between the field and laboratory for the other three samples was as much as 20 percent. The large variation is primarily due to the different size soil sample volumes. The variations could also be attributed to the rock moisture, wood chips or roots in the field sample which were not present in the labortory samples.

In addition to the seven sack samples obtained from the left side, 13 small sack samples were obtained from various strata on the right side of the breach for laboratory classification. The right side samples are numbered 1R through 13R. Field density and moisture tests were not performed on the right side.

STANDARD PROPERTIES

The following standard property tests were performed on the samples obtained:

- Gradation Analysis
- Specific Gravity of Minus #4 Material
- Bulk Specific Gravity of Plus #4 Material (Samples No. 1L through 7L only)
- Absorption (Plus #4 Material, Samples No. 1L through 7L only)
- Atterburg Limits

The specific gravity of the minus #4 material, bulk specific gravity of the plus #4 material, and absorption for the samples are listed on Figure B-8. A summary of results from gradation analysis and Atterburg limits is presented in Figure B-9. Individual gradation curves are plotted and presented in Figures B-10 through B-29.

Samples obtained from the left side of the breach contained between 7 and 26 percent non-plastic to low plasticity fines. Five samples were classified as borderline between a poorly graded sand and a silty sand SP-SM. The other two were classified as SM. The higher liquid limits for samples no. 2L and 5L are a result of the presence of organic material. Organic material absorbs a large amount of water which does not add to the liquidity of the sample during the test.

The most significant difference between material from the right side and material from the left side was the two gravel layers found at a depth of 10 inches and 10' 10" on the right side of the breach. The layer at the 10-inch depth was three inches thick and the layer at the 10' 10" depth was one foot thick. The amount of material passing the #200 sieve in the gravel layers were six percent and four percent, respectively.

In general, the standard property test results and visual field classifications are in agreement, indicating mostly sandy material was used for the construction of the embankment.

LABORATORY PERMEABILITY

Three samples were selected for permeability testing, samples no. 5L, 6L, and 7L. The samples were remolded into a six inch diameter mold, seven inch high. The samples tested included the plus #4 fraction and were placed at their respective field density and moisture content. The test was performed under a constant six inch head. The results are presented on Figures B-30 through B-32.

The results indicate only one sample was impervious, sample, no. 5L. The other two samples, no. 6L and 7L, had permeability rates of 0.7 feet/day and 6.6 feet/day, respectively.

TRIAXIAL SHEAR

Three samples were selected for shear testing, samples no. 2L, 5L, and 6L. For each sample, the minus #4 fraction was remolded into a 2.85 inch diameter by 6.35 inch high specimen. The field density and moisture content was adjusted for the rock present in the bulk sample to determine placement density of the minus #4 material. The nomographs shown on Figures B-33 through B-35 were used for the moisture/density correction.

The triaxial shear tests were multiple-stage on a single specimen. Each stage was performed with the specimen confined by a different lateral pressure. A strip-chart was used to record deviator load, axial strain, and pore pressure. Each stage was completed when the deviator was observed to be changing less than five pounds in 30 minutes. At the end of the first stage, the specimen was unloaded and the second higher lateral pressure applied. The third stage was performed in the same manner. All samples were backpressured to saturation prior to loading.

Samples no. 2L and 6L were tested in a consolidated-drained (CD) mode and sample no. 5L was tested in a consolidated-undrained (CU) mode. The following is a list of confining pressures for the tests:

Sample No.	Type of Test	Effective Confining Pressure (psi)
2L	CD	5, 10, and 20
5L	CU	7, 15, and 30
6L	CD	10, 20, and 30

Failure criteria was based upon maximum deviator load at the end of each stage. This point was estimated to be 95% of the peak strength.

The results are presented on Figures B-36 through B-55.

The results from the triaxial shear test indicate the weaker zones of material existed at depth of 5' 7" (Sample No. 2L) and 9' 9" (Sample No. 5L). The test for sample No. 2L resulted in an effective stress friction angle (ϕ') of 18.4 degrees and cohesion of 1.4 psi. The test for Sample No. 5L resulted in a total stress friction angle (ϕ) of 22.2 degrees and cohesion of 1.3 psi.

Even though the samples had to be remolded, the values obtained from the triaxial sher tests were within an acceptable range of values for the type of material tested. The type of test performed on the samples were chosen to represent conditions observed in the field.

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density Flush or Trans. 8"	Air Gap Gap
______	______	______
______ 90°	______ 90°	______
1087	4985	______
1105	4961	______
2) 2192	2) 9946	) ______
1096 CPM	4973 CPM ÷ into	______
3940 STD	7060 STD	
.278 Ratio	.704 Ratio	______ AGR

Name of Pit ______

Curve No. ______

AASHTO T-99 ☐ AASHTO T-180 ☐ Method __

Tested by Steve Bryant

Equipment Number 8066

Material ______ Class ______

Project Lawn Lake Carr

Test Number 1L

Date 7-22-82

Station 4'-7" below crest

Depth Below Grade or Thickness 4'-7"

In-Place 121.7 Wet Density

In-Place 8.7 Lbs. of H_2O/ft^3

In-Place 113.0 Dry Density

In-Place 7.7 % Moisture

Curve Values	-#4	W/R
Optimum Moisture	______	______
Max Dry Density	______	______

% Relative Compaction ______ %

Soil Classification ______

% Retained on No. 4 Sieve (Rock) 37 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ______ ÷ (100 + ______ % H_2O) (x 100) = Dry Wt. Total Sample ______

Wet Wt. Rock .... ______ ÷ (100 + ______ % H_2O in Rock) (x 100) = Dry Wt. Rock ______

Dry Wt. Rock ...... ______ ÷ Dry Wt. Total Sample ______ = ______ % + #4 and ______ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

______ % x ______ + ______ % x (.9 x ______ = ______)

______ + ______ = ______ pcf Maximum Dry Density Corrected for Rock

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STATE ENGINEER
COLO.

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ______ x ______ % H_2O in - #4 = ______ %

% + #4 ______ x ______ % H_2O in + #4 = ______ %

Total Corrected Optimum Moisture = ______ %

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ______

S Dry Weight ______

T Loss (R-S) ______

% Moisture by Dry Weight : ______ %

((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ______

Tare Wt. ______ (Factor) (Wet Den.)

Net Wt. ______ x ______ = ______ ÷ 100 + ______ % H_2O x 100 = ______ pcf Dry Density

STANDARD COUNT

Moisture	Density
______	______
______	______
______	______
______	______
) ______	) ______
______ CPM	______ CPM

REMARKS

FIGURE

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density Flush or Trans. 8"	Air Gap Gap
90°	90°	
2109	5449	
2141	5400	
2) 4250	2) 10849	)
2125 CPM	5424 CPM ÷ into	
3940 STD	7060 STD	
.539 Ratio	.768 Ratio	AGR

Name of Pit ______

Curve No. ______

AASHTO T-99 ☐ AASHTO T-180 ☐ Method __

Tested by Steve Bryant

Equipment Number 8066

Material ______ Class ______

Project Lawn Lake Dam

Test Number 2L

Date 7-22-82

Station 5'-7" below crest

Depth Below Grade or Thickness 5'-7"

In-Place 118.0 Wet Density

In-Place 20.8 Lbs. of H_2O/ft^3

In-Place 97.2 Dry Density

In-Place 21.4 % Moisture

Curve Values	-#4	W/R
Optimum Moisture		
Max Dry Density		

% Relative Compaction ______ %

Soil Classification ______

% Retained on No. 4 Sieve (Rock) 16 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ______ ÷ (100 + ______ % H_2O) (x 100) = Dry Wt. Total Sample ______
Wet Wt. Rock .... ______ ÷ (100 + ______ % H_2O in Rock) (x 100) = Dry Wt. Rock ______
Dry Wt. Rock ...... ______ ÷ Dry Wt. Total Sample ______ = ______ % + #4 and ______ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

______ % x ______ + ______ % x (.9 x ______ = ______)

______ + ______ = ______ pcf Maximum Dry Density Corrected for Rock

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ______ x ______ % H_2O in - #4 = ______ %
% + #4 ______ x ______ % H_2O in + #4 = ______ %
Total Corrected Optimum Moisture = ______ %

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ______
S Dry Weight ______
T Loss (R-S) ______
% Moisture by Dry Weight : ______ %
((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ______
Tare Wt. ______ (Factor) (Wet Den.)
Net Wt. ______ x ______ = ______ ÷ 100 + ______ % H_2O x 100 = ______ pcf Dry Density

STANDARD COUNT

Moisture	Density
)	)
CPM	CPM

REMARKS

FIGURE B-2

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density: Flush or Trans. 8"	Density: Air Gap Gap
____	____	____
____ 90°	____ 90°	____
2438	4768	____
2364	4757	____
2) 4802	2) 9525	) ____
2401 CPM	4762 CPM ÷ into	____
3940 STD	7060 STD	
.609 Ratio	.674 Ratio	____ AGR

Name of Pit ____

Curve No. ____

AASHTO T-99 ☐ AASHTO T-180 ☐ Method ____

Tested by [signature]

Equipment Number 8035

Material ____ Class ____

Project Lawn Lake Dam

Test Number 3L

Date 7-22-82

Station 7'-1" below crest

Depth Below Grade or Thickness 7'-1"

In-Place 123.5 Wet Density

In-Place 24.1 Lbs. of H^2O/ft^3

In-Place 99.4 Dry Density

In-Place 24.2 % Moisture

Curve Values	-#4	W/R
Optimum Moisture	____	____
Max Dry Density	____	____

% Relative Compaction ____ %

Soil Classification ____

% Retained on No. 4 Sieve (Rock) 25 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ____ ÷ (100 + ____ % H^2O) (x 100) = Dry Wt. Total Sample ____

Wet Wt. Rock .... ____ ÷ (100 + ____ % H^2O in Rock) (x 100) = Dry Wt. Rock ____

Dry Wt. Rock ...... ____ ÷ Dry Wt. Total Sample ____ = ____ % + #4 and ____ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

____ % x ____ + ____ % x (.9 x ____ = ____)

____ + ____ = ____ pcf Maximum Dry Density Corrected for Rock

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ____ x ____ % H^2O in - #4 = ____ %

% + #4 ____ x ____ % H^2O in + #4 = ____ %

Total Corrected Optimum Moisture = ____ %

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ____

S Dry Weight ____

T Loss (R-S) ____

% Moisture by Dry Weight : ____ %
((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ____

Tare Wt. ____ (Factor) (Wet Den.)

Net Wt. ____ x ____ = ____ ÷ 100 + ____ % H^2O x 100 = ____ pcf Dry Density

STANDARD COUNT

Moisture	Density
____	____
____	____
____	____
____	____
) ____	) ____
____ CPM	____ CPM

REMARKS

FIGURE

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density Flush or Trans. 6"	Air Gap Gap
____	____	____
____90°	____90°	____
2863	7862	____
2856	7781	____
2) 5719	2) 15643	) ____
2860 CPM	7821 CPM ÷ into	____
3940 STD	7060 STD	
.726 Ratio	1.108 Ratio	____ AGR

Name of Pit ____

Curve No. ____

AASHTO T-99 ☐ AASHTO T-180 ☐ Method ____

Tested by Steve Bignall

Equipment Number 8066

Material ____ Class ____

Project Lawn Lake Dam

Test Number 4L

Date 7-22-82

Station 8'-8" below crest

Depth Below Grade or Thickness 8'-8"

In-Place 123.6 Wet Density

In-Place 29.5 Lbs. of H^2O/ft^3

In-Place 94.1 Dry Density

In-Place 31.3 % Moisture

Curve Values	-#4	W/R
Optimum Moisture	____	____
Max Dry Density	____	____

% Relative Compaction ____ %

Soil Classification ____

% Retained on No. 4 Sieve (Rock) 15 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ____ ÷ (100 + ____ % H^2O) (x 100) = Dry Wt. Total Sample ____
Wet Wt. Rock .... ____ ÷ (100 + ____ % H^2O in Rock) (x 100) = Dry Wt. Rock ____
Dry Wt. Rock ...... ____ ÷ Dry Wt. Total Sample ____ = ____ % + #4 and ____ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

____ % x ____ + ____ % x (.9 x ____ = ____)

____ + ____ = ____ pcf Maximum Dry Density Corrected for Rock

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ____ x ____ % H^2O in - #4 = ____ %
% + #4 ____ x ____ % H^2O in + #4 = ____ %
Total Corrected Optimum Moisture = ____ %

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ____
S Dry Weight ____
T Loss (R-S) ____
% Moisture by Dry Weight : ____ %
((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ____
Tare Wt. ____ (Factor) (Wet Den.)
Net Wt. ____ x ____ = ____ ÷ 100 + ____ % H^2O x 100 = ____ pcf Dry Density

STANDARD COUNT

Moisture	Density
____	____
____	____
____	____
____	____
) ____	) ____
____ CPM	____ CPM

REMARKS

FIGURE B-4

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density Flush or Trans. 6"	Density Air Gap Gap
90°	90°	
3055	7371	
3057	7348	
2) 6112	2) 14719	)
3056 CPM	7360 CPM ÷ into	
3940 STD	7060 STD	
.776 Ratio	1.042 Ratio	AGR

Name of Pit ______

Curve No. ______

AASHTO T-99 ☐ AASHTO T-180 ☐ Method ___

Tested by Steve Bagnell

Equipment Number 8066

Material ______ Class ______

Project Lawn Lake Dam

Test Number 5L

Date 7-22-82

Station 9'-9" below crest

Depth Below Grade or Thickness 9'-9"

In-Place 126.8 Wet Density

In-Place 31.8 Lbs. of H^2O/ft^3

In-Place 95.0 Dry Density

In-Place 33.4 % Moisture

Curve Values	-#4	W/R
Optimum Moisture		
Max Dry Density		

% Relative Compaction ______ %

Soil Classification ______

% Retained on No. 4 Sieve (Rock) 10 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ______ ÷ (100 + ______% H^2O) (x 100) = Dry Wt. Total Sample ______

Wet Wt. Rock .... ______ ÷ (100 + ______% H^2O in Rock) (x 100) = Dry Wt. Rock ______

Dry Wt. Rock ...... ______ ÷ Dry Wt. Total Sample ______ = ______% + #4 and ______ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

______% x ______ + ______% x (.9 x ______ = ______)

______ + ______ = ______ pcf Maximum Dry Density Corrected for Rock

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ______ x ______ % H^2O in - #4 = ______%

% + #4 ______ x ______ % H^2O in + #4 = ______%

Total Corrected Optimum Moisture = ______%

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ______

S Dry Weight ______

T Loss (R-S) ______

% Moisture by Dry Weight : ______%

((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ______

Tare Wt. ______ (Factor) (Wet Den.)

Net Wt. ______ x ______ = ______ ÷ 100 + ______% H^2O x 100 = ______ pcf Dry Density

STANDARD COUNT

Moisture	Density
)	)
CPM	CPM

REMARKS

FIGURE

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density Flush or Trans. 2"	Air Gap Gap
90°	90°	
2093	5138	
2135	5192	
2) 4228	2) 10 330	)
2114 CPM	5165 CPM ÷ into	
3940 STD	7060 STD	
.536 Ratio	.732 Ratio	AGR

Name of Pit ______

Curve No. ______

AASHTO T-99 ☐ AASHTO T-180 ☐ Method ___

Tested by Steve Bignall

Equipment Number 2066

Material ______ Class ______

Project Lawn Lake Dam

Test Number 6L

Date 7-22-82

Station 11' below crest

Depth Below Grade or Thickness 11'

In-Place 120.0 Wet Density

In-Place 20.7 Lbs. of H^2O/ft^3

In-Place 99.3 Dry Density

In-Place 20.8 % Moisture

Curve Values	-#4	W/R
Optimum Moisture		
Max Dry Density		

% Relative Compaction ______ %

Soil Classification ______

% Retained on No. 4 Sieve (Rock) 13 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ______ ÷ (100 + ______ % H^2O) (x 100) = Dry Wt. Total Sample ______

Wet Wt. Rock .... ______ ÷ (100 + ______ % H^2O in Rock) (x 100) = Dry Wt. Rock ______

Dry Wt. Rock ...... ______ ÷ Dry Wt. Total Sample ______ = ______ % + #4 and ______ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

______ % x ______ + ______ % x (.9 x ______ = ______)

______ + ______ = ______ pcf Maximum Dry Density Corrected for Rock

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ______ x ______ % H^2O in - #4 = ______ %

% + #4 ______ x ______ % H^2O in + #4 = ______ %

Total Corrected Optimum Moisture = ______ %

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ______

S Dry Weight ______

T Loss (R-S) ______

% Moisture by Dry Weight : ______ %

((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ______

Tare Wt. ______ (Factor) (Wet Den.)

Net Wt. ______ x ______ = ______ ÷ 100 + ______ % H^2O x 100 = ______ pcf Dry Density

STANDARD COUNT

Moisture	Density
)	)
CPM	CPM

REMARKS

FIGURE B-6

STATE OF COLORADO
DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS
DOH Form No. 427
Revised: September, 1979

NUCLEAR DENSITY TEST

Moisture	Density Flush or Trans. 6"	Air Gap Gap
90°	90°	
1767	7654	
1765	7605	
2) 3536	2) 15259	)
1766 CPM	7630 CPM ÷ into	
3940 STD	7060 STD	
.448 Ratio	1.081 Ratio	AGR

Material ________ Class ________

Project Lawn Lake Dam

Test Number 7L

Date 7-22-82

Station 13' below crest

Depth Below Grade or Thickness 13'

In-Place 124.9 Wet Density

In-Place 16.6 Lbs. of H_2O/ft^3

In-Place 108.3 Dry Density

In-Place 15.3 % Moisture

Name of Pit ________

Curve No. ________

AASHTO T-99 ☐ AASHTO T-180 ☐ Method ___

Tested by Steve Rignall

Equipment Number 8068

Curve Values	-#4	W/R
Optimum Moisture		
Max Dry Density		

% Relative Compaction ________ %

Soil Classification ________

% Retained on No. 4 Sieve (Rock) 25 %

CALCULATIONS FOR PERCENT ROCK

Wet Wt. Total Sample ______ ÷ (100 + ______ % H_2O) (x 100) = Dry Wt. Total Sample ______
Wet Wt. Rock .... ______ ÷ (100 + ______ % H_2O in Rock) (x 100) = Dry Wt. Rock ______
Dry Wt. Rock ...... ______ ÷ Dry Wt. Total Sample ______ = ______ % + #4 and ______ % - #4

ROCK CORRECTION FORMULA AND CALCULATIONS

% - #4 x Maximum Dry Density of - #4 Plus % + #4 x (.9 x Wt. per cu ft of + #4 Rock)

______ % x ______ + ______ % x (.9 x ______ = ______)

______ + ______ = ______ pcf Maximum Dry Density Corrected for Rock

OPTIMUM MOISTURE CORRECTION FOR - #4 W/ROCK

% - #4 ______ x ______ % H_2O in - #4 = ______ %
% + #4 ______ x ______ % H_2O in + #4 = ______ %
Total Corrected Optimum Moisture = ______ %

COMPACTION CYLINDER MOISTURE DATA

R Wet Weight ______
S Dry Weight ______
T Loss (R-S) ______
% Moisture by Dry Weight : ______ %
((T ÷ S) x 100)

COMPACTION CYLINDER DENSITY DATA

Gross Wt. ______
Tare Wt. ______ (Factor) (Wet Den.)
Net Wt. ______ x ______ = ______ ÷ 100 + ______ % H_2O x 100 = ______ pcf Dry Density

STANDARD COUNT

Moisture	Density
)	)
CPM	CPM

REMARKS

FIGURE B-7

DOH Form No. 193
Revised: July, 1978

TEST REPORT

DIVISION OF HIGHWAYS - STATE OF COLORADO
Staff Materials Branch
4340 East Louisiana Avenue
Denver, Colorado 80222

9/3/82

BULK SPECIFIC GRAVITY OF + #4 MATERIAL

TEST NO.	SPECIFIC GRAVITY	ABSORPTION (%)
1 L	2.58	1.21
2 L	2.52	2.25
3 L	2.58	1.21
4 L	2.58	1.21
5 L	2.58	1.21
6 L	2.58	1.21
7 L	2.55	1.42

SPECIFIC GRAVITY OF - #4 MATERIAL

TEST NO.	SPECIFIC GRAVITY
1 L	2.65
2 L	2.57
3 L	2.65
4 L	2.65
5 L	2.54
6 L	2.65
7 L	2.63

SAMPLES TAKEN RIGHT SIDE OF BREACH

1 R	2.67
2 R	2.63
3 R	2.62
4 R	2.64
5 R	2.62
6 R	2.62
7 R	2.48
8 R	2.66
9 R	2.65
10 R	2.62
11 R	2.65
12 R	2.64
13 R	2.62

Staff Materials Engineer

FIGURE B-8

STATE OF COLORADO
Department of Highways
Division of Highways
DOH Form No. 323
October, 1978

LABORATORY REPORT ON ITEM 203

(Embankment or Borrow)
☐ PRELIMINARY
☐ CONSTRUCTION

Field Sheet No. ______
Project No. Division of Water Resources
Location Lawn Lake Dam
District ______ Date 9/3/82

Test No.	Station and Log	Max. Size	Percent Passing 3	1	3/4	3/8	#4	#10	#40	#200	L L	P I	Unified Classification	Lab Moist %	Field Moist %
1 L	4' 7"		89	70	68	64	60	56	38	8	NV	NP	SP-SM	7.4	7.7
2 L	5' 7"		100	87	85	81	75	62	35	20	40	6	SM (OL)	25.0	21.4
3 L	7' 1"		100	92	90	85	79	72	50	10	NV	NP	SP-SM	10.6	24.2
4 L	8' 8"		100	91	90	87	82	77	56	9	NV	NP	SP-SM	10.6	31.3
5 L	9' 9"		100	99	97	94	90	76	51	26	56	13	SM	29.8	33.4
6 L	11' 0"		100	94	92	88	80	70	42	7	NV	NP	SP-SM	10.5	20.8
7 L	13' 0"		100	90	89	84	77	67	44	13	NV	NP	SP-SM	12.1	15.3
			SAMPLES TAKEN RIGHT SIDE OF BREACH												
1 R	10" to 1'1"		100	69	66	57	49	40	24	6	NV	NP	GP-GM		
2 R	1'1" to 2'4"				100	95	91	78	44	21	NV	NP	SM		
3 R	2'4" to 3'1"				100	95	90	77	48	26	26	1	SM		
4 R	3'1" to 3'3"						100	96	52	9	NV	NP	SP-SM		
5 R	3'3" to 3'9"					100	95	84	60	32	NV	NP	SM		
6 R	3'9" to 4'9"				100	95	91	84	56	19	29	3	SM		
7 R	5'11" to 6'6"		100	90	90	85	80	73	46	23	49	2	SM		

SHEET 1 OF 2 FIGURE B-9

☐ T-99 ☐ T-180
☐ Rigid Pavement
☐ Flexible Pavement

DISTRIBUTION
☐ Staff Construction
☐ Staff Design
Staff Materials
District Office – as required

Notes and Samples by ______

18[k] EDLA ______
Regional Factor ______
Serviceability Index ______
Are special corrosive resistant culverts req'd?

Division of Highways
DOH Form No. 323
October, 1978

LABORATORY REPORT ON ITEM 203
(Embankment or Borrow)
☐ PRELIMINARY
☐ CONSTRUCTION

Field Sheet No.
Project No. Division of Water Resources
Location Lawn Lake Dam
District ________ Date 9/3/82

Test No.	Station and Log	Max. Size	Percent Passing 3	1	3/4	3/8	#4	#10	#40	#200	L L	P I	Class, and Group Index	Moist %	R Value
8 R	6'11" to 7'10"		100	98	98	88	75	57	31	9	NV	NP	SP-SM		
9 R	7'10" to 10'4"		100	97	94	91	82	66	38	12	NV	NP	SP-SM		
10 R	10'4" to 10'10"				100	97	94	80	36	13	NV	NP	SM		
11 R	10'10" to 11'10"		100	61	61	52	44	33	15	4	NV	NP	GW		
12 R	11'10" to 12'7"				100	98	90	67	29	5	NV	NP	SW-SM		
13 R	4' 9" to 5' 11"		100	96	96	92	88	80	59	31	NV	NP	SM		

/Sample #13 - No depth identification on sample sack.

SHEET 2 OF 2

FIGURE B-9

DISTRIBUTION
☐ Staff Construction
☐ Staff Design
Staff Materials
District Office - as required

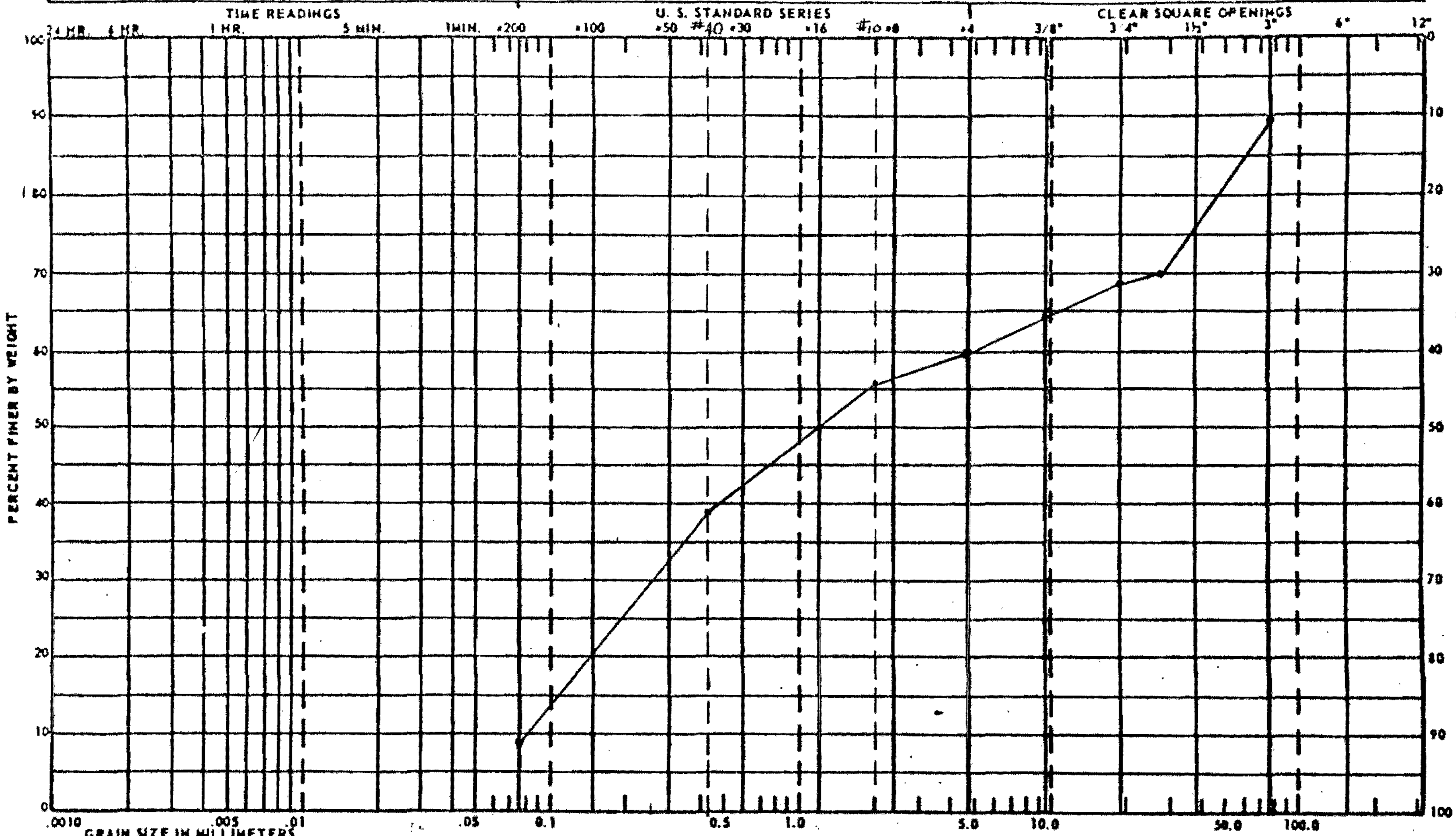
Notes and Samples by ____________

☐ T-99 ☐ T-180
☐ Rigid Pavement
☐ Flexible Pavement
18ᵏ EDLA ________
Regional Factor ________
Serviceability Index ________
Are special corrosive resistant culverts req'd? ________

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

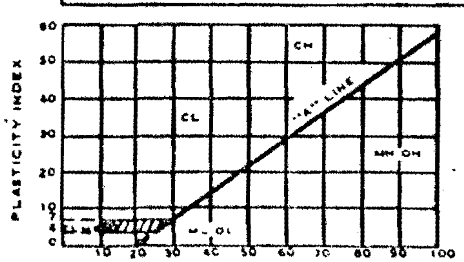
GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



PLASTICITY CHART

Lab. Classification SP-SM

Specific Gravity, Go, + #4 2.58 − #4 2.65

Remarks: From left side of breach

Non-Plastic 40% gravel
50% sand
8% fines

Request No. ______

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 1L F.S. No. ______

Elev. or Depth, Ft., From 4'-7" To ______

Drawn JY Checked ______ Date ______

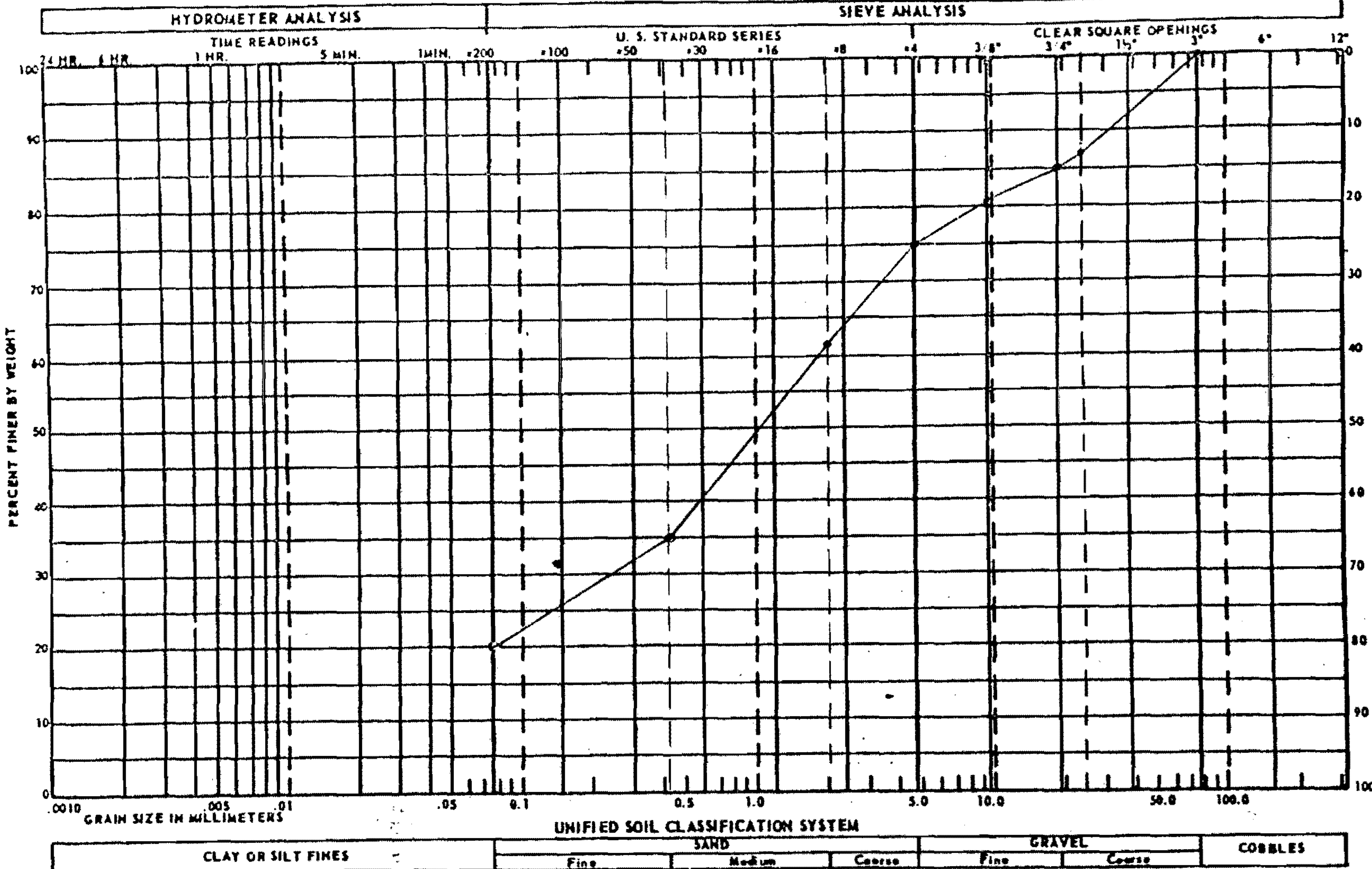
Lab. Sample No. ______

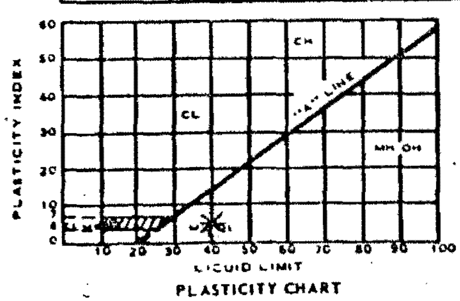
FIGURE B-10

DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

SOILS LABORATORY





Lab. Classification SM (OL)

Specific Gravity, Gs, + #4 2.52 - #4 2.57

Remarks: From left side of breach

LL = 40, PI = 6

25% gravel
55% sand
20% fines

Request No. ____

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 2L F.S. No. ____

Elev. or Depth, Ft., From 5'-7" To ____

Drawn JM Checked ____ Date ____

Lab. Sample No. ____

DWR 665 (Rev. 6 65)

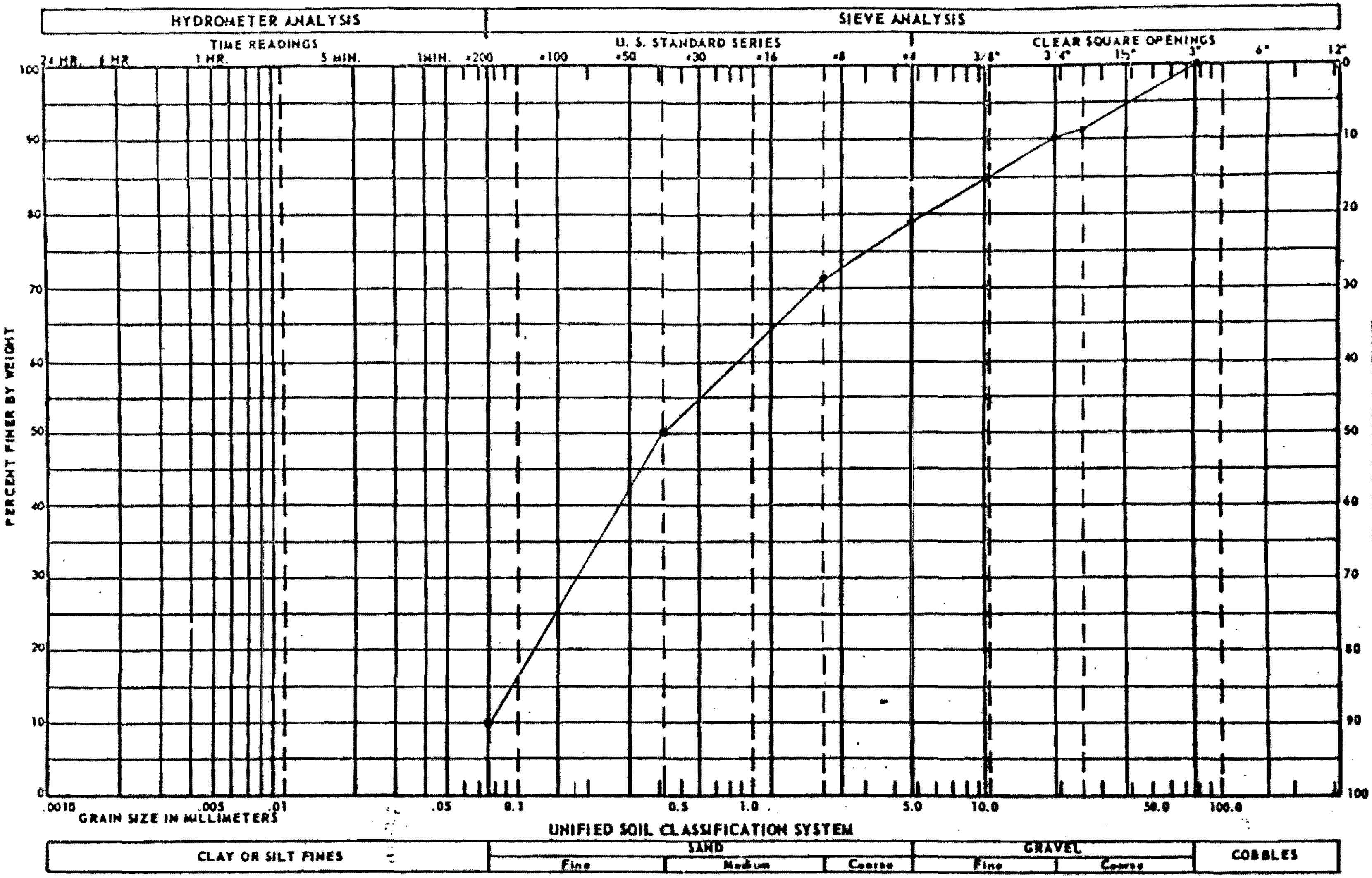
FIGURE B-11

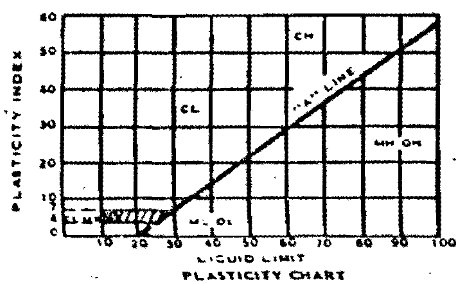
FIGURE B-11

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY





B-12

Lab. Classification SP-SM

Specific Gravity, Go, + #4 2.58 - #4 2.65

Remarks: From left side of breach

Non-Plastic

21% gravel
69% gravel
10% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist 4

Hole No. 3L F.S. No.

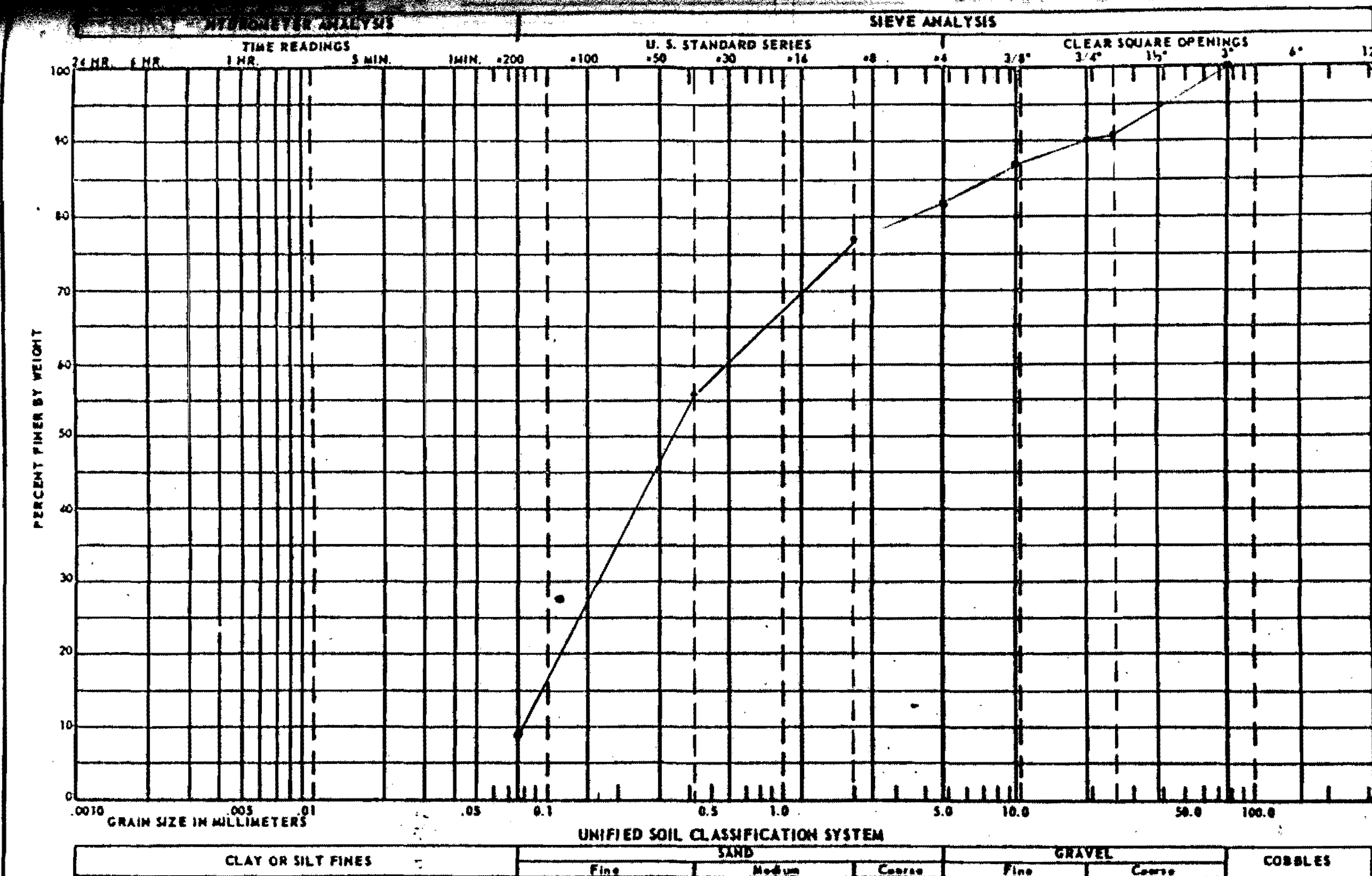
Elev. or Depth, Ft., From 7'-1" To

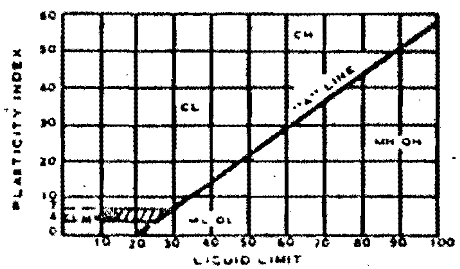
Drawn JJ Checked Date

Lab. Sample No.

FIGURE B

SOILS LABORATORY





PLASTICITY CHART

Lab. Classification SP-SM

Specific Gravity, Gs, + #4 2.58 – #4 2.65

Remarks: From left side of breach

Non-plastic

18% gravel
73% sand
9% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 4L F.S. No.

Elev. or Depth, Ft., From 8'-8" To

Drawn JN Checked Date

Lab. Sample No.

DWR 665 (Rev. 6 65)

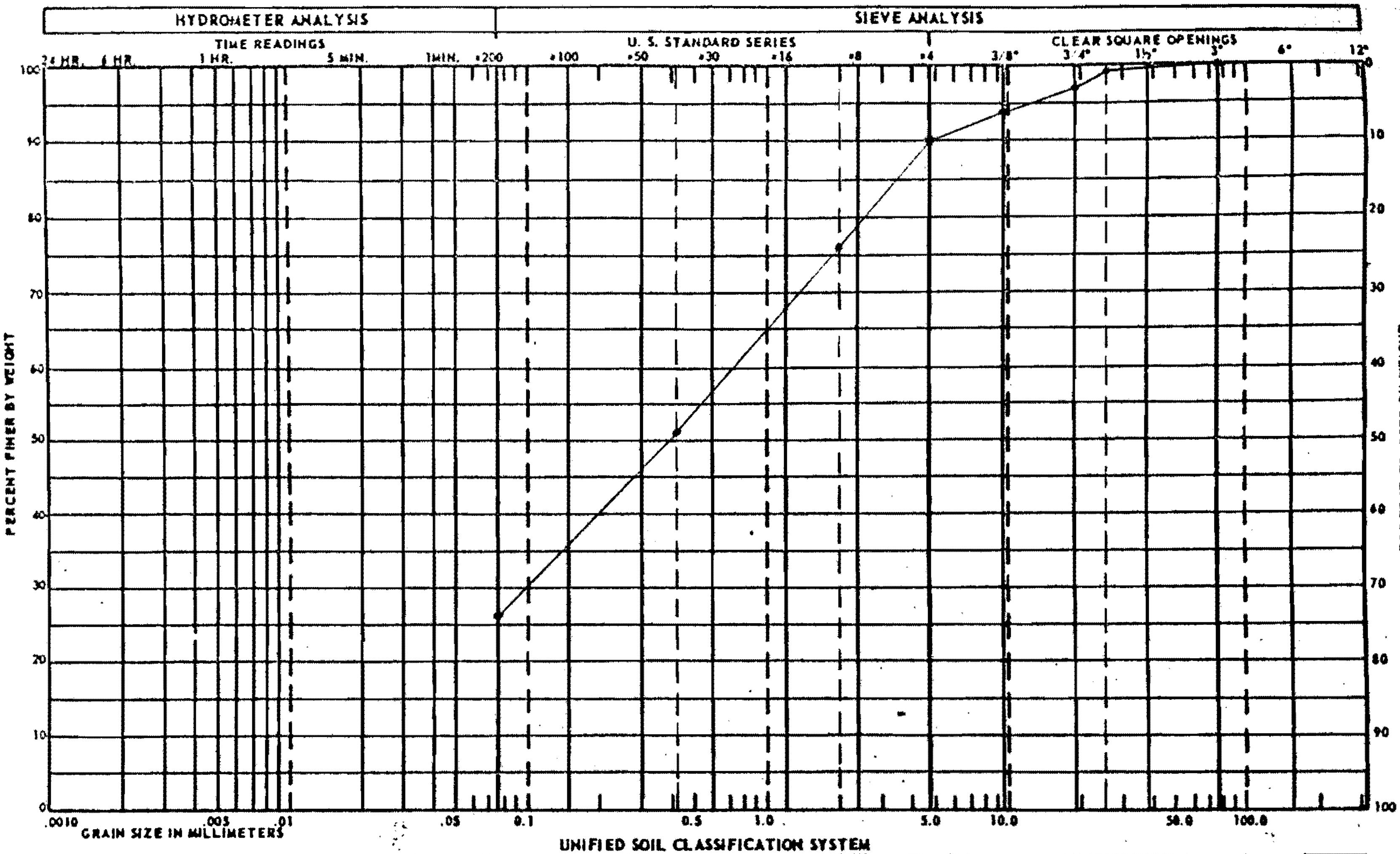
FIGURE B-13

FIGURE B-13

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

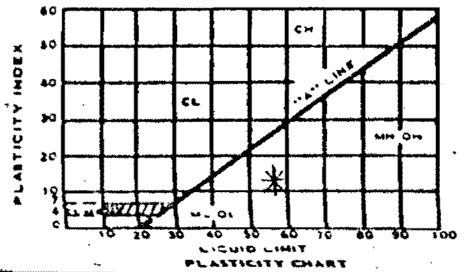
GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



Lab. Classification SM

Specific Gravity, Go, + #4 2.58 − #4 2.54

Remarks: From left side of breach

LL = 56, PI = 13

10% gravel
64% sand
26% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 5L F.S. No.

Elev. or Depth, Ft., From 9'-9" To

Drawn JM Checked Date

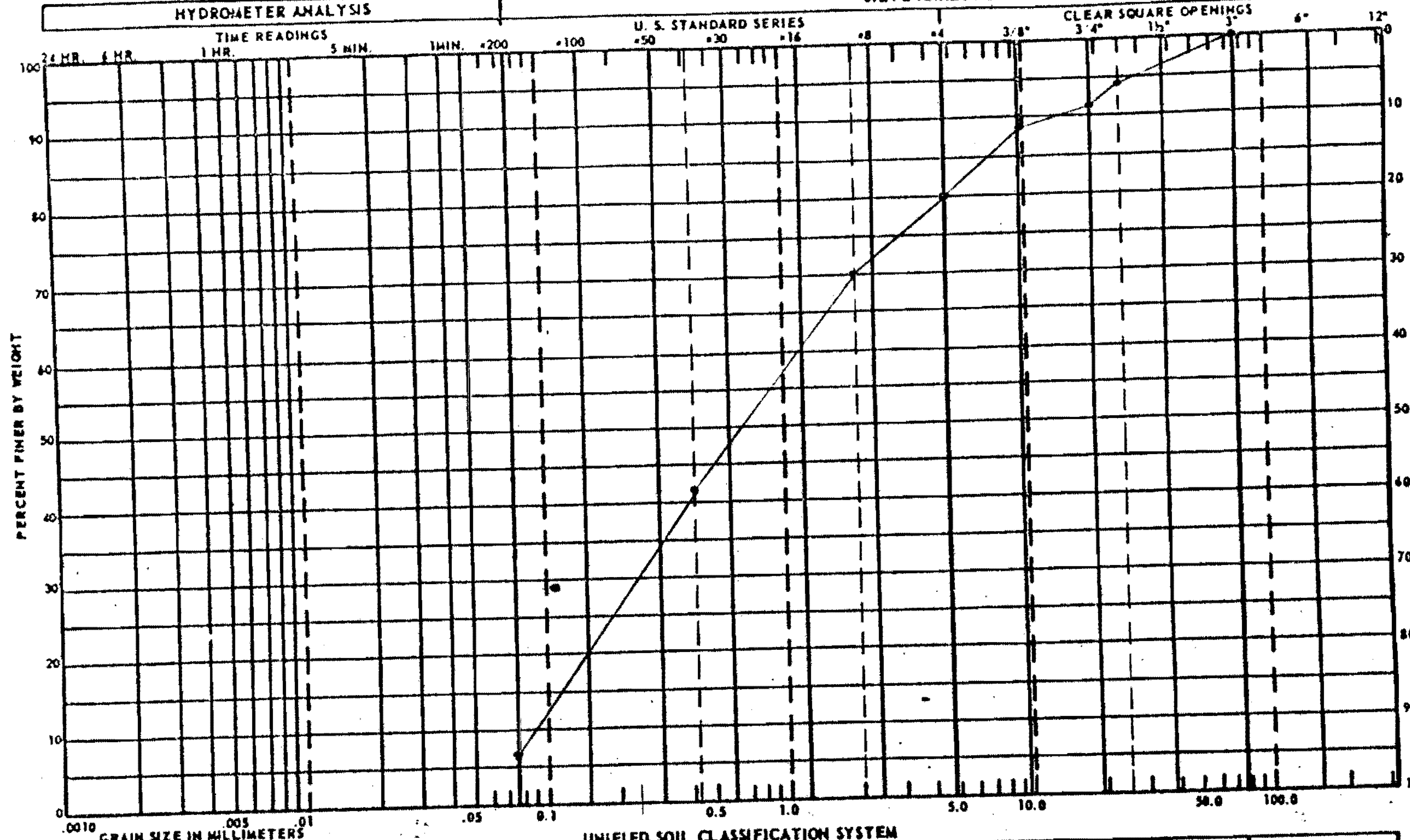
Lab. Sample No.

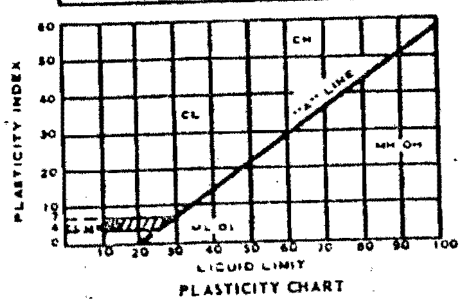
FIGURE B-

DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

SOILS LABORATORY





Lab. Classification SP-SM

Specific Gravity, Gs, + #4 2.58 − #4 2.65

Remarks: From left side of breach

Non-Plastic

20% gravel
73% sand
7% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist 4

Hole No. 6L F.S. No.

Elev. or Depth, Ft., From 11'-0" To

Drawn JA Checked Date

Lab. Sample No.

DWR 665 (Rev. 6-65)

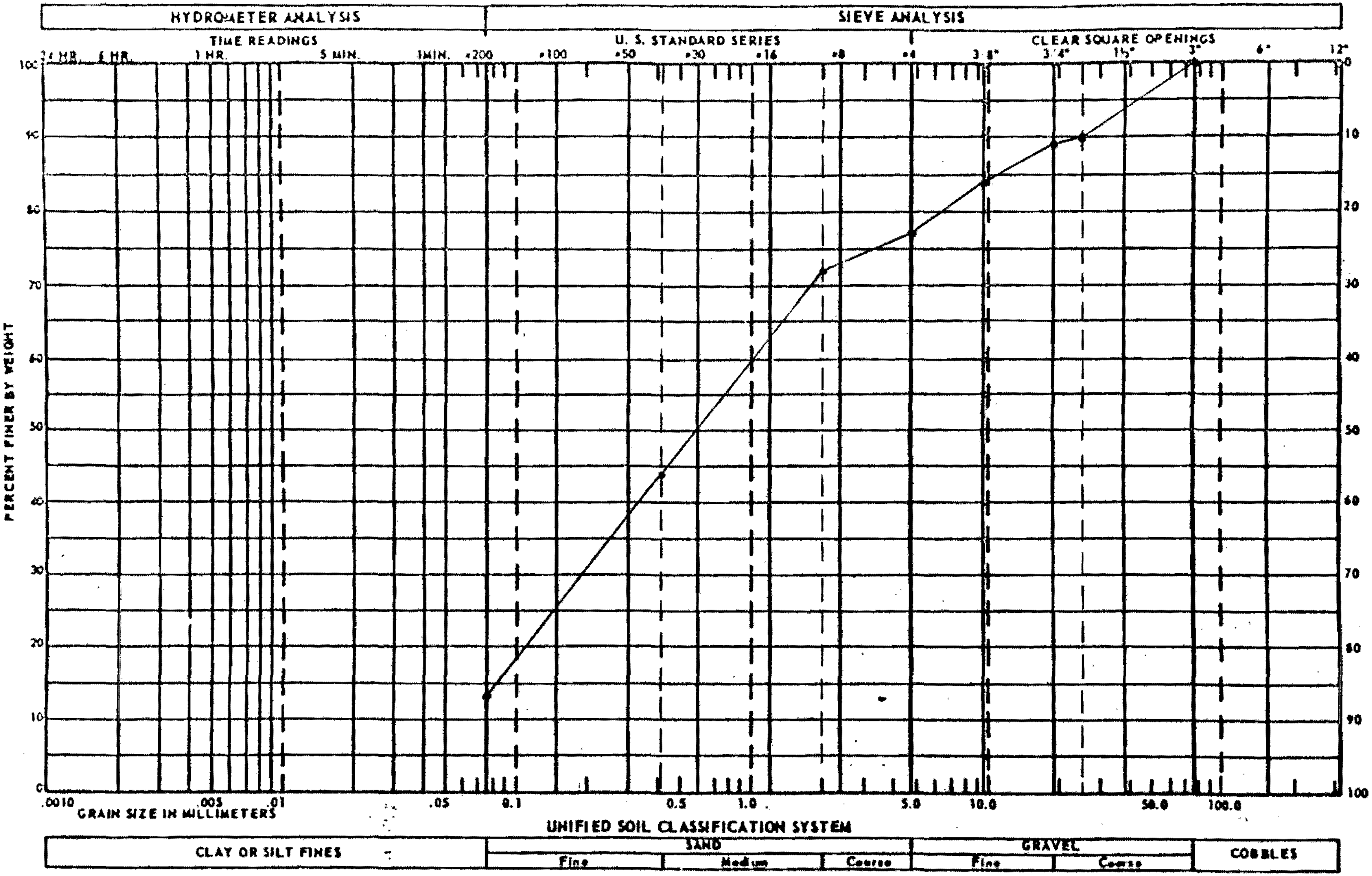
FIGURE B-15

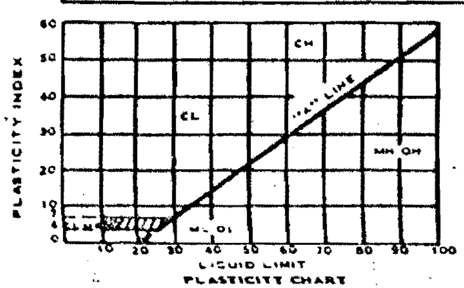
FIGURE B-15

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY





Lab. Classification SP- SM

Specific Gravity, Go, + #4 2.55 - #4 2.63

Remarks: From left side of breach

Non-plastic

23% gravel
64% sand
13% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 7L F.S. No.

Elev. or Depth, Ft., From 13'-0 To

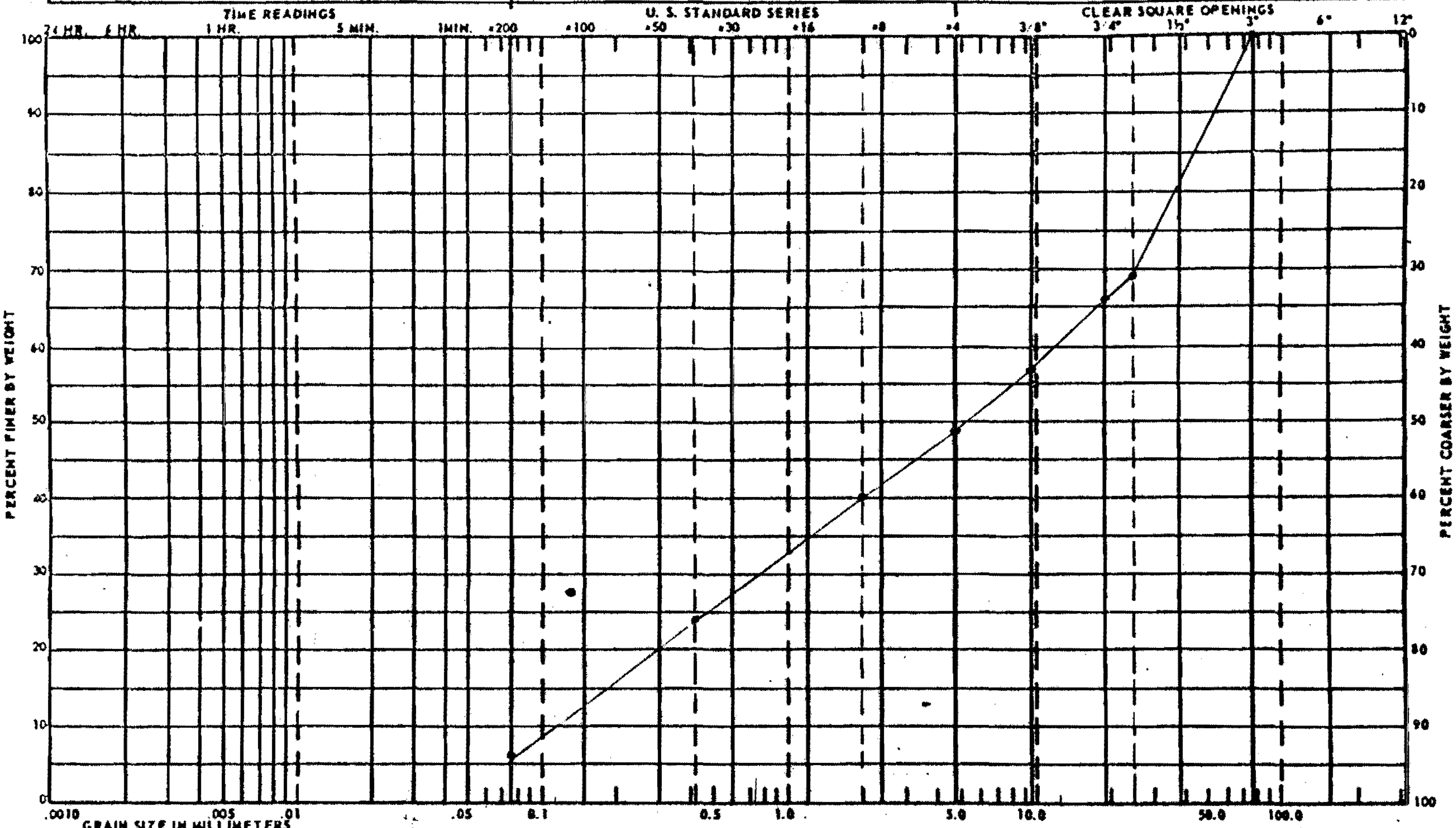
Drawn JV Checked Date

Lab. Sample No.

B-16

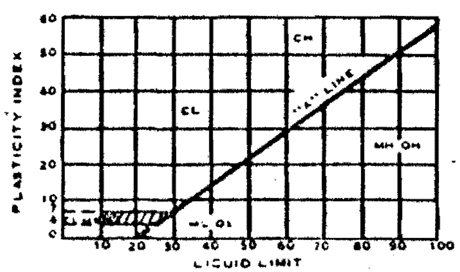
FIGURE B-

HYDROMETER ANALYSIS | SIEVE ANALYSIS



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



PLASTICITY CHART

Lab. Classification GP-GM

Specific Gravity, Gs, +4 ______ -4 2.67

Remarks: From right side of breach

Non-Plastic

51% gravel
43% sand
6% fines

Request No. ______

Project LAWN LAKE

Location W. Div 1 W. Dist 4

Hole No. 1R F.S. No. ______

Elev. or Depth, Ft., From 10" To 1'-1"

Drawn JM Checked ______ Date ______

Lab. Sample No. ______

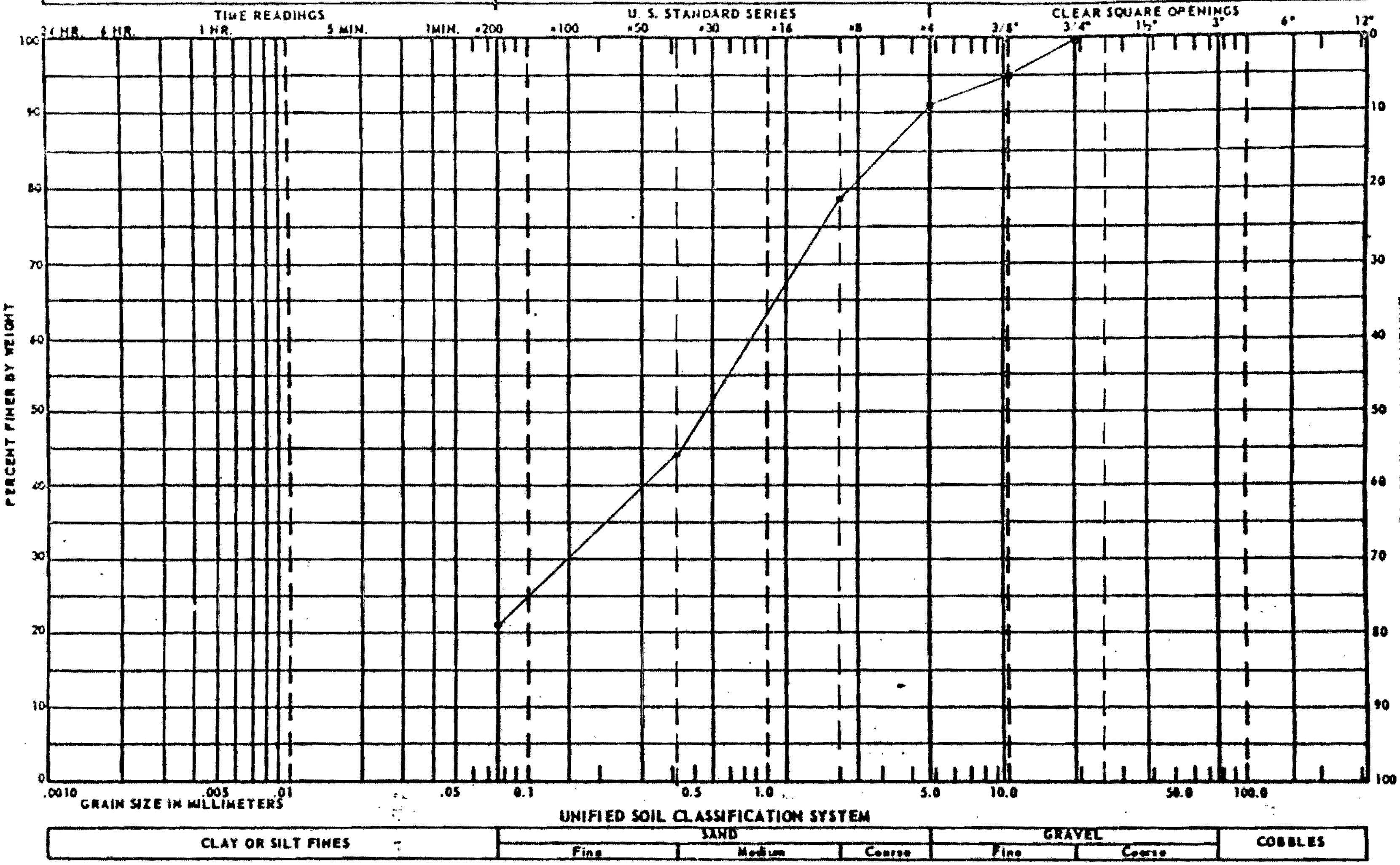
DWR 665 (Rev. 6-65)

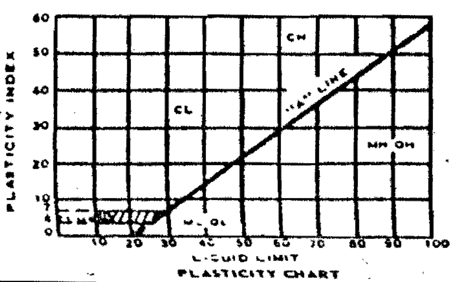
FIGURE B-17

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY





Lab. Classification SM

Specific Gravity, Gs, + #4 ______ − #4 2.63

Remarks: From right side of breach

Non-plastic 9% gravel
70% sand
21% fines

Project LAWN LAKE

Location W. Div. 1 W. Dist 4

Hole No. 2R F.S. No. ______

Elev. or Depth, Ft., From 1'-1" To 2'-4"

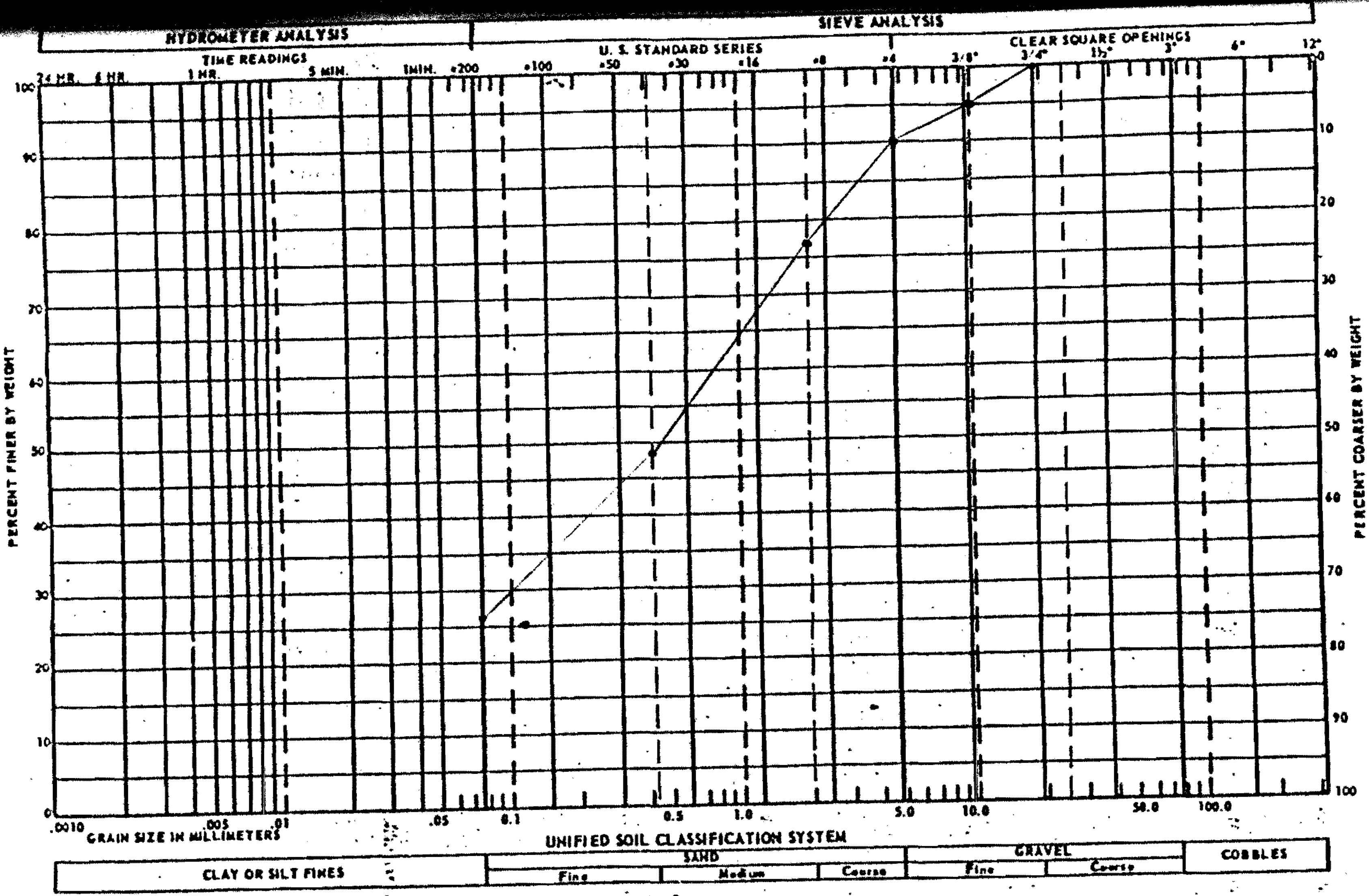
Drawn [signature] Checked ______ Date ______

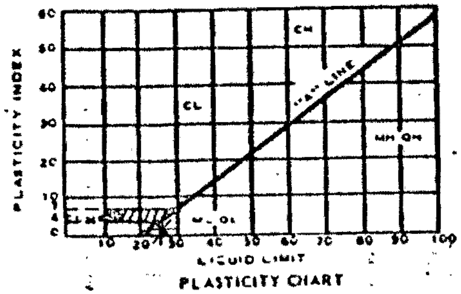
Request No. ______

Lab. Sample No. ______

B-18

FIGURE B





Lab. Classification SM

Specific Gravity, Gs, + #4 2.62

Remarks: From right side of breach

10% gravel

LL = 26 64% sand

PI = 1 26% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 3R F.S. No.

Elev. or Depth, Ft., From 2'-4" To 3'-1"

Drawn JM Checked Date

Lab. Sample No.

DWR 655 (Rev. 6 65)

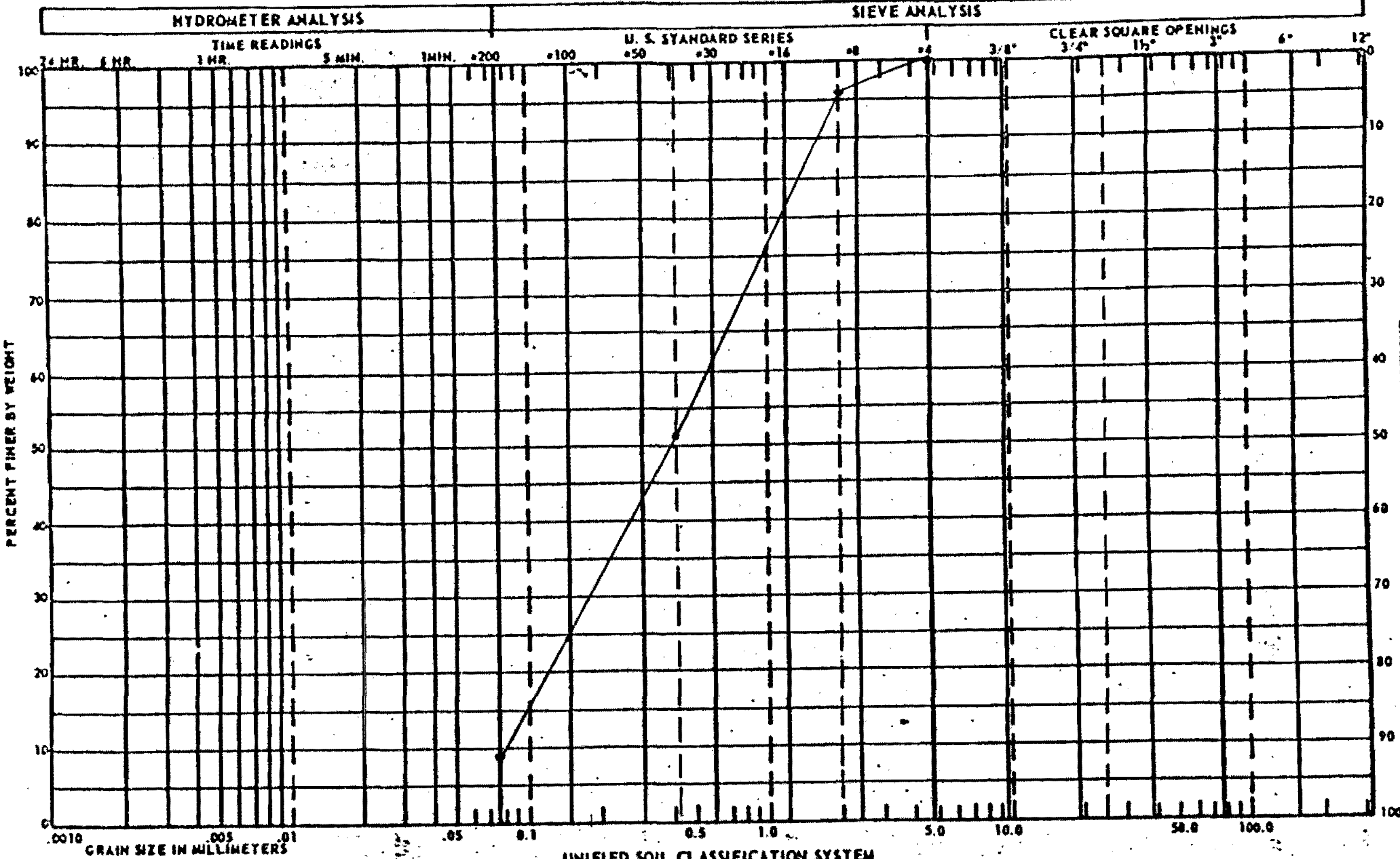
FIGURE B-19

FIGURE B-19

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

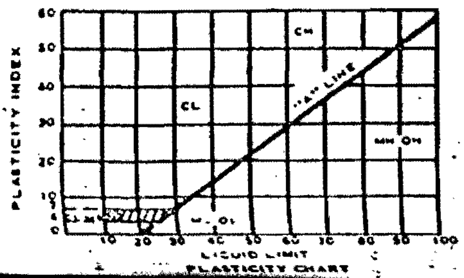
GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



Lab. Classification SP-SM

Specific Gravity, Gs, + #4 ______ − #4 2.64

Remarks: From right side of breach (2' sand lens)

0% gravel
91% sand
Non-plastic 9% fines

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 4R F.S. No. ______

Elev. or Depth, Ft., From 3'-1" To 3'-3"

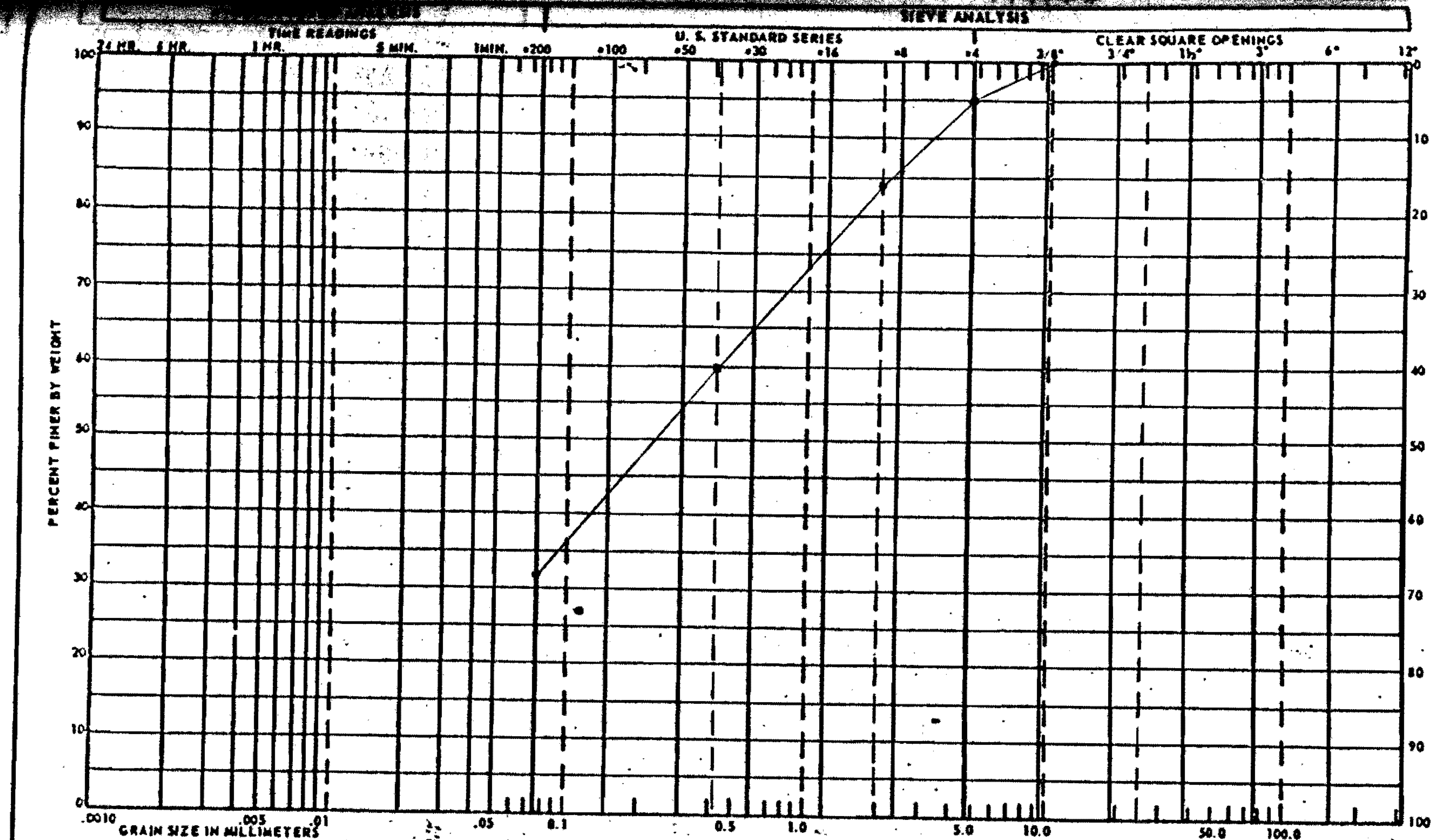
Drawn JN Checked ______ Date ______

Lab. Sample No.

Request No.

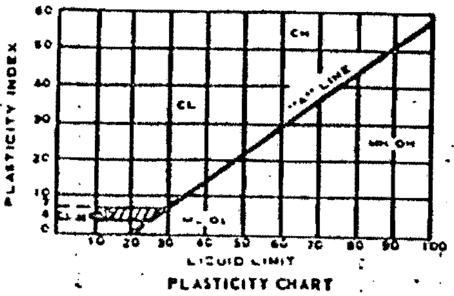
B-20

FIGURE



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



Lab. Classification: SM

Specific Gravity, Gs, + #4: 2.62

Remarks: From right side of breach

Non-plastic — 5% gravel, 63% sand, 32% fines

Request No.

Project: LAWN LAKE

Location: W. Div. 1 W. Dist. 4

Hole No.: 5R F.S. No.

Elev. or Depth, Ft., From 3'3" To 3'9"

Drawn: JM Checked Date

Lab. Sample No.

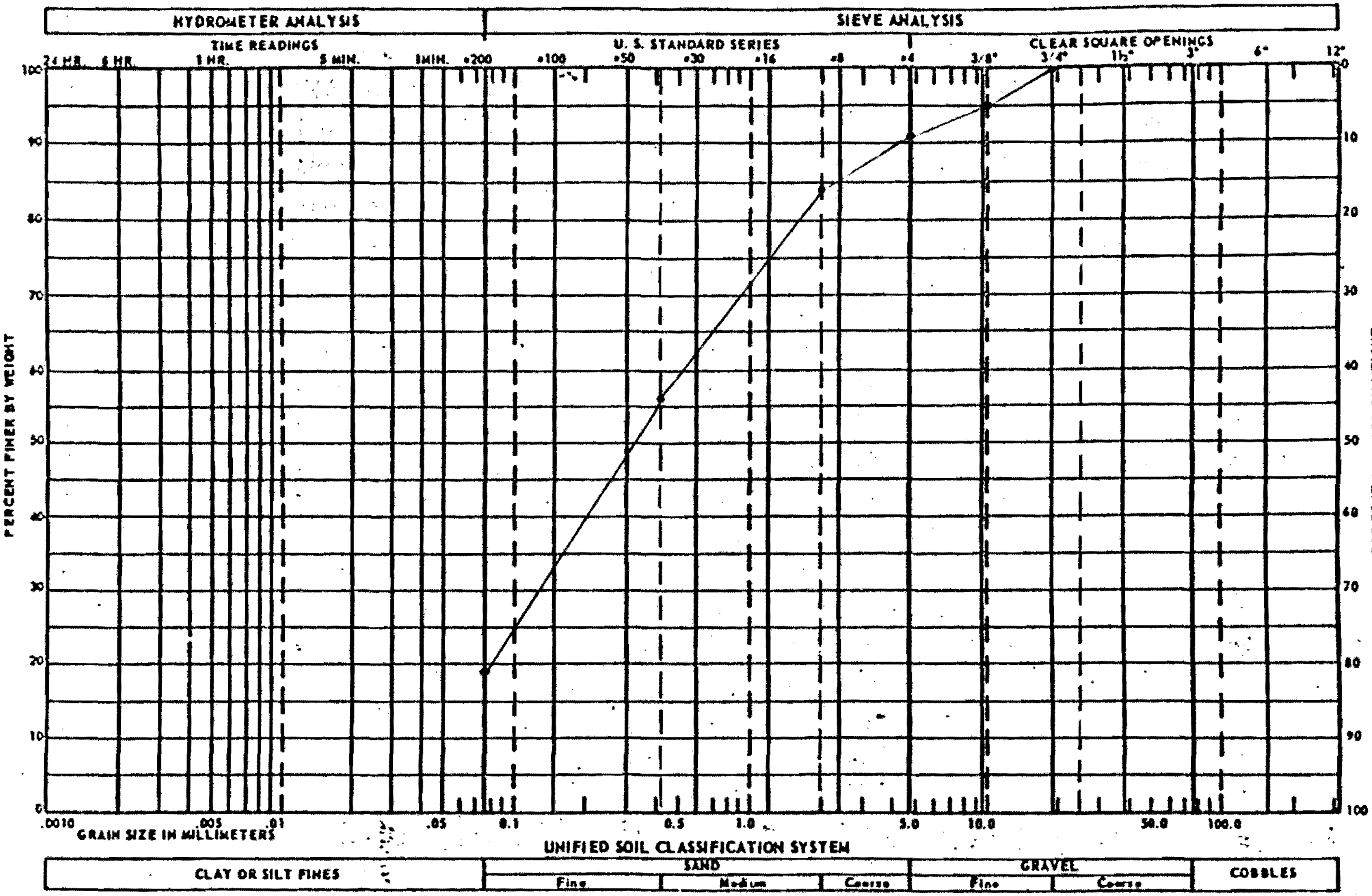
DWR 655 (Rev. 6 65)

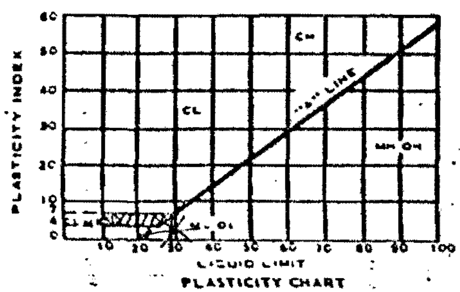
FIGURE B-21

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY





Lab. Classification SM

Specific Gravity, Gs, + #4 2.62

Remarks: From right side of breach

9% gravel

LL = 29 72% sand

PI = 3 19% fines

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 6R F.S. No.

Elev. or Depth, Ft., From 3'-9" To 4'-9"

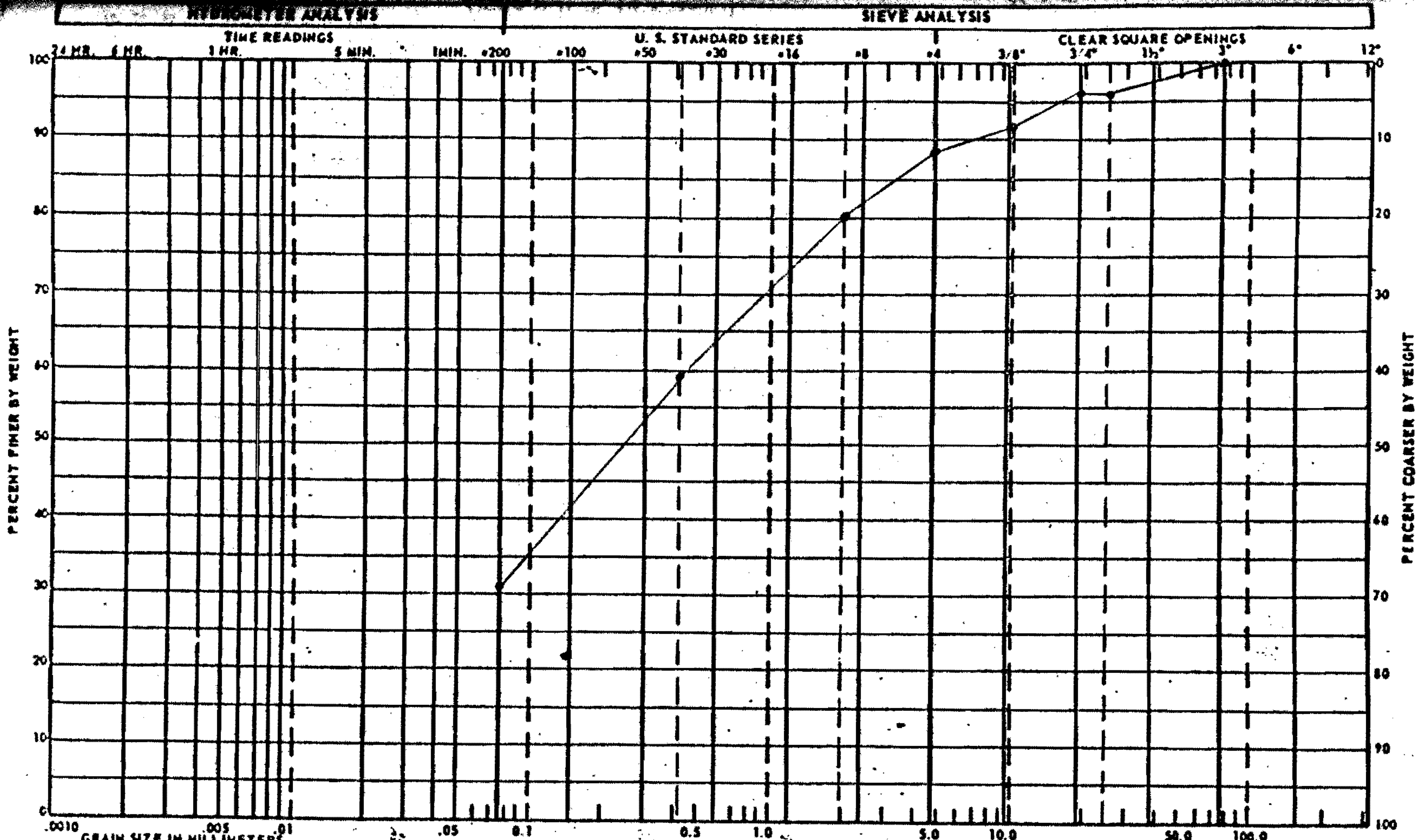
Drawn [signature] Checked Date

Request No.

Lab. Sample No.

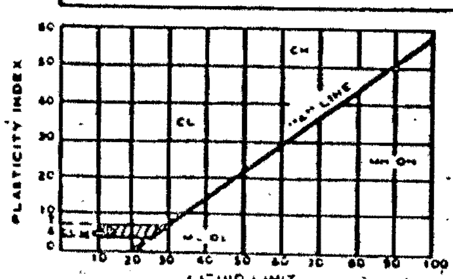
DWR 663 (Rev. 6-65)

FIGURE B-22



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



PLASTICITY CHART

Lab. Classification SM

Specific Gravity, Go, + #4 2.62

Remarks: From right side of breach

Non-plastic. 12% gravel
57% sand
31% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 7R F.S. No.

Elev. or Depth, Ft., From 4'-9" To 5'-11"

Drawn JN Checked Date

Lab. Sample No.

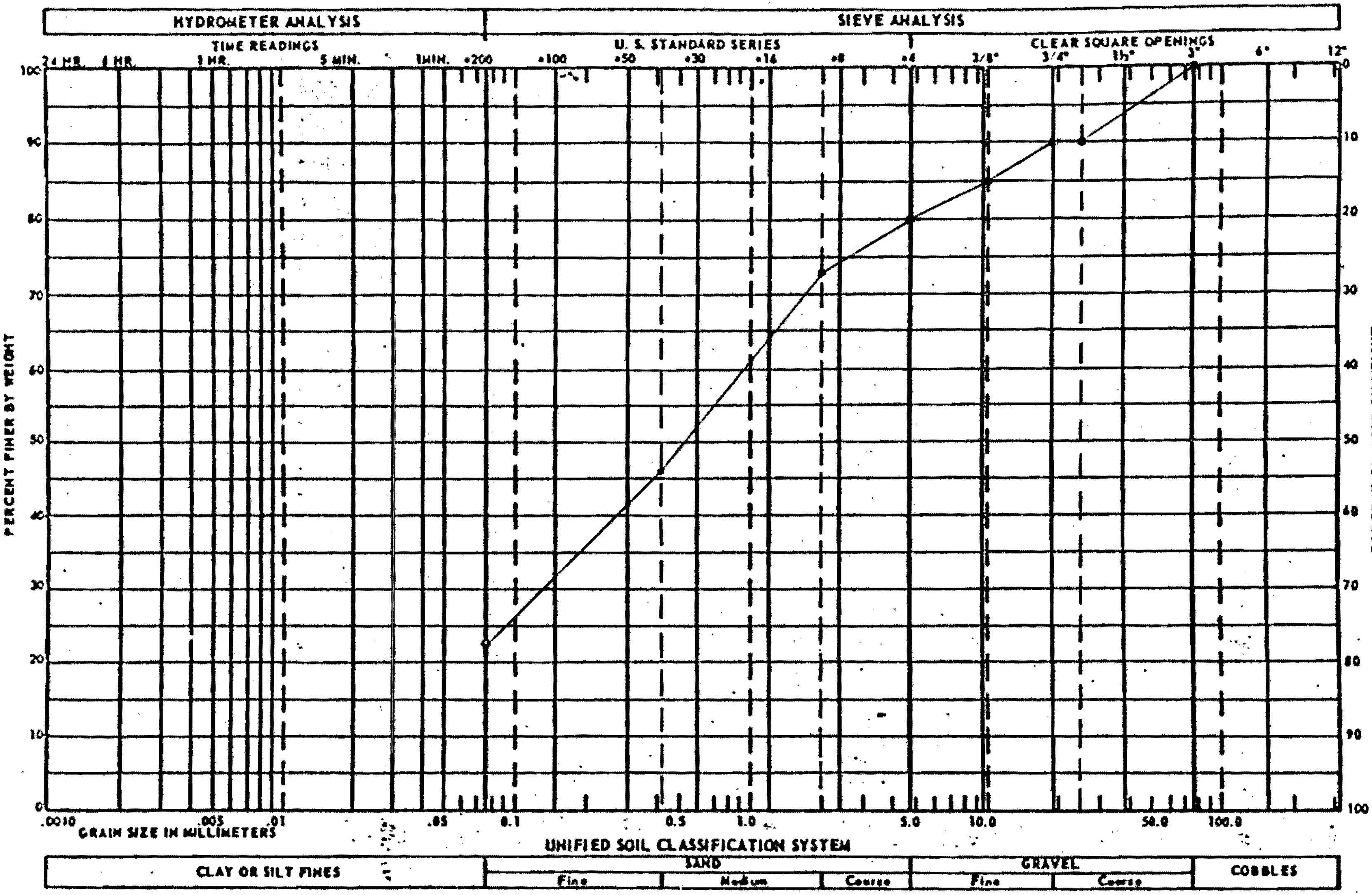
DWR 655 (Rev. 6 65)

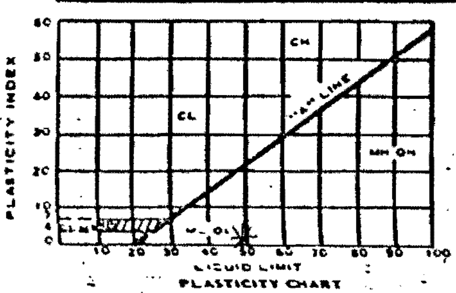
FIGURE B-23

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY





Lab. Classification SM

Specific Gravity, Go, + #4 ——— -#4 2.48

Remarks: From right side of breach

LL = 49 20% gravel

PI = 2 57% sand

23% fines

organics present

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

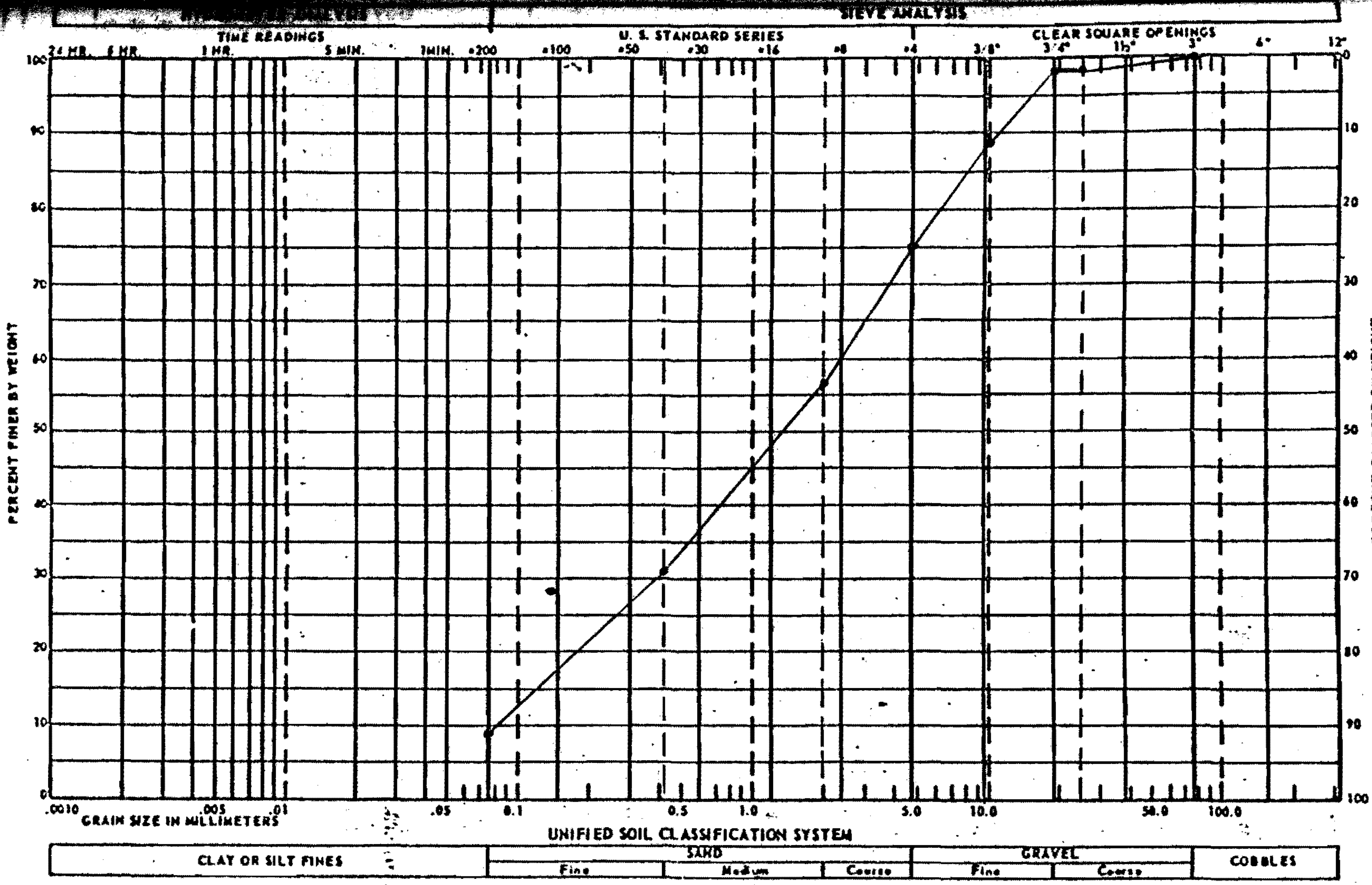
Hole No. 8R F.S. No.

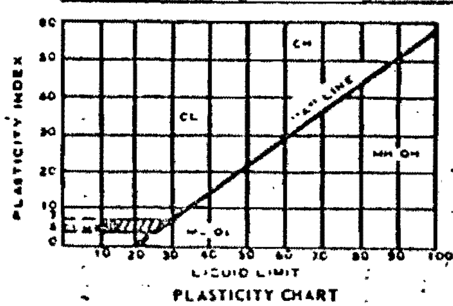
Elev. or Depth, Ft., From 5'-11" To 6'-6"

Drawn JL Checked Date

Lab. Sample No.

FIGURE B-24





Lab. Classification SP-SM

Specific Gravity, Go, + 4 ______ - 4 2.66

Remarks: From right side of breach

25% gravel
66% sand
9% fines

Non-plastic

Request No. ______

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 9R F.S. No. ______

Elev. or Depth, Ft., From 6'-6" To 7'-10"

Drawn ______ Checked ______ Date ______

Lab. Sample No. ______

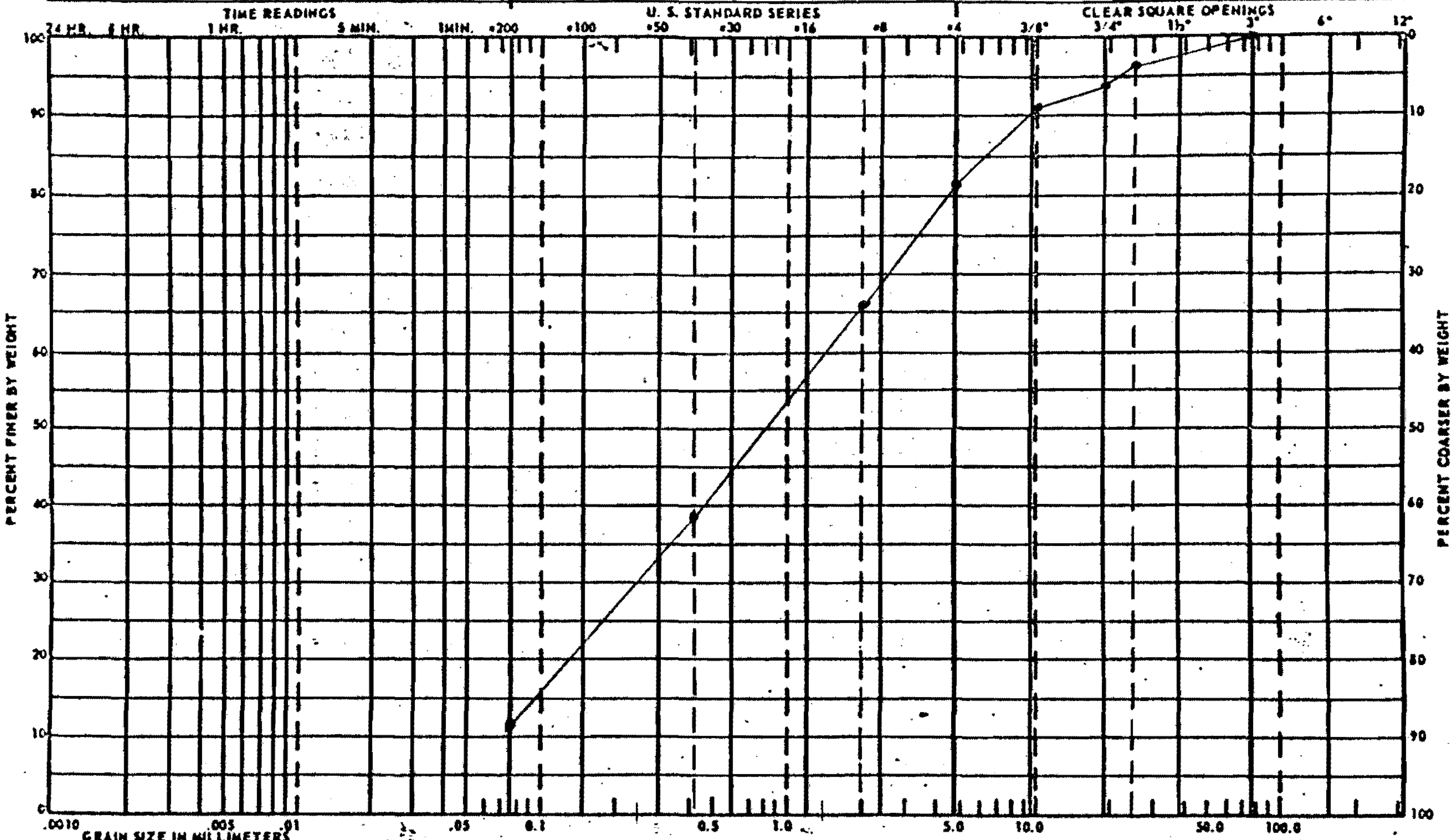
DWR 655 (Rev. 6/65)

FIGURE B-25

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

GRADATION CURVE

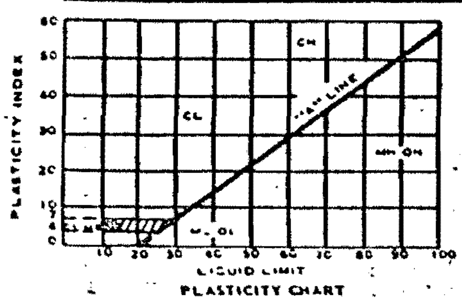
Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	

B-26



PLASTICITY CHART

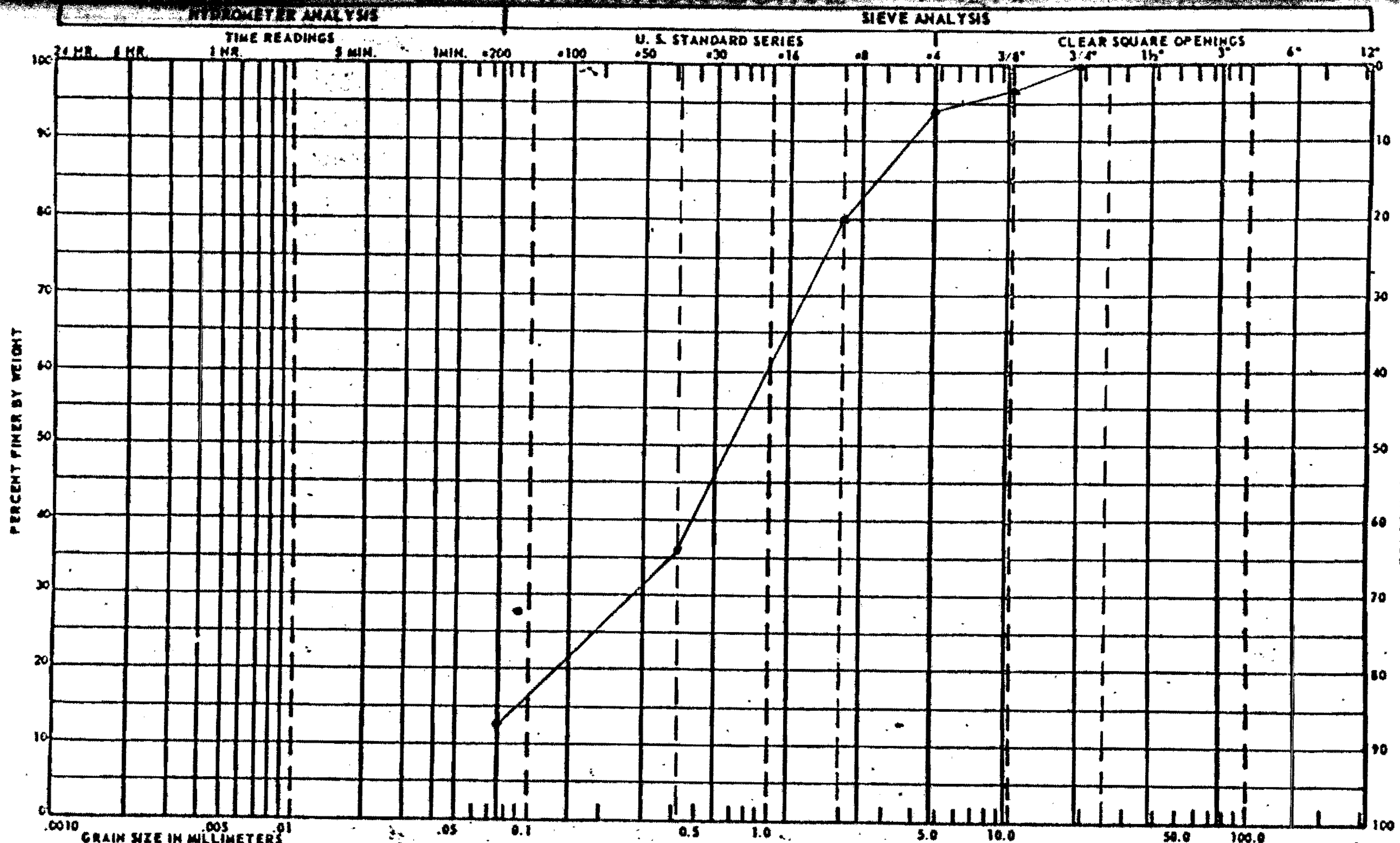
Lab. Classification SP-SM
Specific Gravity, Go, + #4 2.65
Remarks: From right side of breach

Non-plastic 12% gravel
70% sand
12% fines

Project LAWN LAKE
Location W. Div. 1 W. Dist. 4
Hole No. 10R F.S. No.
Elev. or Depth, Ft., From 7'-10" To 10'-4"
Drawn JL Checked Date
Request No.
Lab. Sample No.

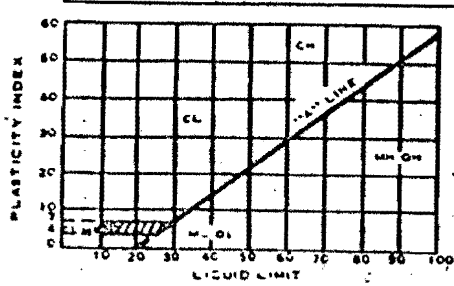
DWR 465 (Rev. 6-65)

FIGURE B-26



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



PLASTICITY CHART

Lab. Classification SM

Specific Gravity, Go, + #4 — #4 2.62

Remarks: From right side of breach

6% gravel
81% sand
Non-plastic 13% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 11R F.S. No.

Elev. or Depth, Ft., From 10'4" To 10'10"

Drawn JD Checked Date

Lab. Sample No.

DWR 655 (Rev. 6-65)

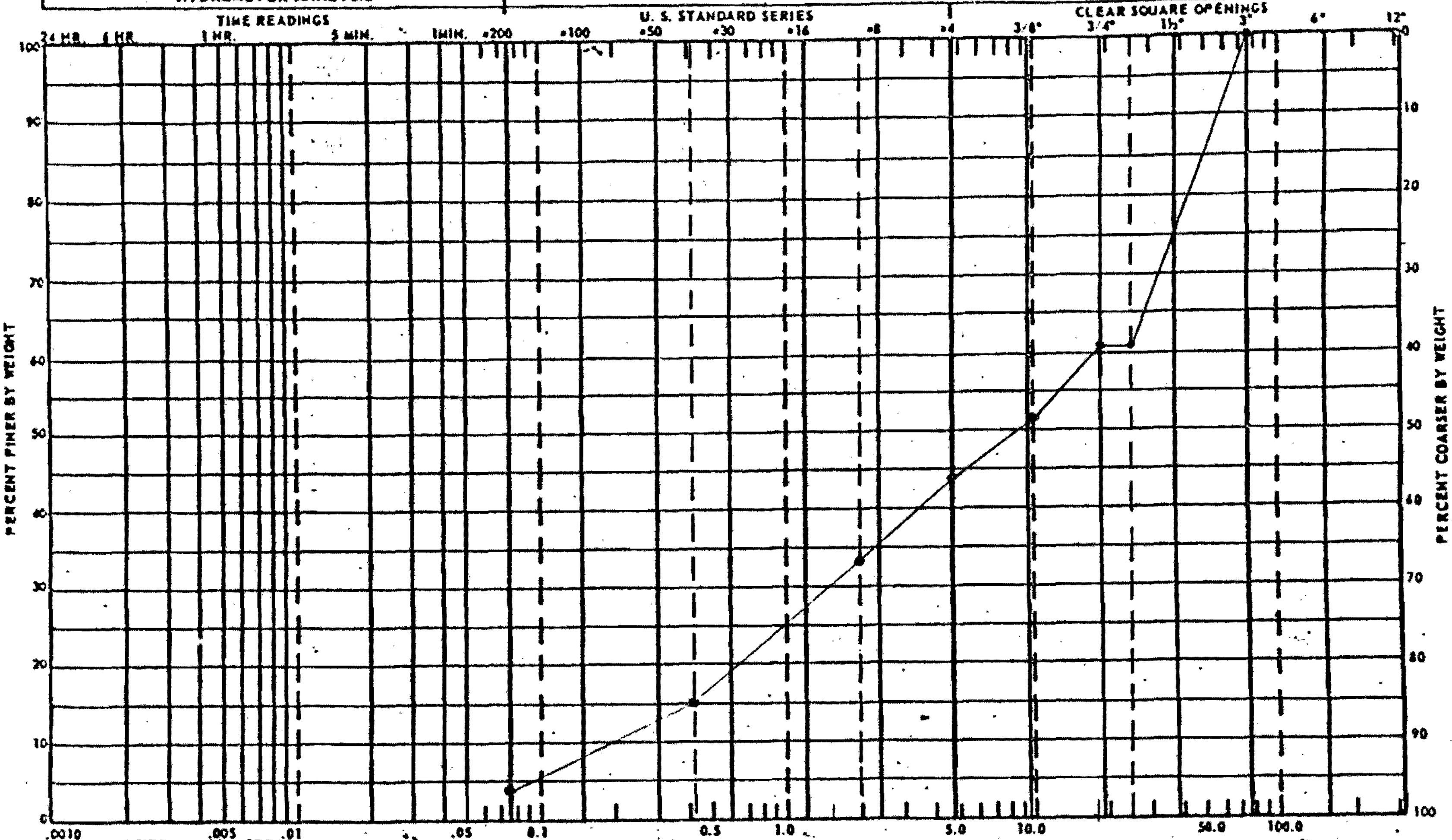
FIGURE B-27

FIGURE B-27

State of California
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

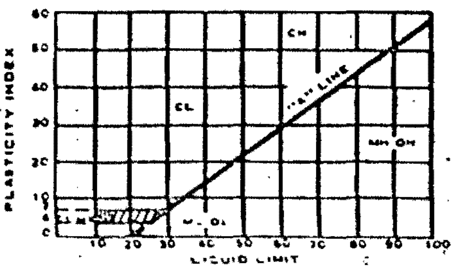
GRADATION CURVE

Technical Services Office
LABORATORIES BRANCH
SOILS LABORATORY



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY OR SILT FINES	SAND			GRAVEL		COBBLES
	Fine	Medium	Coarse	Fine	Coarse	



PLASTICITY CHART

Lab. Classification GW

Specific Gravity, Gs, + #4 2.65

Remarks: From right side of breach

56% gravel
40% sand
Non-plastic 4% fines

Request No.

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 12R F.S. No.

Elev. or Depth, Ft., From 10'-10" To 11'-10"

Drawn JV Checked Date

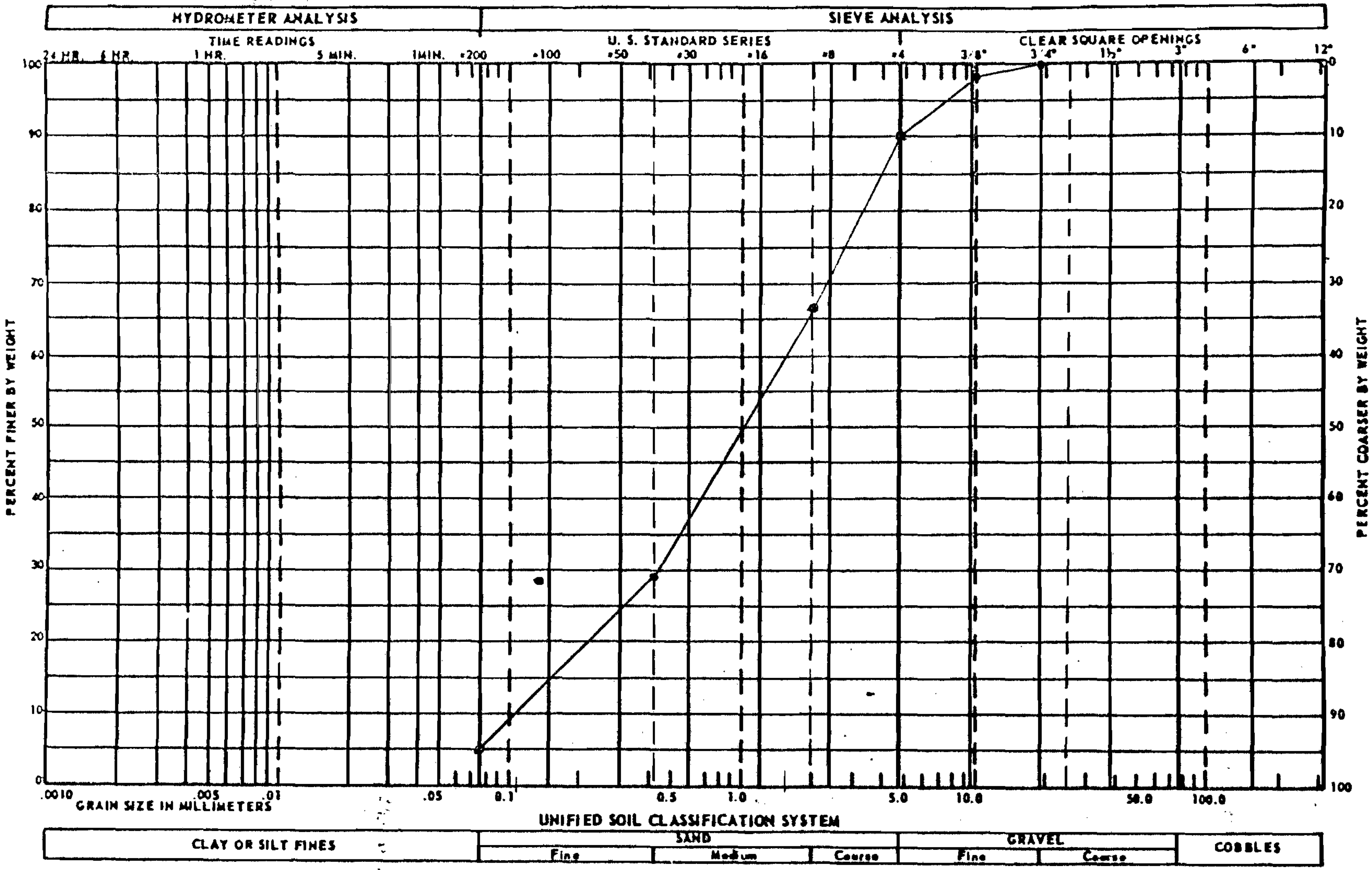
Lab. Sample No.

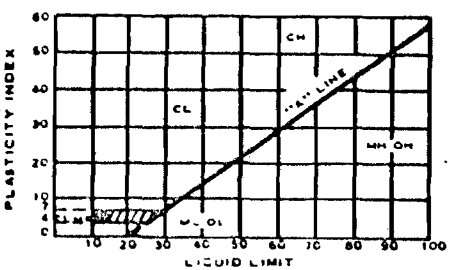
B-28

FIGURE B-28

DEPARTMENT OF WATER RESOURCES

SOILS LABORATORY





PLASTICITY CHART

Lab. Classification SW-SM

Specific Gravity, Gs, + #4 ______ - #4 2.64

Remarks: From right side of breach

10% gravel
85% sand
Non-plastic 5% fines

Request No. ______

Project LAWN LAKE

Location W. Div. 1 W. Dist. 4

Hole No. 13R F.S. No. ______

Elev. or Depth, Ft., From 11'-10" To 12'-7"

Drawn [signature] Checked ______ Date ______

Lab. Sample No. ______

DWR 665 (Rev. 6 65)

FIGURE B-29

FIGURE B-29

CONSTANT HEAD
PERMEABILITY TEST

Sample No. 5L 9'9"

Lab. No. 792-82

Project Div. of Water Reso

Location Lawn Lake Dam

Date 9/3/82

Diameter of specimen 6 inches

Length of specimen 7 inches

Area of specimen .1964 sq.ft.

Volume of specimen .1145 cu.ft.

G_s ______ Est. ______ Det.

Dry weight 10.9 lbs.

Dry Density 95.0 lbs/cu.ft

$$K_t = \frac{QL}{THA}$$

$$K_{20} = K_t \frac{V_t}{V_{20}}$$

Trial No.	Water Temp. C	Time t Min.	Quantity Q CM^3	Quantity Q FT^3	Head h Inches	K_t Feet/day	K_{20} Feet/day
1	MATERIAL IS IMPERMEABLE. NO FLOW OF WATER THROUGH SAMPLE AFTER 3 DAYS.						

FIGURE B-30

CONSTANT HEAD
PERMEABILITY TEST

Sample No. 6L 11'0"

Lab. No. 793-82

Project Div. of Water Resources

Location Lawn Lake Dam

Date 9/3/82

Diameter of specimen 6 inches

Length of specimen 7 inches

Area of specimen .1964 sq.ft.

Volume of specimen .1145 cu.ft.

G_s ______ Est. ______ Det.

Dry weight 11.4 lbs.

Dry Density 99.3 lbs/cu.ft.

$$K_t = \frac{QL}{THA}$$

$$K_{20} = K_t \frac{V_t}{V_{20}}$$

Trial No.	Water Temp. C	Time t Min.	Quantity Q CM^3	Quantity Q FT^3	Head h Inches	K_t Feet/day	K_{20} Feet/day
1	20°	40	100	.0035	6	.75	.75
2	20°	45	100	.0035	6	.67	.67
3	20°	45	100	.0035	6	.67	.67
	AVERAGE = .70 feet/day = 8.4 inches/day						

FIGURE B-31

CONSTANT HEAD
PERMEABILITY TEST

Sample No. 7L 13'0"

Lab. No. 794-82

Project Div. of Water Resources

Location Lawn Lake Dam

Date 9/3/82

Diameter of specimen 6 inches

Length of specimen 7 inches

Area of specimen .1964 sq.ft.

Volume of specimen .1145 cu.ft.

G_s ______ Est. ______ Det.

Dry weight 12.4 lbs.

Dry Density 108.3 lbs/cu.ft.

$$K_t = \frac{QL}{THA}$$

$$K_{20} = K_t \frac{V_t}{V_{20}}$$

Trial No.	Water Temp. C	Time t Min.	Quantity Q CM^3	Quantity Q FT^3	Head h Inches	K_t Feet/day	K_{20} Feet/day
1	21°	21.75	500	.0177	6	6.96	6.75
2	21°	22.25	500	.0177	6	6.79	6.59
3	21°	22.50	500	.0177	6	6.72	6.52
4	21°	22.50	500	.0177	6	6.72	6.52
	AVERAGE = 6.6 feet/day = 79.2 inches/day						

FIGURE B-32

DIVISION OF HIGHWAYS
STATE OF COLORADO
DOH Form No. 548
Revised: August 1970

D.D. = 88.5 PC.F. without Rock
based on 97.2 D.D. with Rock
& 21.4 % Moisture

Project
Station
Curve No. #2 L

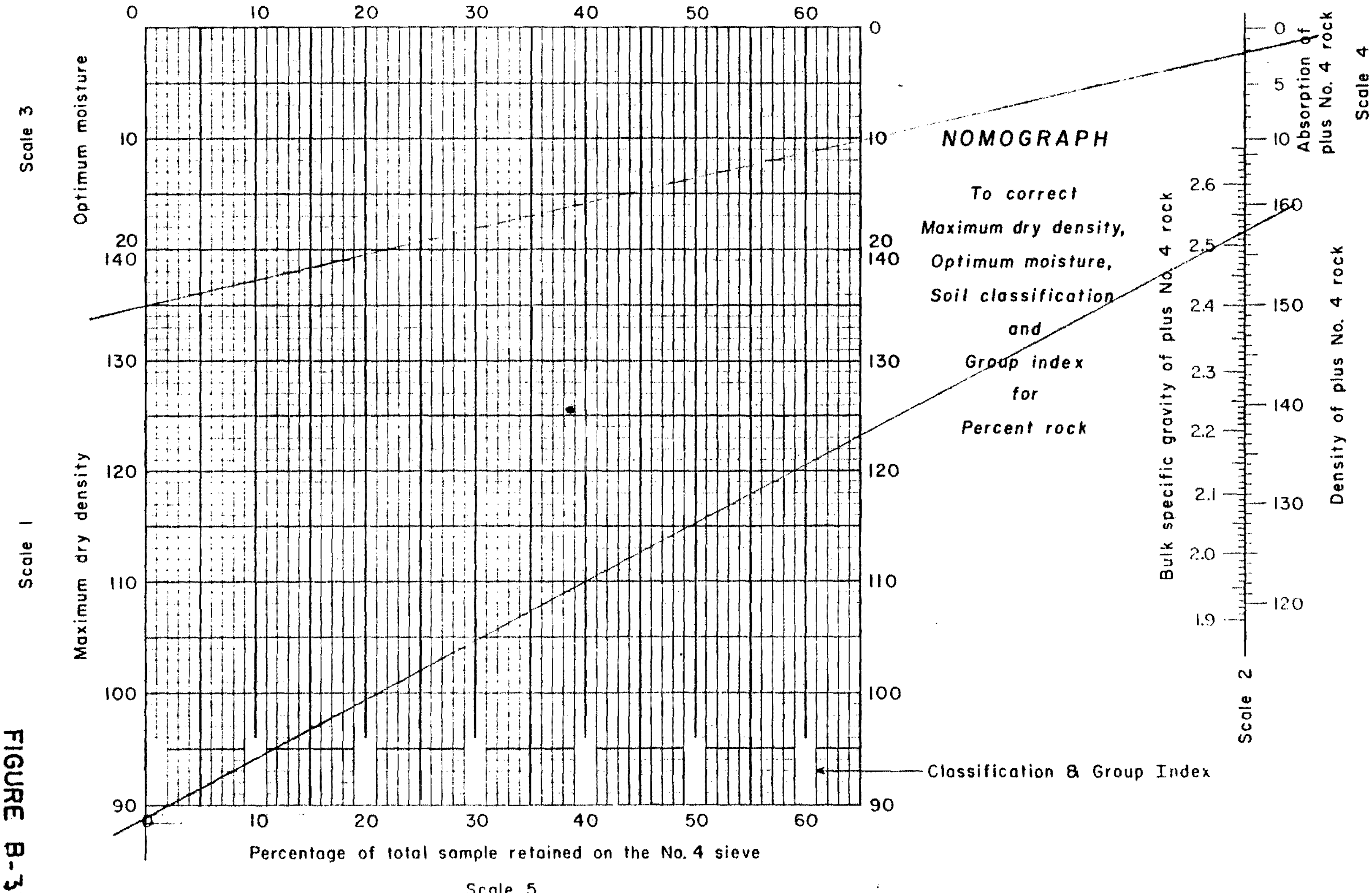
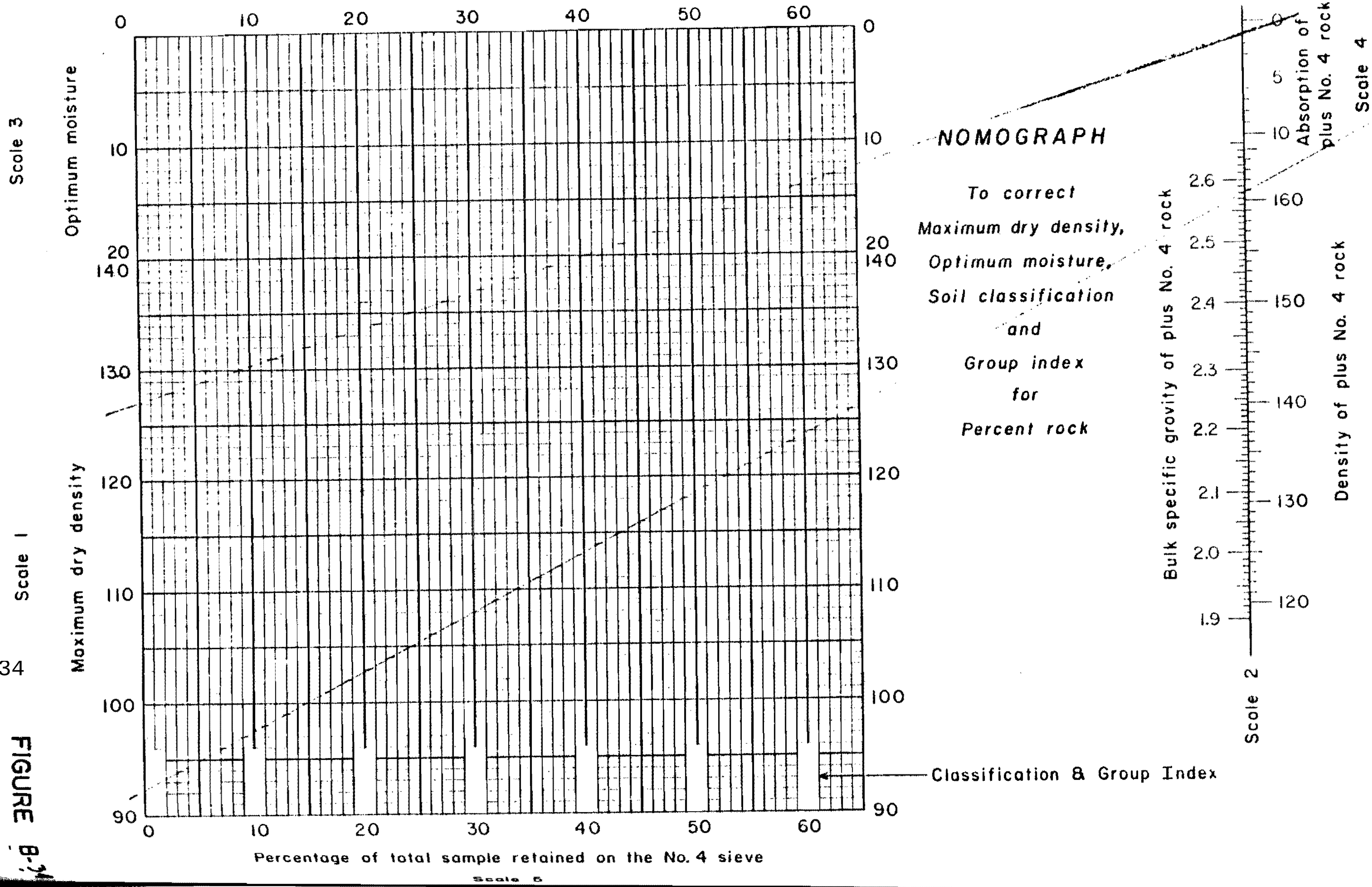


FIGURE B-33

DIVISION OF HIGHWAYS
STATE OF COLORADO
DOH Form No. 548
Revised: August 1970

Dry Den = 92.3 P.C.F. Without rock.
based on 96.7 D.D. with Rock & 29.8%
Field Moisture

Project #5L
Station
Curve No.



B-34

FIGURE B-34

DIVISION OF HIGHWAYS
STATE OF COLORADO
DOH Form No. 548
Revised: August 1970

D.D. = 89.0 P.C.F. without Rock
based on 99.3 D.D. with Rock
& 20.8 % Moisture

Project ....
Station ....
Curve No. #6L

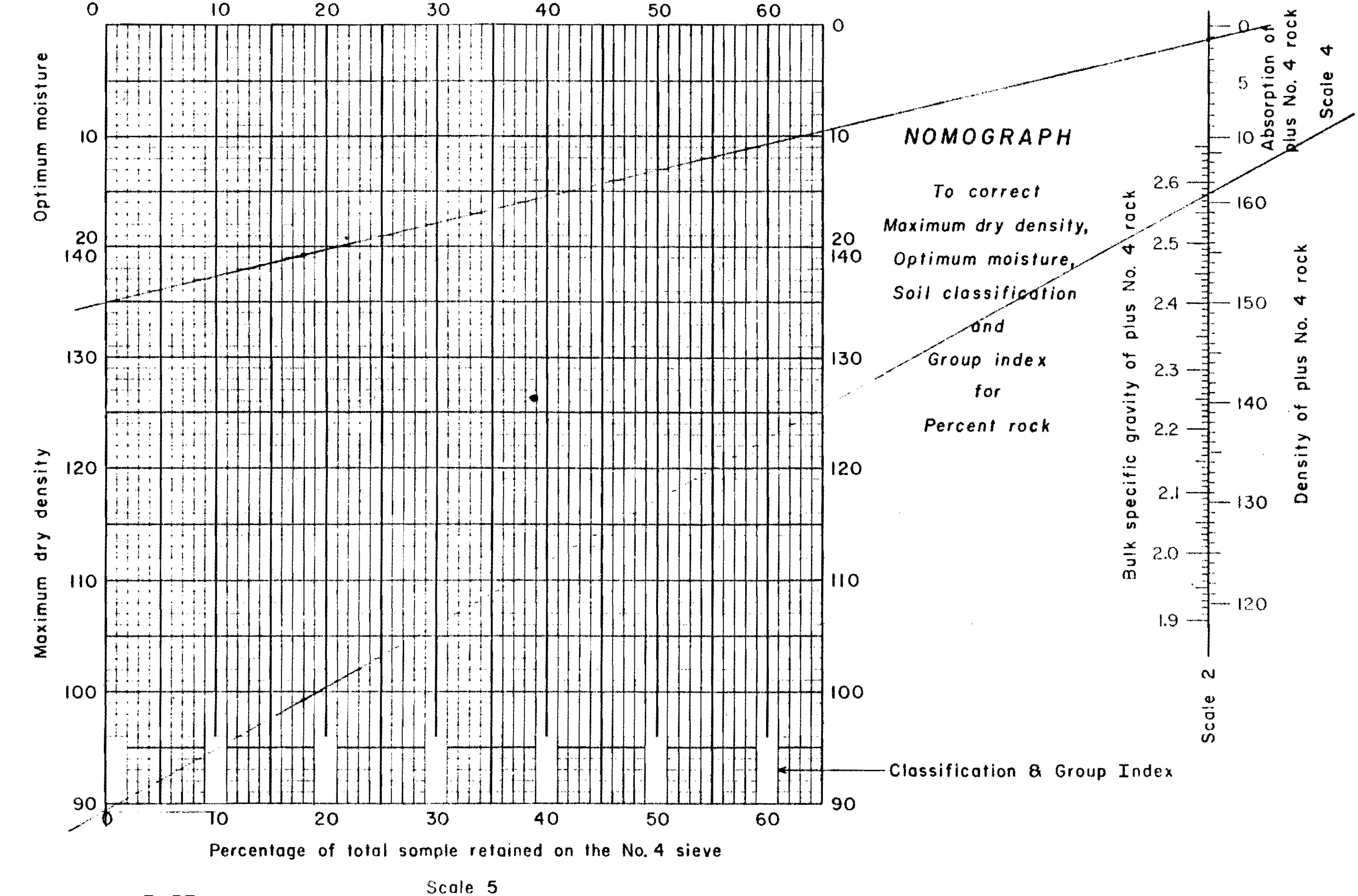


FIGURE B-35

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
Materials Division
Form DOH 161
July 1967

TRIAXIAL DATA SHEET

Sample No. 2L
Depth 5' 7"
Lab. No. 789-82
Proving Ring Factor

Project No. Div. of Water Resources
Location Lawn Lake Dam
Structure
Date 9/3/82
Tested By

Height of Specimen .... h = 6.320 in.

Diameter of Specimen .... d = 2.850 in.

Area of Specimen .... $A_0 = .7854d^2$ = 6.379 in.^{2}

Volume of Specimen .... $V_0 = A_0 h$ = 40.318 in.^{3}

Volume of Specimen ÷ 1728 .... V_e = .0234 ft.^{3}

Wt. Sample Wet + Tare .... = gms.

Tare .... = gms.

Wt. Sample Wet .... = 1083.4 gms.

Wt. Sample Wet ÷ 453.6 .... = 2.39 lbs.

Wt. Dry Sample W_s .... = 924.8 gms.

Wt. of Water W_w .... = 158.6 gms.

$w = W_w / W_s$ .... = 17.15 %

In Place Density = Wet Wt./V_0 .... = 102.1 $\frac{lbs.}{ft.^3}$

Dry Density = I.D./1 + w .... = 87.1 $\frac{lbs.}{ft.^3}$

Specific Gravity .... = 2.57

$V_w = W_w \times 3.534 \times 10^{-5}$ .... = .0056 ft.^{3}

$V_s = \frac{W_s}{S.G.} \times 3.534 \times 10^{-5}$ .... = .0127 ft.^{3}

$V_v = V_0 - V_s$ .... = .0107 ft.^{3}

Degree of Saturation V_w/V_v .... = 52.3 %

Void Ratio $e = V_v/V_s$ .... = .84

Moisture (as rec'd) 25.0

Liquid Limit 40

Plastic Limit 34

Plastic Index 6

Color Brown Sand

Sieve Analysis

Passing	
3"	100
1"	87
3/4"	85
3/8"	81
#4	75
#10	62
#40	35
#60	
#200	20

Classification

Visual Silty Sand

Corps. of Engineers

AASHO

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
Materials Division
Form DOH 161
July 1967

TRIAXIAL DATA SHEET

Sample No. 2L
Depth
Lab. No.
Proving Ring Factor

Project No.
Location
Structure
Date
Tested By

AFTER TEST RUN

Height of Specimen .... h = 6.130 in.

Diameter of Specimen .... d = 2.884 in.

Area of Specimen .... $A_0 = .7854d^2$ = 6.533 in^2

Volume of Specimen .... $V_0 = A_0 h$ = 40.047 in^3

Volume of Specimen ÷ 1728 .... V_0 = .0232 ft^3

Wt. Sample Wet + Tare .... = gms.

Tare .... = gms.

Wt. Sample Wet .... = 1211.2 gms.

Wt. Sample Wet ÷ 453.6 .... = 2.67 lbs.

Wt. Dry Sample W_s .... = 989.5 gms.

Wt. of Water W_w .... = 221.7 gms.

$w = W_w / W_s$ .... = 22.4 %

In Place Density = Wet Wt./V_0 .... = 115.1 lbs./ft^3

Dry Density = I.D./1 + w .... = 94.0 lbs./ft^3

Specific Gravity .... = 2.57

$V_w = W_w \times 3.534 \times 10^{-5}$ .... = .0078 ft^3

$V_s = \frac{W_s}{S.G.} \times 3.534 \times 10^{-5}$ .... = .0136 ft^3

$V_v = V_0 - V_s$ .... = .0096 ft^3

Degree of Saturation V_w/V_v .... = 81.3 %

Void Ratio $e = V_v/V_s$ .... = .71

Moisture (as rec'd)

Liquid Limit

Plastic Limit

Plastic Index

Color

Sieve Analysis

Passing	
3"	
1"	
3/4"	
3/8"	
#4	
#10	
#40	
#60	
#200	

Classification

Visual

Corps. of Engineers

AASHO

FIGURE B-37

MATERIALS BRANCH
WORK SHEET NO. (01031)41

TRIAXIAL DATA SHEET

SAMPLE NO. 2L
LAB NO. 789-82
DEPTH 5' 7"

FIELD SHEET NO. ____
PROJECT Div. of Water Resources
LOCATION Lawn Lake Dam

$$\emptyset = \sin^{-1} \tan \alpha$$

$$C = \frac{a}{\cos \emptyset}$$

WET DENSITY 102.1 PCF
DRY DENSITY 87.1 PCF
MOISTURE 17.15 %
SATURATION 52.3 %
VOIDS RATIO .84

X REMOLDED SAMPLE
__ UNDISTURBED SAMPLE
__ UNCONSOLIDATED UNDRAINED (UU)
__ CONSOLIDATED UNDRAINED (CU)
X CONSOLIDATED DRAINED (CD)

TEST RESULTS

αT = ____ ^aT = ____ αE = 17.5 ^aE = 1.3

TOTAL STRESSES: C = ____ PSI; Ø = ____ °
EFFECTIVE STRESSES: C = 1.4 PSI; Ø = 18.4 °

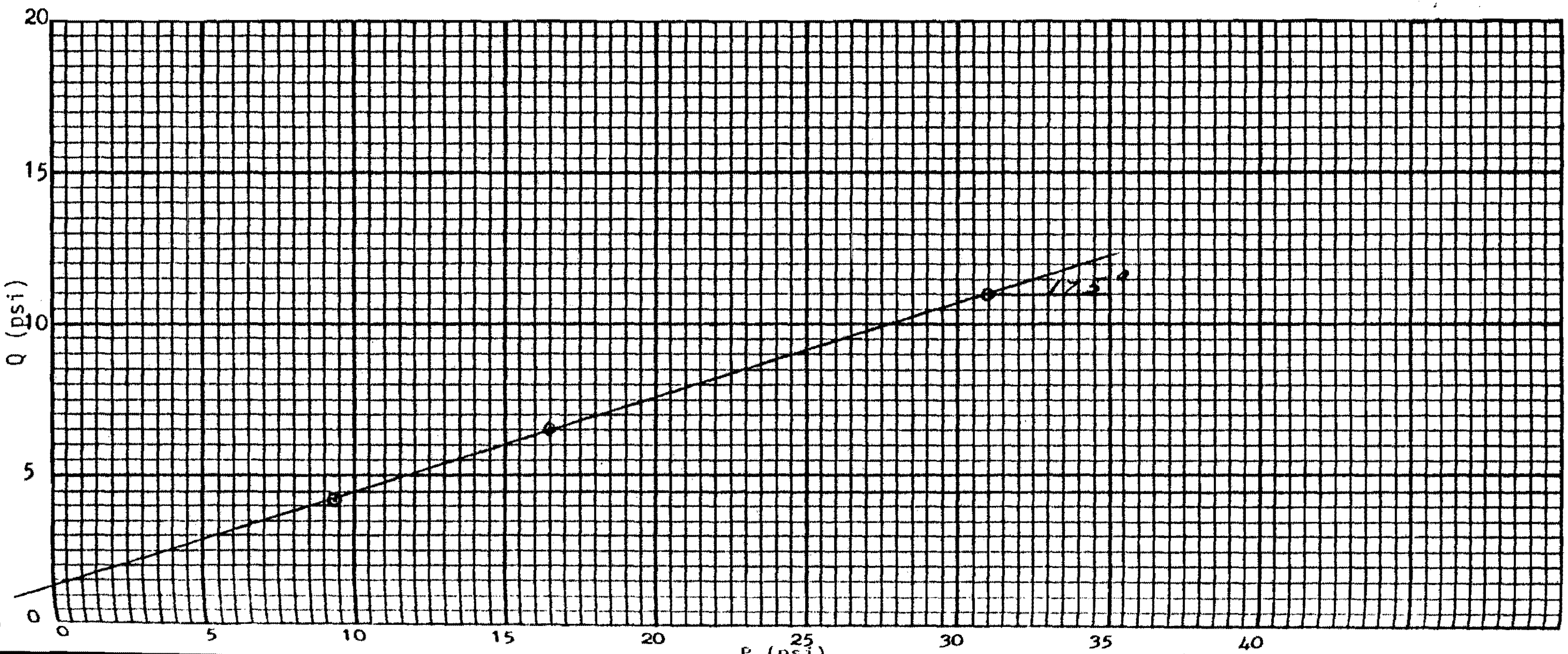


FIGURE B-38

DIVISION OF WATER RESOURCES
OFFICE OF THE STATE ENGINEER

BY Jim Norfleet DATE Oct 28, 1982

TITLE Sample No. 2L SHEET 1 OF 2

STAGE I

Area = 6.379 in²
Length = 6.320 in

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Strain %
1	0	0	0	0
2	7	1.1	0.002	0.03
3	9	1.4	0.004	0.06
4	10.5	1.6	0.005	0.08
5	12.0	1.9	0.006	0.09
6	13.5	2.1	0.007	0.11
7	14.5	2.3	0.008	0.13
8	16.0	2.5	0.010	0.16
9	26.0	4.1	0.017	0.27
10	36.0	5.6	0.027	0.43
11	41.0	6.4	0.032	0.51
12	45.0	7.1	0.039	0.62
13	47.5	7.4	0.045	0.71
14	50.0	7.8	0.051	0.81
15	51.0	8.0	0.058	0.92
16	53.0	8.3	0.062	0.98

STAGE II

Area = 6.379 in²
Length = 6.258 in

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Strain %
1	0	0	0	0
2	21.5	3.4	0.007	0.11
3	40.0	6.3	0.013	0.21
4	52.5	8.2	0.020	0.32
5	60.0	9.4	0.026	0.42
6	65.0	10.2	0.033	0.53
7	69.0	10.8	0.039	0.62
8	72.0	11.3	0.045	0.72
9	75.0	11.8	0.052	0.83
10	77.5	12.1	0.058	0.93
11	79.0	12.4	0.065	1.04
12	84.0	13.2	0.072	1.15

FIGURE B-39

BY: Jim Norfleet DATE: Oct 28 1982

TITLE: Sample No. 2L SHEET 2 OF 2

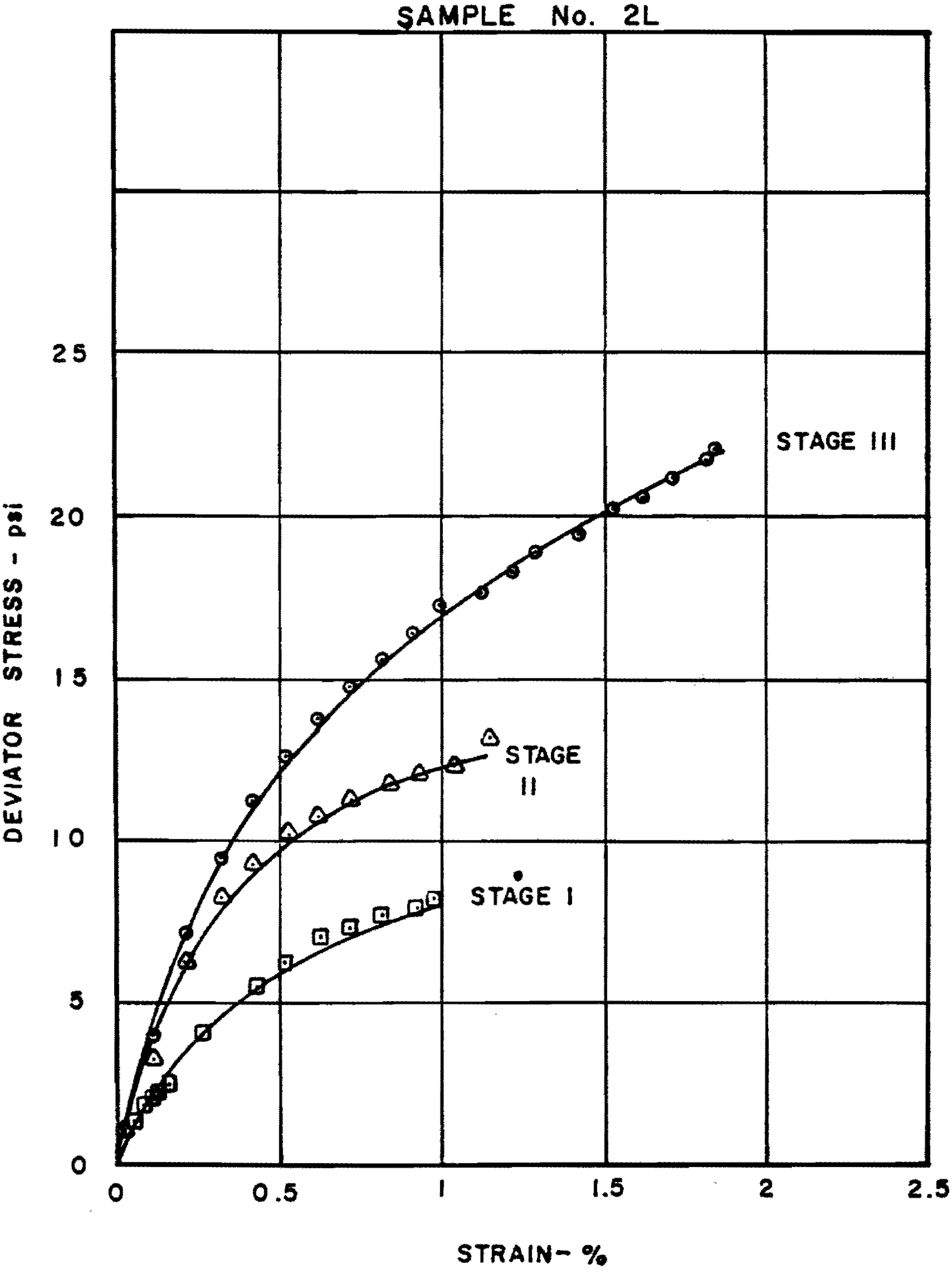
STAGE III

Area = 6.379 in^2
Length = 6.186

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Strain (%)
1	0	0	0	0
2	25.5	4.0	0.007	0.11
3	46.0	7.2	0.013	0.21
4	61.0	9.6	0.020	0.32
5	72.0	11.3	0.026	0.42
6	81.0	12.7	0.032	0.52
7	88.0	13.8	0.038	0.61
8	94.5	14.8	0.044	0.71
9	99.5	15.6	0.050	0.81
10	104.5	16.4	0.056	0.91
11	109.5	17.2	0.062	1.00
12	113.5	17.8	0.069	1.12
13	117.5	18.4	0.075	1.21
14	121.0	19.0	0.080	1.29
15	125.0	19.6	0.088	1.42
16	129.0	20.2	0.094	1.52
17	132.0	20.7	0.100	1.62
18	135.0	21.2	0.106	1.71
19	139.0	21.8	0.112	1.81
20	141.0	22.1	0.114	1.84

There are two (2) figure B-39s because there are three (3) stages.

FIGURE B-39



SAMPLE No. 2L
25
20
15
10
5
0
DEVIATOR STRESS - psi
0
0.5
1
1.5
2
2.5
STRAIN- %
STAGE III
STAGE II
STAGE I

FIGURE A-4

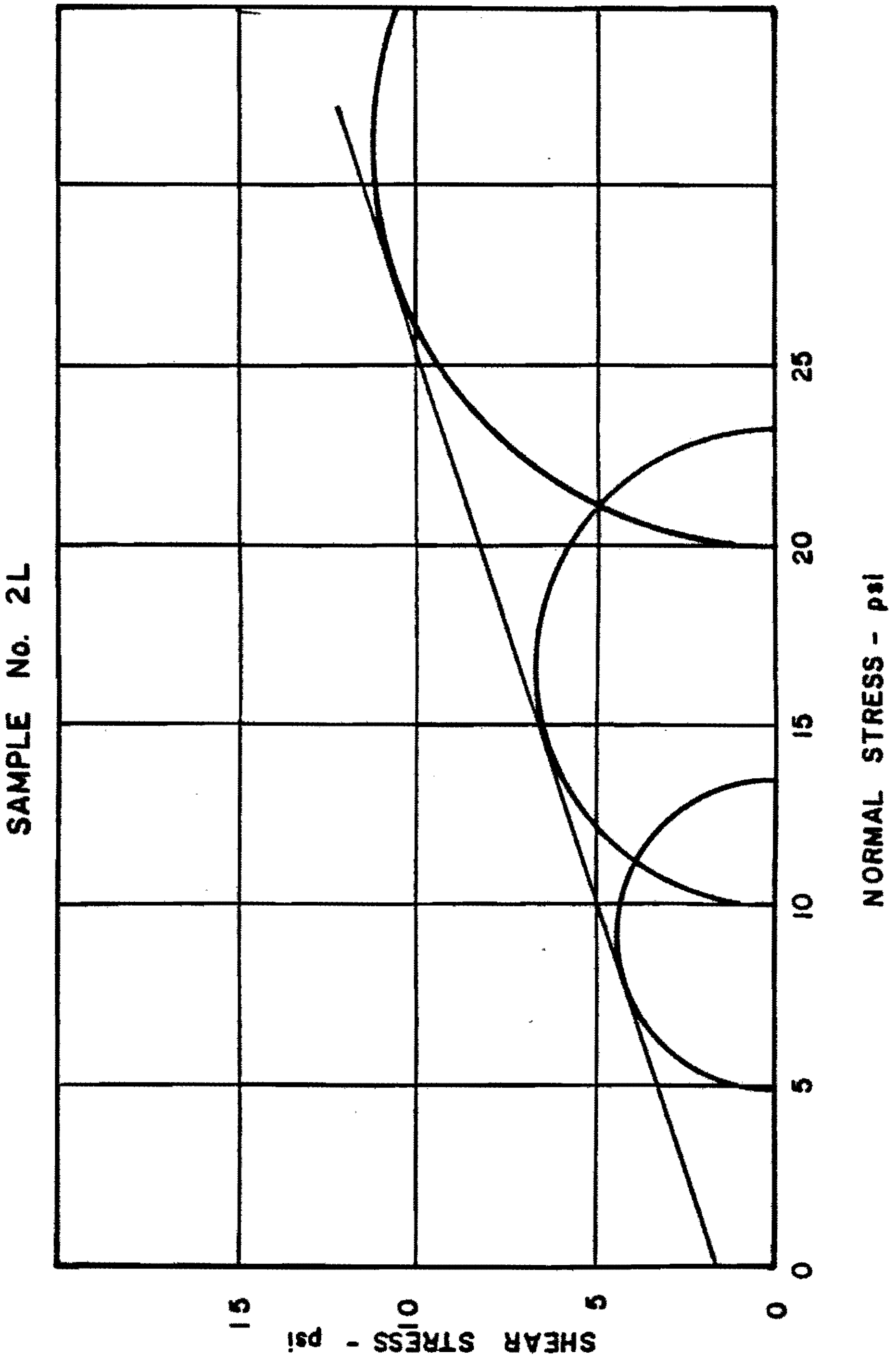


FIGURE B-41

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
Materials Division
Form DOH 161
July 1967

TRIAXIAL DATA SHEET

Sample No. 5L
Depth 9' 9"
Lab. No. 792-82
Proving Ring Factor

Project No. Div. of Water Resources
Location Lawn Lake Dam
Structure
Date 9/3/82
Tested By

Height of Specimen .... h = 6.350 in.

Diameter of Specimen .... d = 2.850 in.

Area of Specimen .... $A_0 = .7854d^2$ = 6.379 in^2

Volume of Specimen .... $V_0 = A_0h$ = 40.507 in^3

Volume of Specimen ÷ 1728 .... V_o = .0234 ft^3

Wt. Sample Wet + Tare .... = gms.

Tare .... = gms.

Wt. Sample Wet .... = 1222.8 gms.

Wt. Sample Wet ÷ 453.6 .... = 2.70 lbs.

Wt. Dry Sample W_s .... = 942.1 gms.

Wt. of Water W_w .... = 280.7 gms.

$w = W_w/W_s$ .... = 29.8 %

In Place Density = Wet Wt./V_0 .... = 115.4 $\frac{lbs.}{ft^3}$

Dry Density = I.D./1 + w .... = 88.9 $\frac{lbs.}{ft^3}$

Specific Gravity .... = 2.54

$V_w = W_w \times 3.534 \times 10^{-5}$ .... = .0099 ft^3

$V_s = \frac{W_s}{S.G.} \times 3.534 \times 10^{-5}$ .... = .0131 ft^3

$V_v = V_0 - V_s$ .... = .0103 ft^3

Degree of Saturation V_w/V_v .... = 96.1 %

Void Ratio $e = V_v/V_s$ .... = .79

Moisture (as rec'd) 29.8

Liquid Limit 56

Plastic Limit 43

Plastic Index 13

Color Black Silty Sand

Sieve Analysis

Passing	
3"	100
1"	99
3/4"	97
3/8"	94
#4	90
#10	76
#40	51
#60	
#200	26

Classification

Visual Black Silty Sand

Corps. of Engineers

AASHO

FIGURE B-42

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
Materials Division
Form DOH 161
July 1967

TRIAXIAL DATA SHEET

Sample No. 5L
Depth
Lab. No.
Proving Ring Factor

Project No.
Location
Structure
Date
Tested By

AFTER TEST RUN

Height of Specimen	$h =$	5.880	in.
Diameter of Specimen	$d =$	2.885	in.
Area of Specimen	$A_0 = .7854d^2 =$	6.537	in^2
Volume of Specimen	$V_0 = A_0 h =$	38.438	in^3
Volume of Specimen ÷ 1728	$V_0 =$	.0222	ft^3
Wt. Sample Wet + Tare	=		gms.
Tare	=		gms.
Wt. Sample Wet	=	1204.8	gms.
Wt. Sample Wet ÷ 453.6	=	2.66	lbs.
Wt. Dry Sample W_s	=	955.1	gms.
Wt. of Water W_w	=	249.7	gms.
$w = W_w / W_s$	=	26.14	%
In Place Density = Wet Wt./V_0	=	119.6	lbs./ft^3
Dry Density = I.D./1 + w	=	94.8	lbs./ft^3
Specific Gravity	=	2.54	
$V_w = W_w \times 3.534 \times 10^{-5}$	=	.0088	ft^3
$V_s = \frac{W_s}{S.G.} \times 3.534 \times 10^{-5}$	=	.0133	ft^3
$V_v = V_0 - V_s$	=	.0089	ft^3
Degree of Saturation V_w/V_v	=	98.9	%
Void Ratio $e = V_v/V_s$	=	.67	

Moisture (as rec'd)

Liquid Limit

Plastic Limit

Plastic Index

Color

Sieve Analysis

Passing	
3"	
1"	
3/4"	
3/8"	
#4	
#10	
#40	
#60	
#200	

Classification

Visual

Corps. of Engineers

AASHO

FIGURE B-43

MATERIALS BRANCH
WORK SHEET NO. (01031)41

TRIAXIAL DATA SHEET

SAMPLE NO. 5 L
LAB NO. 792-82
DEPTH 9' 9"

FIELD SHEET NO. ______
PROJECT Div. of Water Resources
LOCATION Lawn Lake Dam

$\emptyset = \sin^{-1} \tan \alpha$

$C = \frac{a}{\cos \emptyset}$

WET DENSITY 115.4 PCF
DRY DENSITY 88.9 PCF
MOISTURE 29.8 %
SATURATION 96.1 %
VOIDS RATIO .79

X REMOLDED SAMPLE
__ UNDISTURBED SAMPLE
__ UNCONSOLIDATED UNDRAINED (UU)
X CONSOLIDATED UNDRAINED (CU)
__ CONSOLIDATED DRAINED (CD)

TEST RESULTS

αT = 20.7 a_T = 1.2 αE = 32.3 a_E = 0.0

TOTAL STRESSES: C = 1.3 PSI; Ø = 22.2° EFFECTIVE STRESSES: C = 0.0 PSI; Ø = 39.2°

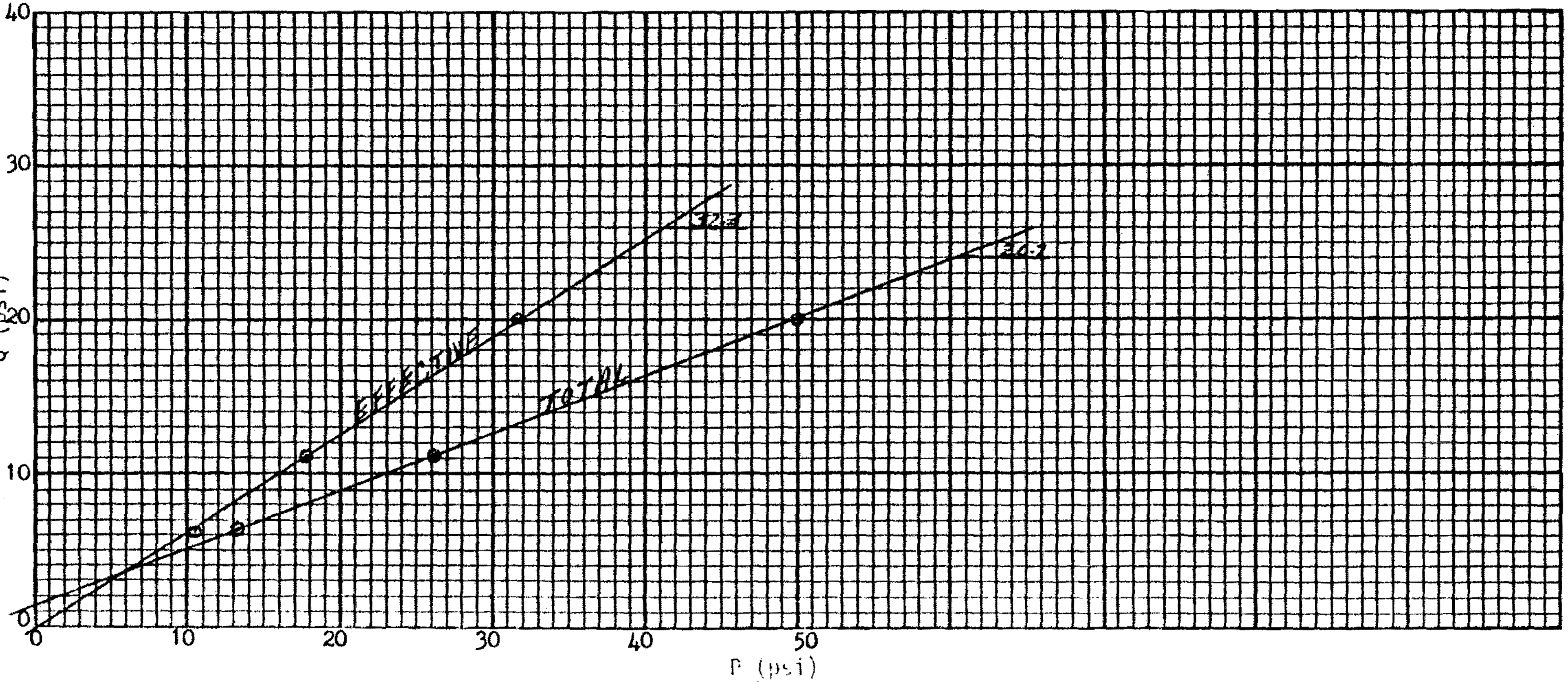


FIGURE B-44

DIVISION OF WATER RESOURCES
OFFICE OF THE STATE ENGINEER

BY Jim Norfleet   DATE Oct 28, 1982

TITLE Sample No. 5L   SHEET 1 OF 1

Stage I

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Axial Strain (%)	Pore Pressure (psi)	
1	0	0	0	0	0	Area = 6.379 in
2	24	3.8	0.013	0.20	0.8	Length = 6.3
3	40	6.3	0.022	0.35	1.6	
4	50.5	7.9	0.030	0.47	2.0	
5	57.5	9.0	0.039	0.60	2.2	
6	64.0	10.0	0.046	0.72	2.4	
7	69.0	10.8	0.054	0.85	2.6	
8	74.0	11.6	0.062	0.98	2.6	
9	78.0	12.2	0.069	1.09	2.6	

Stage II

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Axial Strain (%)	Pore Pressure (psi)	
1	0	0	0	0	0	
2	40	6.3	0.013	0.21	2.0	Length = 6.2
3	69	10.8	0.025	0.40	4.0	
4	88	13.8	0.038	0.60	5.6	
5	100	15.7	0.049	0.78	6.4	
6	108	16.9	0.062	0.99	7.0	
7	115	18.0	0.074	1.18	7.2	
8	121	19.0	0.086	1.37	7.4	
9	126.5	19.8	0.097	1.54	7.6	
10	132.0	20.7	0.109	1.74	7.6	
11	140.0	21.9	0.125	1.99	7.6	

Stage III

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Axial Strain (%)	Pore Pressure (psi)	
1	0	0	0	0	0	
2	47	7.4	0.013	0.21	2.4	Length = 6.
3	90	14.1	0.027	0.44	5.6	
4	122	19.1	0.037	0.60	8.4	
5	147.5	23.1	0.049	0.80	10.8	
6	172.5	27.0	0.065	1.06	13.0	
7	193.5	30.3	0.085	1.38	14.8	
8	207.0	32.5	0.101	1.64	16.0	
9	217.0	34.0	0.116	1.88	16.4	
10	227.0	35.6	0.132	2.14	17.0	
11	235.0	36.8	0.147	2.39	17.4	
12	245.5	38.5	0.167	2.71	17.4	
13	255.0	40.0	0.187	3.04	17.4	
14	263.5	41.3	0.203	3.30	17.4	

FIGURE R-45

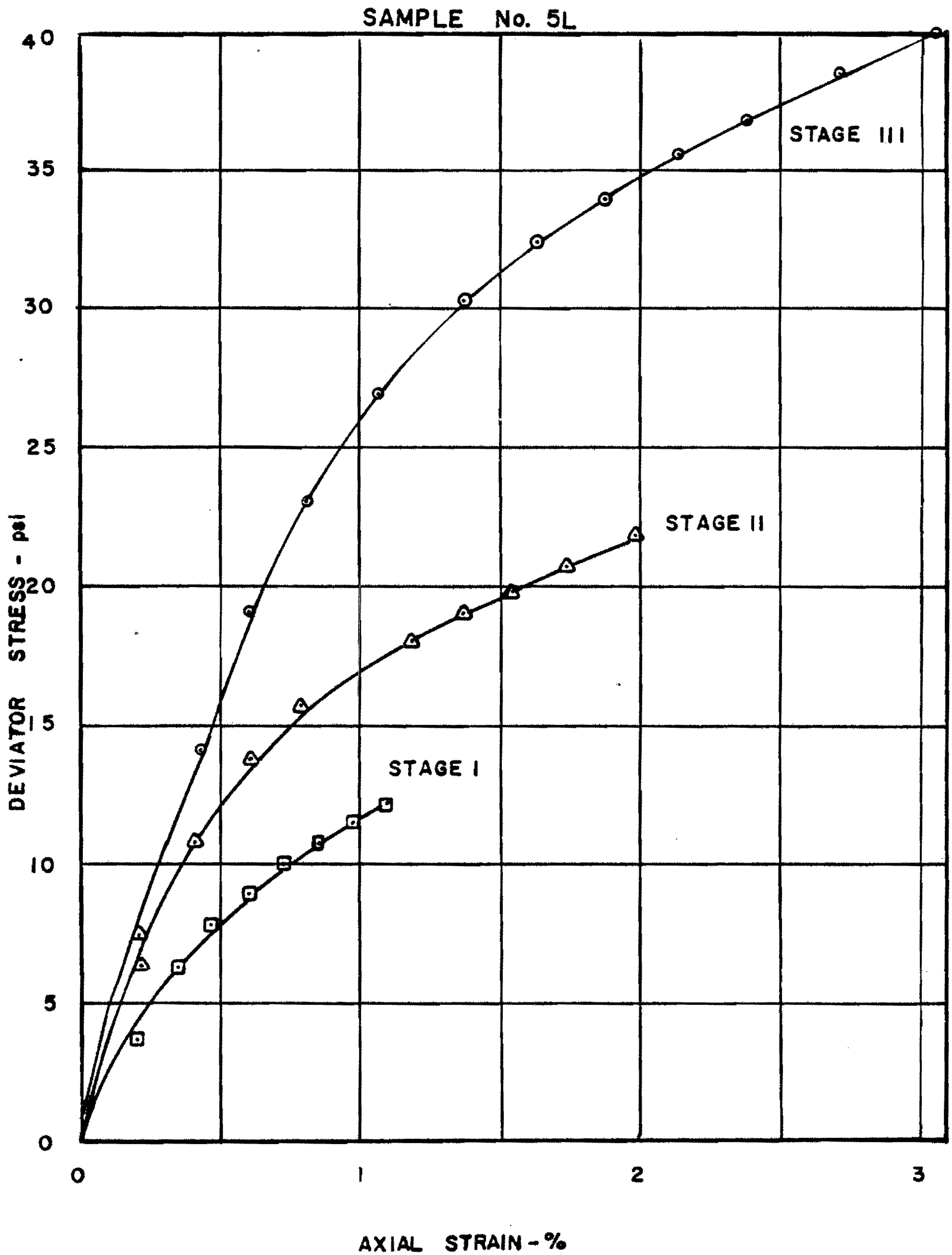

SAMPLE No. 5L
STAGE III
STAGE II
STAGE I
DEVIATOR STRESS - psi
AXIAL STRAIN - %
40
35
30
25
20
15
10
5
0
0
1
2
3

FIGURE B-46

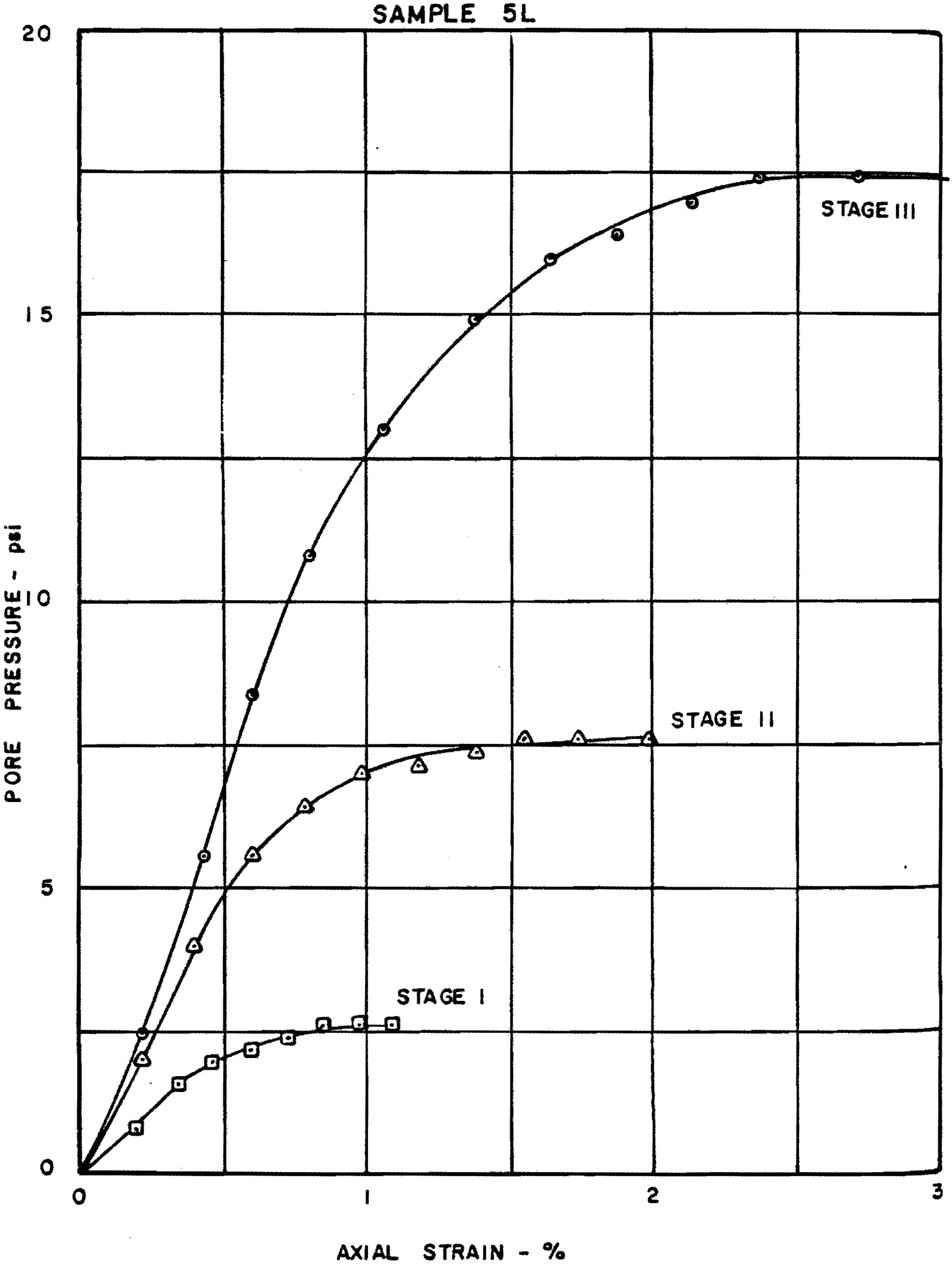

SAMPLE 5L
20
15
10
5
0
PORE PRESSURE - psi
STAGE III
STAGE II
STAGE I
0
1
2
3
AXIAL STRAIN - %

FIGURE B-47

SAMPLE No. 5L
EFFECTIVE STRESS

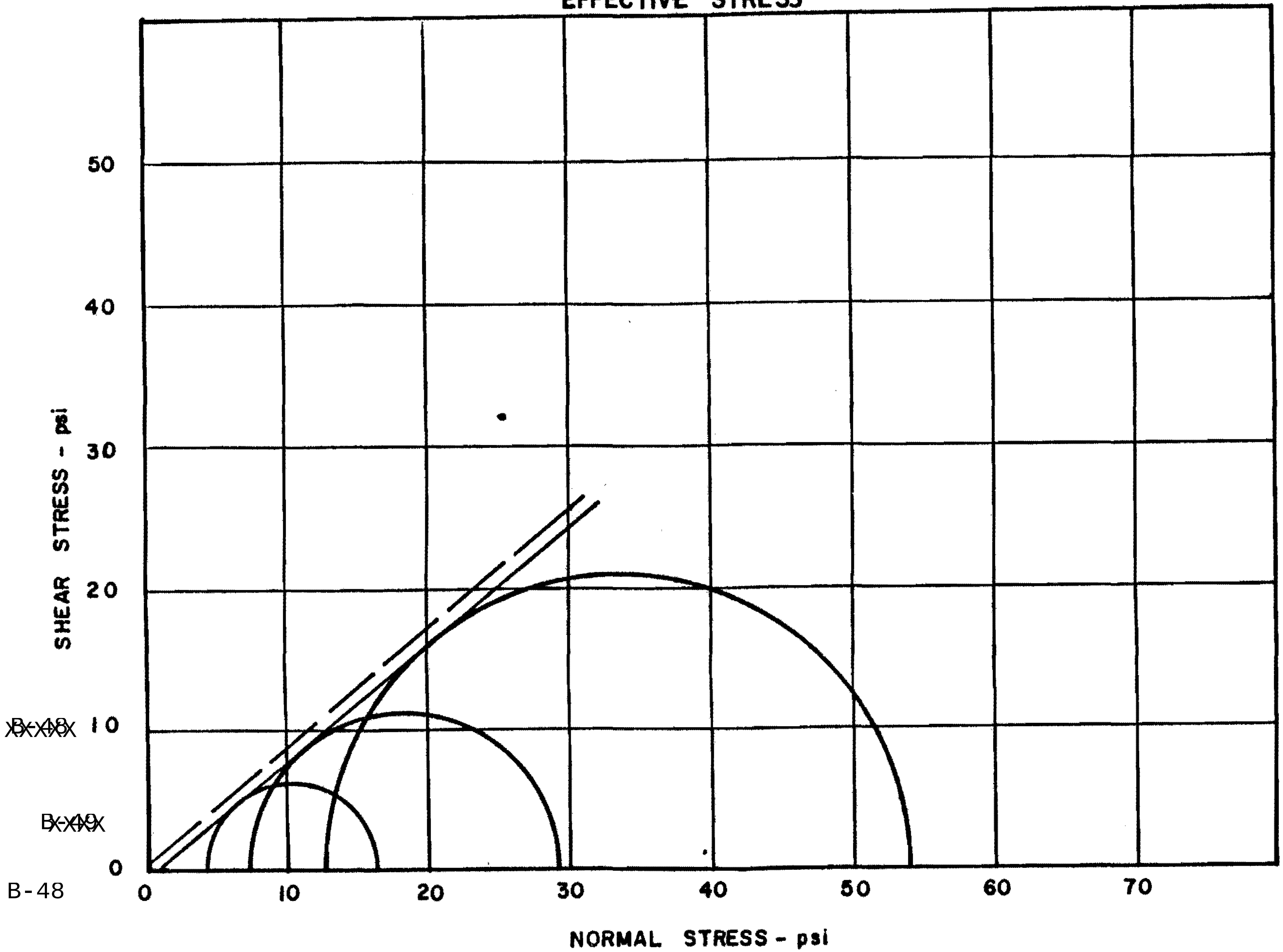
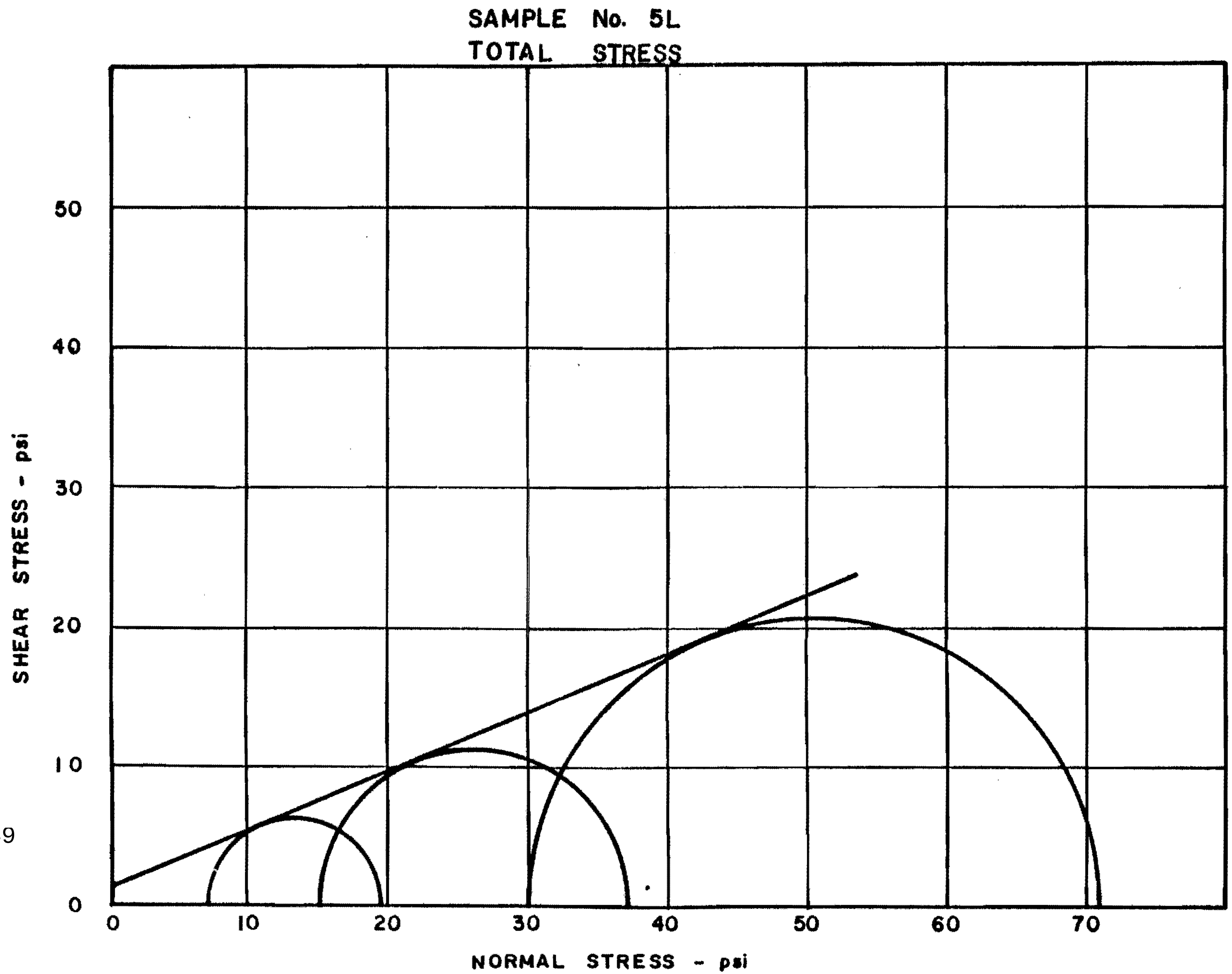


FIGURE B-4



B-49

FIGURE B-49

DEPARTMENT OF [illegible]S
STATE OF COLOR[illegible]
Materials Division
Form DOH 161
July 1967

TRIAXIAL DATA SHEET

Sample No. 6 L
Depth 11' 0"
Lab. No. 793-82
Proving Ring Factor

Project No. Div. of Water Resources
Location Lawn Lake Dam
Structure
Date 9/3/82
Tested By

Height of Specimen .... h = 5.500 in.

Diameter of Specimen .... d = 2.850 in.

Area of Specimen .... $A_o = .7854d^2$ = 6.379 in^2

Volume of Specimen .... $V_o = A_o h$ = 35.085 in^3

Volume of Specimen ÷ 1728 .... V_o = .0203 ft^3

Wt. Sample Wet + Tare .... = gms.

Tare .... = gms.

Wt. Sample Wet .... = 915.0 gms.

Wt. Sample Wet ÷ 453.6 .... = 2.02 lbs.

Wt. Dry Sample W_s .... = 820.0 gms.

Wt. of Water W_w .... = 95.0 gms.

$w = W_w / W_s$ .... = 11.6 %

In Place Density = Wet Wt./V_o .... = 99.5 $lbs./ft^3$

Dry Density = I.D./1 + w .... = 89.2 $lbs./ft^3$

Specific Gravity .... = 2.54

$V_w = W_w \times 3.534 \times 10^{-5}$ .... = .0034 ft^3

$V_s = \frac{W_s}{S.G.} \times 3.534 \times 10^{-5}$ .... = .0114 ft^3

$V_v = V_o - V_s$ .... = .0089 ft^3

Degree of Saturation V_w/V_v .... = 38.2 %

Void Ratio $e = V_v/V_s$ .... = .78

Moisture (as rec'd) 10.5

Liquid Limit NV

Plastic Limit NP

Plastic Index NP

Color Brown

Sieve Analysis

Passing	
3"	100
1"	94
3/4"	92
3/8"	88
#4	80
#10	70
#40	42
#60	
#200	7

Classification

Visual Brown Sand

Corps. of Engineers

AASHO

FIGURE B-50

DEPARTMENT OF H...
STATE OF COLORADO
Materials Division
Form DOH 161
July 1967

TRIAXIAL DATA SHEET

Sample No. 6 L
Depth
Lab. No.
Proving Ring Factor

Project No.
Location
Structure
Date
Tested By

AFTER TEST RUN

Height of Specimen	$h =$	5.064	in.
Diameter of Specimen	$d =$	2.970	in.
Area of Specimen	$A_0 = .7854d^2 =$	6.929	in^2
Volume of Specimen	$V_0 = A_0 h =$	35.090	in^3
Volume of Specimen ÷ 1728	$V_0 =$	.0203	ft^3
Wt. Sample Wet + Tare	=		gms.
Tare	=		gms.
Wt. Sample Wet	=	968.6	gms.
Wt. Sample Wet ÷ 453.6	=	2.14	lbs.
Wt. Dry Sample W_s	=	814.6	gms.
Wt. of Water W_w	=	154.0	gms.
$w = W_w/W_s$	=	18.9	%
In Place Density = Wet Wt./V_0	=	105.4	lbs./ft^3
Dry Density = I.D./1 + w	=	88.7	lbs./ft^3
Specific Gravity	=	2.54	
$V_w = W_w \times 3.534 \times 10^{-5}$	=	.0054	ft^3
$V_s = \frac{W_s}{S.G.} \times 3.534 \times 10^{-5}$	=	.0113	ft^3
$V_v = V_0 - V_s$	=	.0090	ft^3
Degree of Saturation V_w/V_v	=	60.0	%
Void Ratio $e = V_v/V_s$	=	.80	

Moisture (as rec'd)
Liquid Limit
Plastic Limit
Plastic Index
Color

Sieve Analysis

Passing 3"
1"
3/4"
3/8"
#4
#10
#40
#60
#200

Classification

Visual
Corps. of Engineers
AASHO

WORK SHEET NO. (01031)41

TRIAXIAL DATA SHEET

SAMPLE NO. 6L

LAB NO. 793-82

DEPTH 11' 0"

FIELD SHEET NO. ____

PROJECT Div. of Water Resources

LOCATION Lawn Lake Dam

$\emptyset = SIN^{-1} TAN\alpha$

$C = \frac{a}{COS\ \emptyset}$

WET DENSITY 99.5 PCF

DRY DENSITY 89.2 PCF

MOISTURE 11.6 %

SATURATION 38.2 %

VOIDS RATIO .78

X REMOLDED SAMPLE

__ UNDISTURBED SAMPLE

__ UNCONSOLIDATED UNDRAINED (UU)

__ CONSOLIDATED UNDRAINED (CU)

X CONSOLIDATED DRAINED (CD)

TEST RESULTS

αT = ____ a_T = ____ αE = 28.0 a_E = 0.0

TOTAL STRESSES: C = ____ PSI; Ø = ____ °

EFFECTIVE STRESSES: C = 0.0 PSI; Ø = 32.1 °

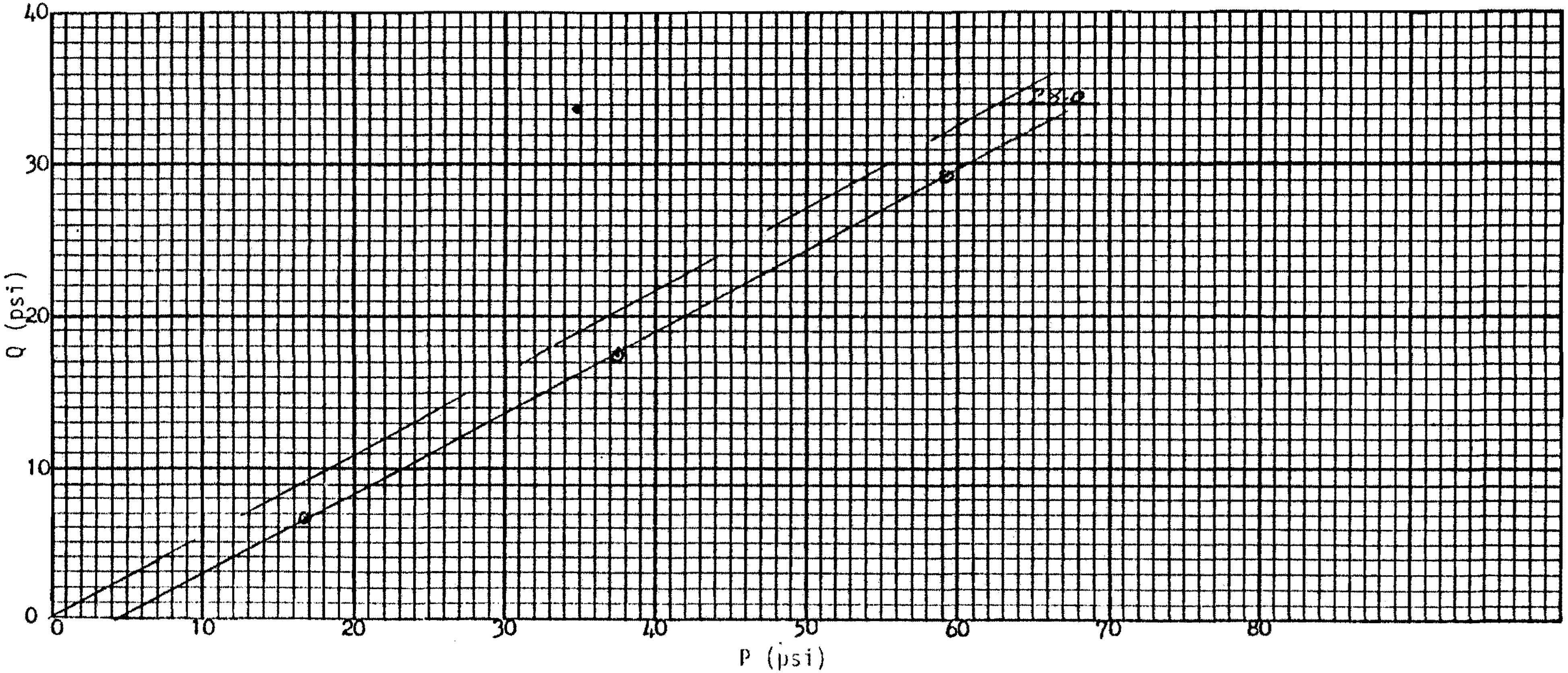


FIGURE B-52

DIVISION OF WATER RESOURCES
OFFICE OF THE STATE ENGINEER

BY: Jim Norfleet | DATE: Oct 23, 1983

TITLE: Sample No. 6L | SHEET 1 OF 1

Stage I

Area = 6.379 in²
Length = 5.5 in

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Axial Strain (%)
1	0	0	0	0
2	8.5	1.3	0.008	0.15
3	22.0	3.4	0.018	0.33
4	34.0	5.3	0.027	0.[illegible]
5	45.0	7.1	0.037	0.[illegible]
6	54.0	8.5	0.046	0.8[illegible]
7	61.5	9.6	0.056	[illegible]
8	68.0	10.7	0.065	1.18
9	73.0	11.4	0.074	[illegible]
10	78.0	12.2	0.084	1.53
11	82.5	12.9	0.096	1.75
12	86.5	13.6	0.110	2.00

Stage II

Length = 5.39 in

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Axial Strain (%)
1	0	0	0	0
2	86	13.5	0.025	0.46
3	133.5	20.9	0.050	0.93
4	151.5	23.7	0.066	1.22
5	171.5	26.9	0.088	1.63
6	188.0	29.5	0.109	2.02
7	200.0	31.4	0.128	2.37
8	209.0	32.8	0.144	2.67
9	216.5	33.9	0.159	2.95
10	224.0	35.1	0.174	3.23
11	229.0	35.9	0.186	3.45

Stage III

Length = [illegible]

Point No.	Deviator (lbs)	Stress (psi)	Deformation (in)	Axial Strain (%)
1	0	0	0	0
2	98.0	15.4	0.020	0.37
3	191.0	29.9	0.038	0.73
4	255.0	40.0	0.047	0.91
5	291.5	45.6	0.076	1.47
6	311.5	48.8	0.092	1.77
7	330.5	51.8	0.110	2.12
8	346.5	54.3	0.128	2.47
9	360.0	56.4	0.147	2.84
10	372.0	58.3	0.166	3.20
11	385.0	60.4	0.188	3.53
12	396.0	[illegible]	0.210	4.05

FIGURE B-53

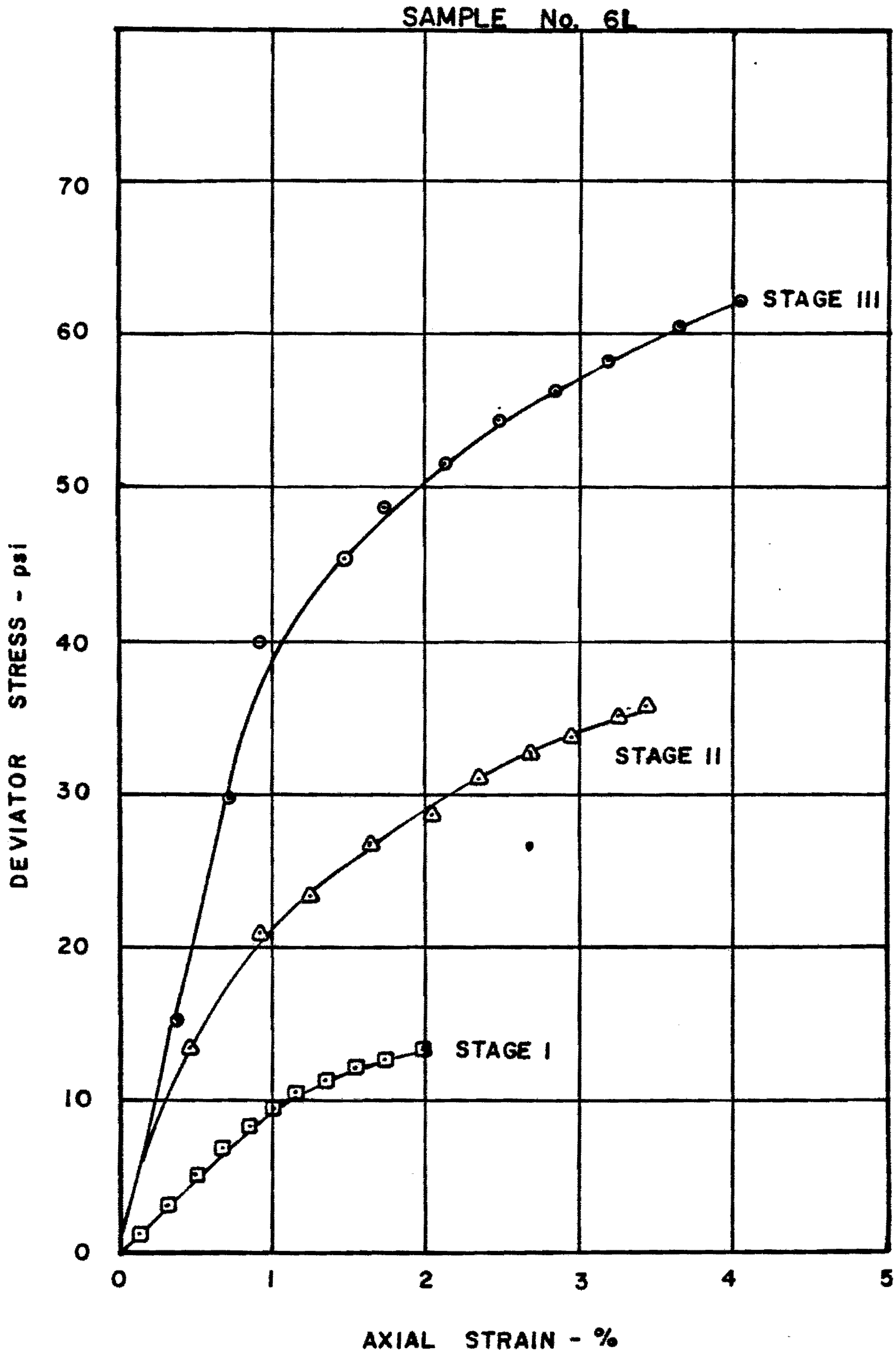

SAMPLE No. 6L
DEVIATOR STRESS - psi
AXIAL STRAIN - %
STAGE III
STAGE II
STAGE I
0
10
20
30
40
50
60
70
0
1
2
3
4
5

FIGURE B-54

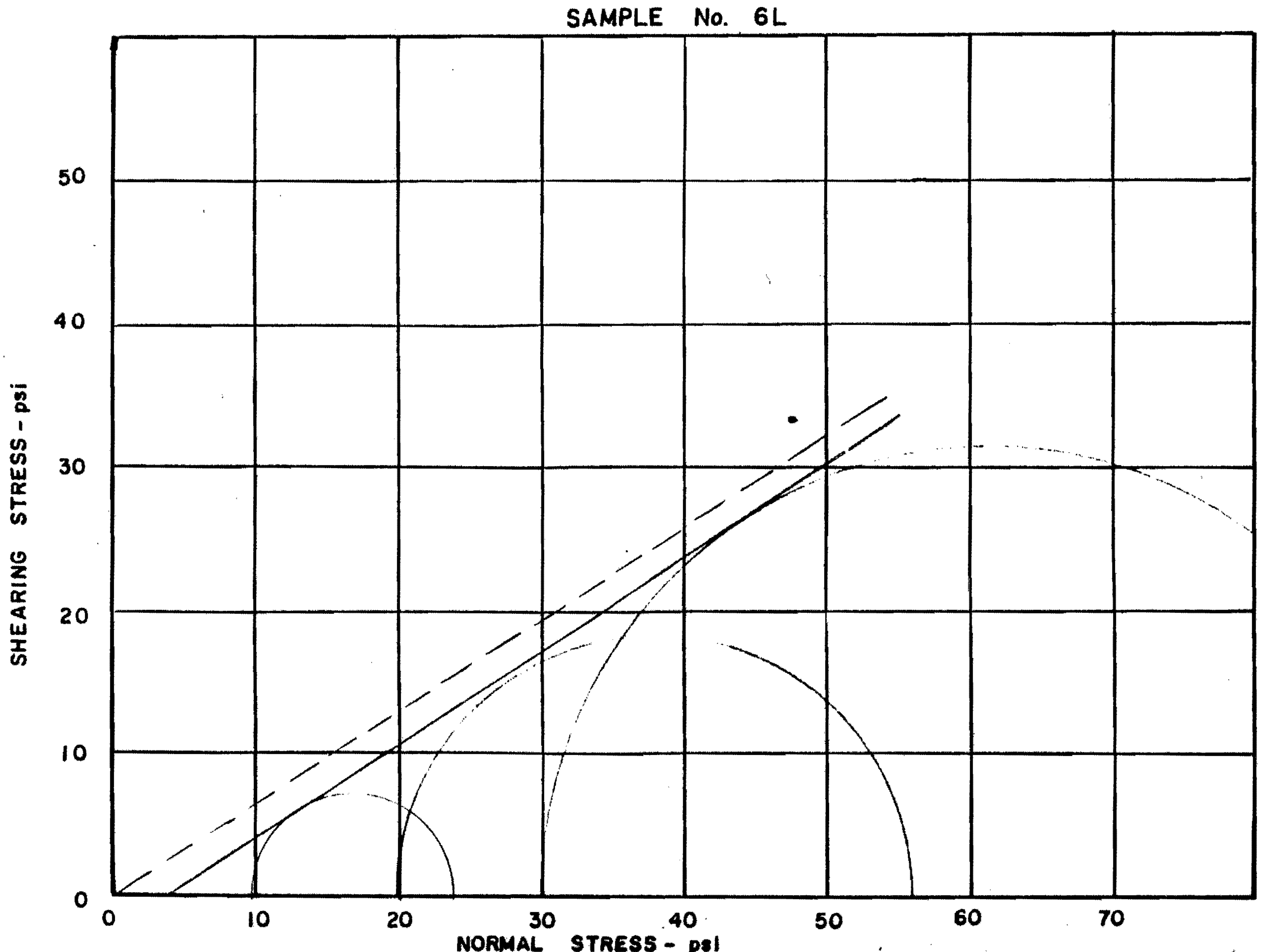

SAMPLE No. 6L
SHEARING STRESS - psi
0
10
20
30
40
50
NORMAL STRESS - psi
0
10
20
30
40
50
60
70

FIGURE B-55

LAWN LAKE DAM
FAILURE INVESTIGATION
SLOPE STABILITY ANALYSIS

APPENDIX C

by

Steve Spann, Supervisor, Water Resources Engineer
Louis DeGrave, Senior, Water Resources Engineer
James Norfleet, Senior, Water Resources Engineer

LAWN LAKE DAM
FAILURE INVESTIGATION
SLOPE STABILITY ANALYSIS

APPENDIX C

THE MODEL

Transverse Cross-Sections of the dam were developed from data provided by the U.S. Geologic Survey. A drawing of the right and left side sections are presented in Figures C-1 and C-2. A third drawing was developed from the left and right side cross-sections to depict the configuration at the maximum section. The length of the outlet was obtained from a report by Mr. Jaycox dated September 22, 1903. Old photos were used to assist in developing the maximum section. The drawing of the assumed maximum section at the outlet is shown in Figure C-3.

The stratigraphy of the embankment stability model was constructed from geological mapping of the adjacent sections performed on July 22, 1982 (See Figure A-1). Similar materials were grouped together and the same shear strength was assigned to layers having similar properties. The backfill around the outlet was assumed to be the same native material as the first layer above the glacial moraine. A list of the assigned properties for the model are presented in Table C-1.

THE STUDY

The Bishop method was used to determine the stability of the Lawn Lake Dam. The computer program uses an approximate form of the limiting equalibrium approach developed by Bishop. The program estimates the factor of safety for a circular arc slope failure of an embankment. The factor of safety is defined as the ratio of the resisting forces to the driving forces. Hence, a factor of safety greater than 1.0 implies a stable structure. A factor of safety equal to 1.0 implies a state of balance equalibrium. This program has a search routine which examines numerous failure arcs until the minimum factor of safety is found.

To complete the embankment model previously discussed, a phreatic water surface had to be estimated. It was assumed that the steady state phreatic water surface would be similar to one which develops in a homogeneous dam. While this is not a true representation of the actual phreatic water surface, it is considered adequate for an initial evaluation.

The minimum factor of safety was found to be 0.586 for the first assumed phreatic water surface, as shown on Figure C-4. Because the factor of safety is less than 1.0, the dam would be unstable with a phreatic water surface as depicted.

The first model obviously was not a normal operating condition because it would be unstable. The first reaction was that perhaps the dam did not store water long enough to establish the level of the assumed steady state. The test data, however, indicates the coefficient of permeability for the major portion of the embankment was 0.7 feet per day. Assuming a coefficient of 0.7 feet per day, it was estimated that steady state seepage would develop within a period of 20 days. A review of the storage records compiled by the Division I hydrographers shows the reservoir was full for about 2,000 consecutive days between 1959 and 1965, providing sufficient time to establish steady state seepage. Therefore, other factors which affect the level and extent of the steady state must have been present.

Based on the results of the initial study, we then, assumed that the structure had internal drainage. Internal drainage would cause the phreatic water surface to be lower than first assumed.

The plans, OC-39, showed a rock fill in the downstream portion of the embankment. Photographs taken during the 1979 inspection show the toe of the dam was covered by rockfill around the outlet, but the depth of the rock can only be surmised.

A second study was performed to determine the phreatic water surface which has a minimum factor of safety near 1.0. Results of the second study are shown in Figure C-5 along with the phreatic water surface which produced a minimum factor of safety near 1.0.

Close inspection of photographs No. A-1 and A-5 in the geologic section (Appendix A) of this report, reveal a phreatic water surface nearly equivalent to that shown on Figure C-5. The phreatic water surface shown in the photographs, support the assumption that the toe was drained.

CONCLUSIONS

The results of the slope stability analysis indicate the dam was near impending failure for the assumed conditions. Comparing the phreatic water surface in the photographs (A-1 and A-5, Appendix A) with the phreatic water surface shown in Figure C-5 reveals distinct similarities. Records also show the reservoir was full for several consecutive years; sufficient time to establish the state of seepage presented on Figure C-5. Because the dam was near a state of impending failure, a small imbalance in the resisting forces or additional driving forces could cause failure.

An imbalance in the resisting forces could be attributed, but not limited, to an increase in pore pressure within the embankment. An increase in pore water pressure can be a result of an increase in the reservoir height above any previous maximum level, or a leaking outlet system. A leaking outlet would transfer the pressure of the reservoir to the point of the leak. For Lawn Lake, a leak near the valve or in the portion of the pipe upstream of the valve would significantly increase the potential for failure.

Although not a consideration of the slope stability analysis, a leak in the outlet system could erode a void within the embankment due to the highly erodible nature of the material from which the dam was constructed. If a sufficiently large void developed, the embankment above the void could collapse. A collapse of any portion of the embankment would lead to instability of the remaining embankment and the total failure of the dam.

An increase in the driving forces could have also led to the failure of the dam. A large snowbank for instance, on the slope, would effectively add a surcharge weight to the embankment. This would seem unlikely in July, although snowdrifts were observed near the right toe of the dam and downstream on the right side of the river channel as late as July 8, 1982. Also, the melt water from a snowdrift could saturate the embankment. A saturated downstream slope would have increased the potential for failure. This phenomenon is not uncommon for high mountain dams, especially those dams having a steep downstream slope inclination. A case in point is the recent surface slide on Yamcolo Dam.

In summary, for the conditions analyzed, the Lawn Lake Dam by today's standard did not possess an acceptable factor of safety against a sliding failure. Current design practice requires a minimum factor of safety of 1.5 for reservoir embankments like Lawn Lake. A factor of safety of 1.5 would preclude failure when minor changes in the resisting or driving forces occur.

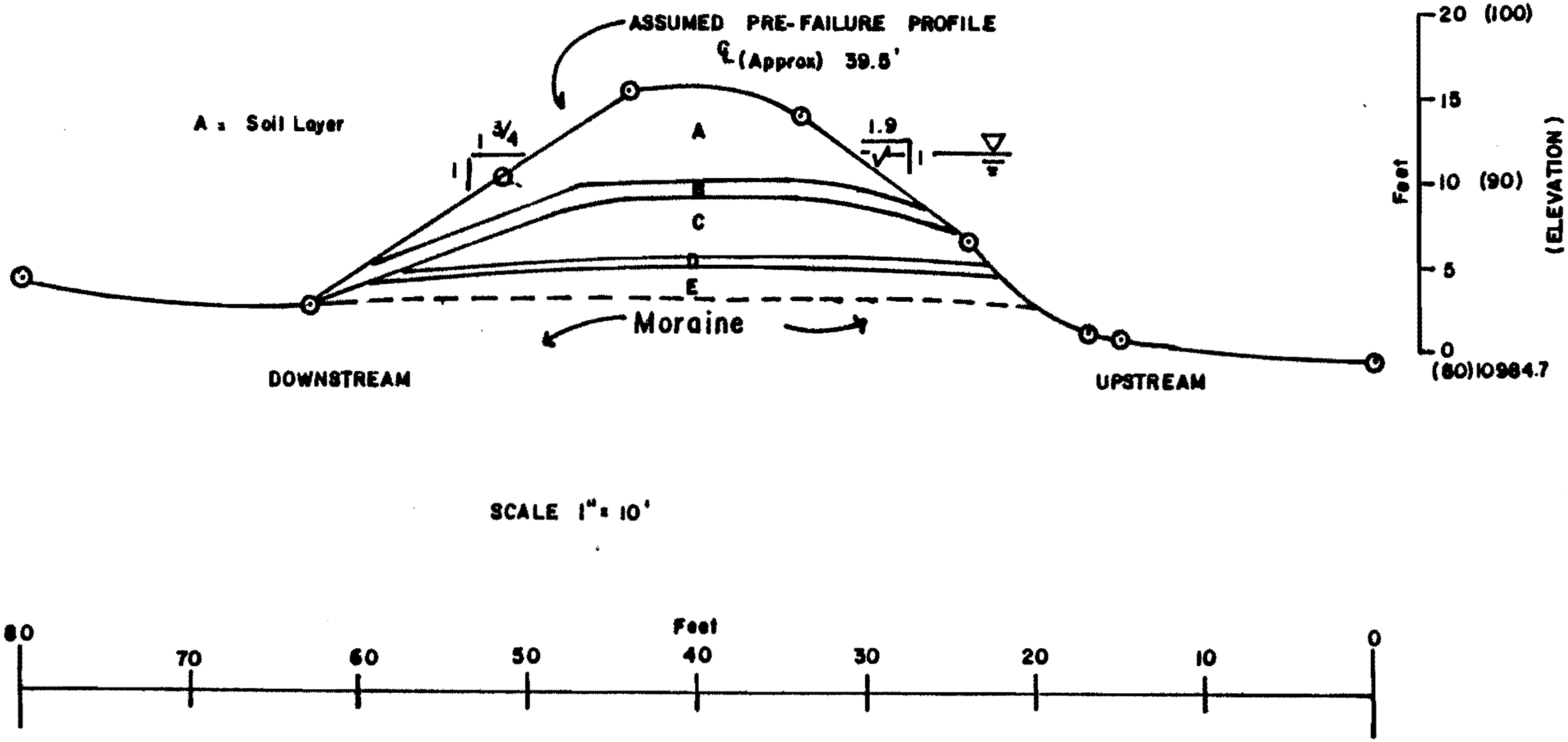
TABLE C-1

Soil Number	Inplace Density (PCF)	Cohesion (PSI)	ϕ (DEGREES)	TAN ϕ
A	121.7	0.0	30	0.577
B	102.1	1.4	18.4	0.333
C	123.5	0.0	32	0.625
D	115.4	1.3	22	0.408
E	120.0	0.0	32	0.625
FOUNDATION				
(Glacial Moraine)	135.0	100.0	45	1.000

LAWN LAKE DAM
CROSS-SECTION

(All Sections Looking Towards Right Abutment)

Right Side Of Breach
(Surveyed)

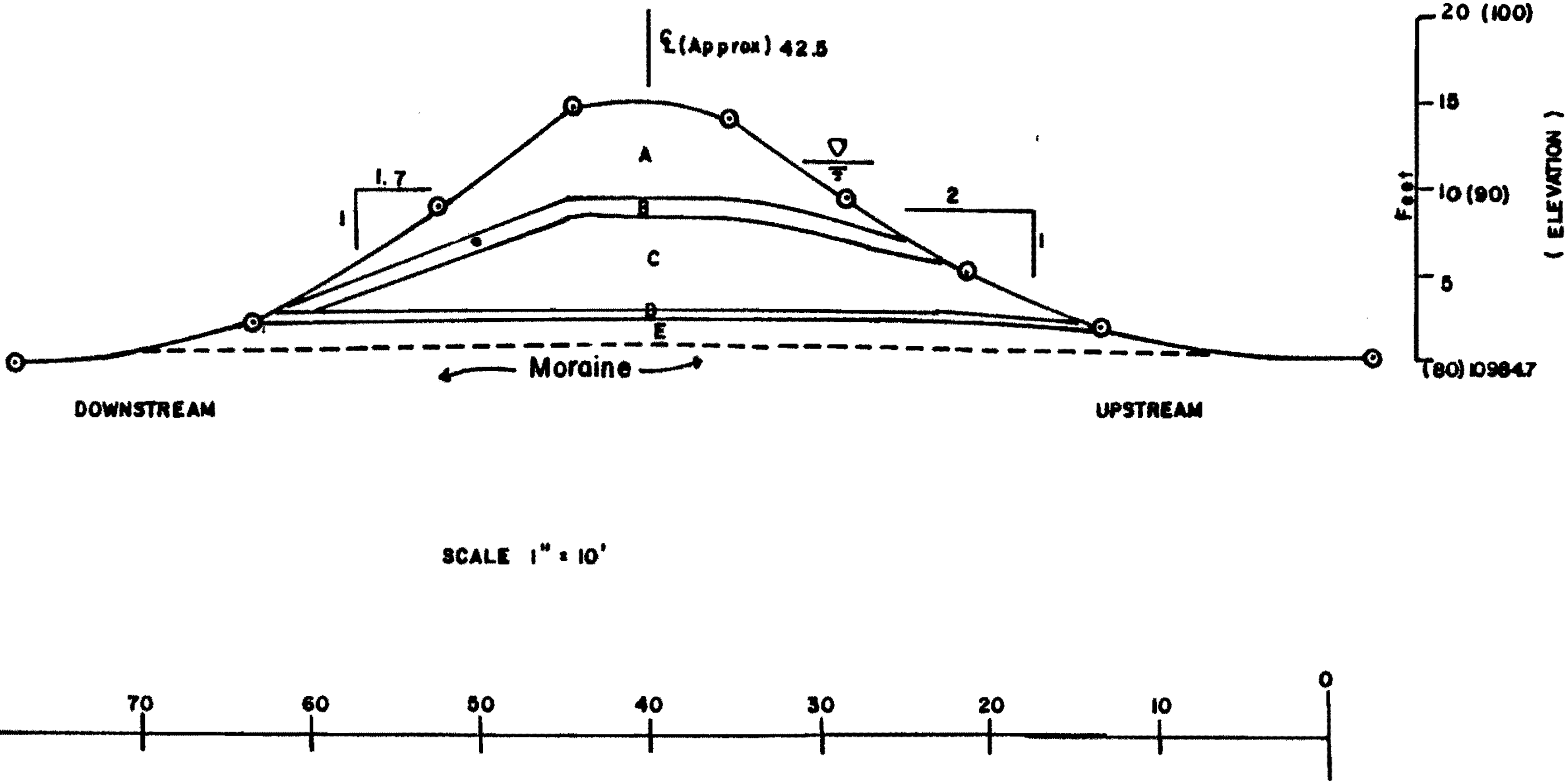


G. Van Slyke
9-14-82

FIGURE C-1

LAWN LAKE DAM
CROSS-SECTION
(Looking Towards Right Abutment)

Left Side Of Breach
(Surveyed)



G. Van Slyke
9-14-82

FIGURE C-2

LAWN LAKE DAM
CROSS-SECTION
(Looking Towards Right Abutment)

Along Outlet Pipe
(Assumed)

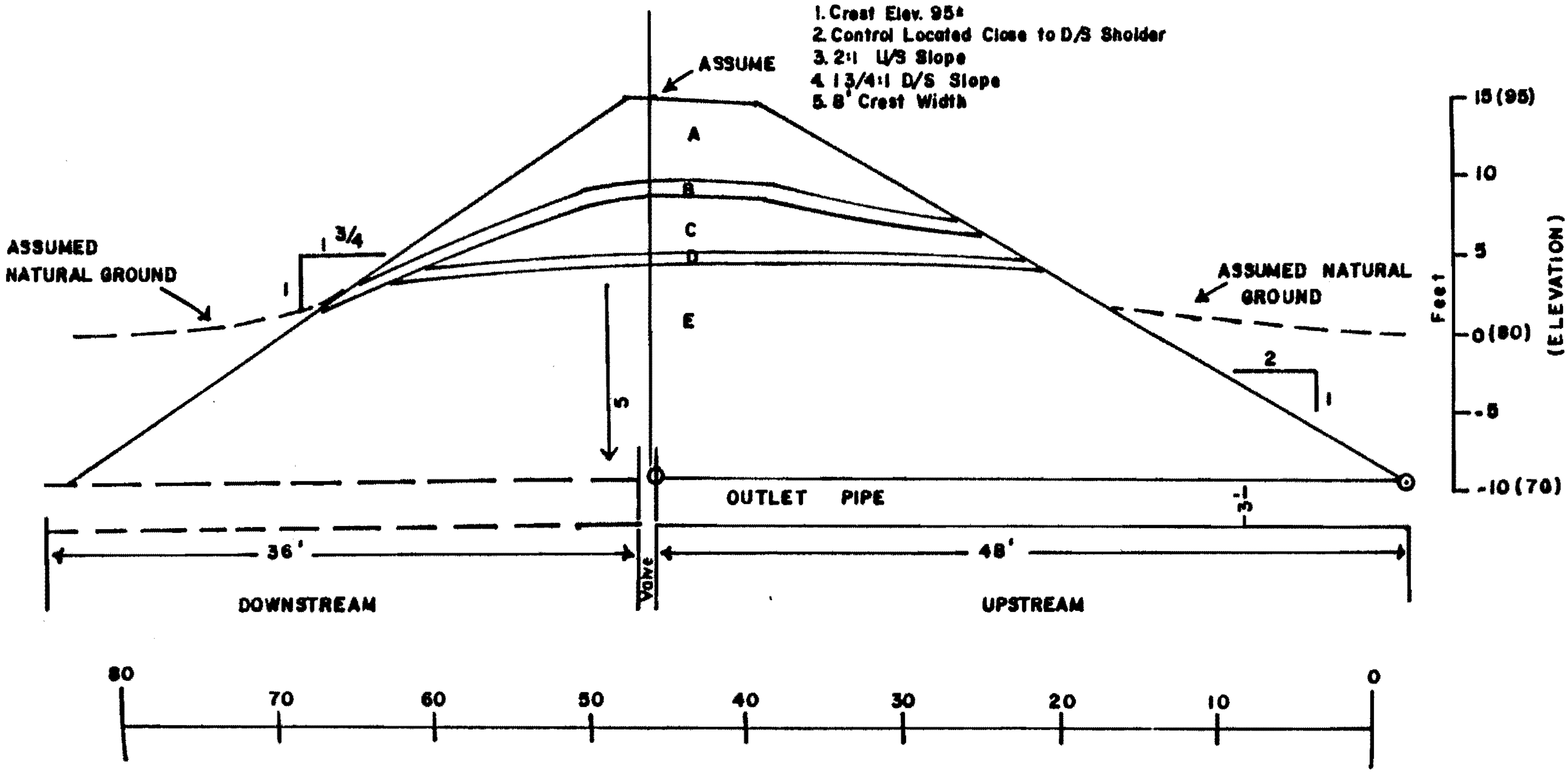


FIGURE C-3

LAWN LAKE
STEADY STATE SEEPAGE (Homogenous)
Scale 1" = 10'

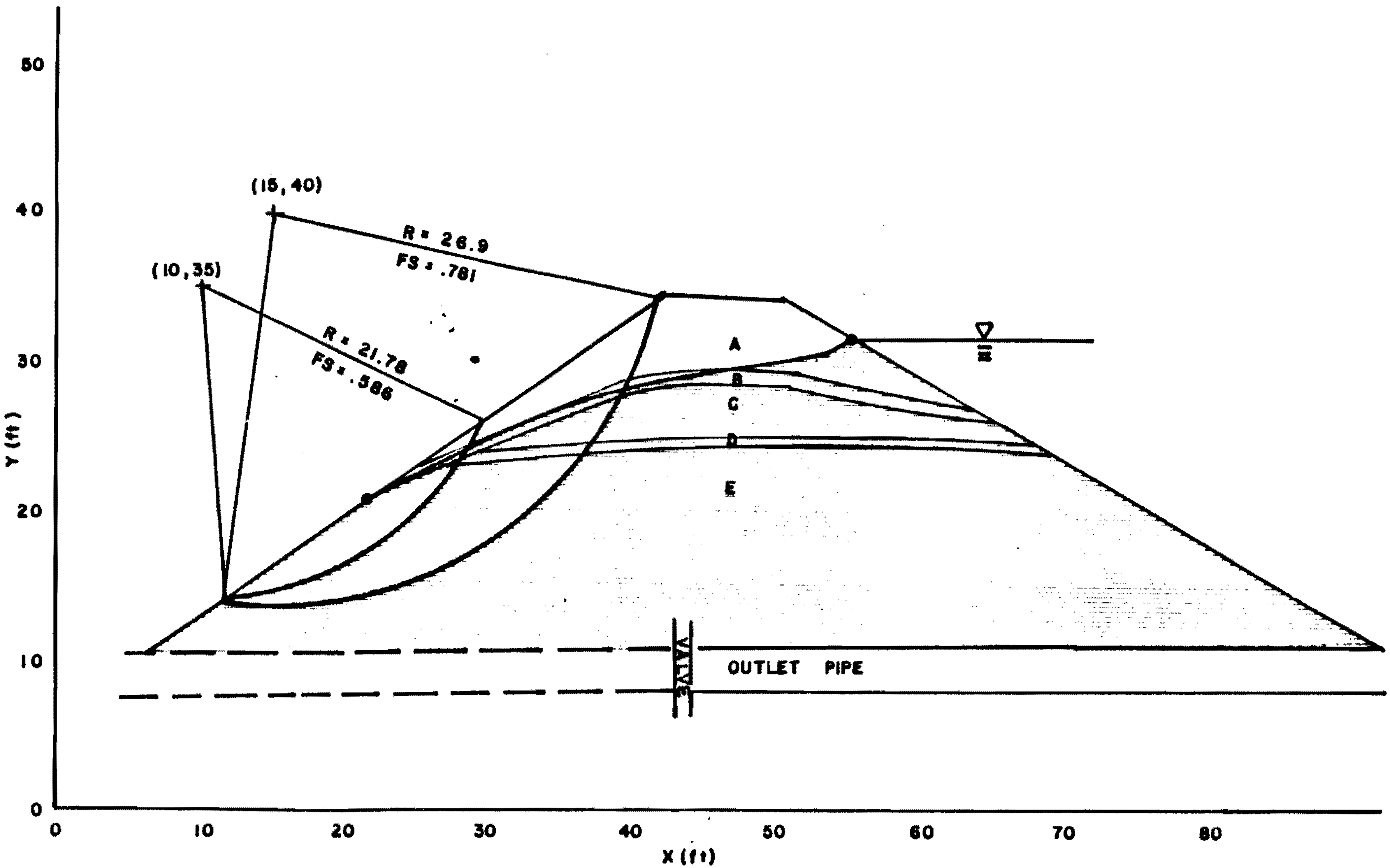


FIGURE C-4

LAWN LAKE
STEADY STATE SEEPAGE
w/Drained Toe.

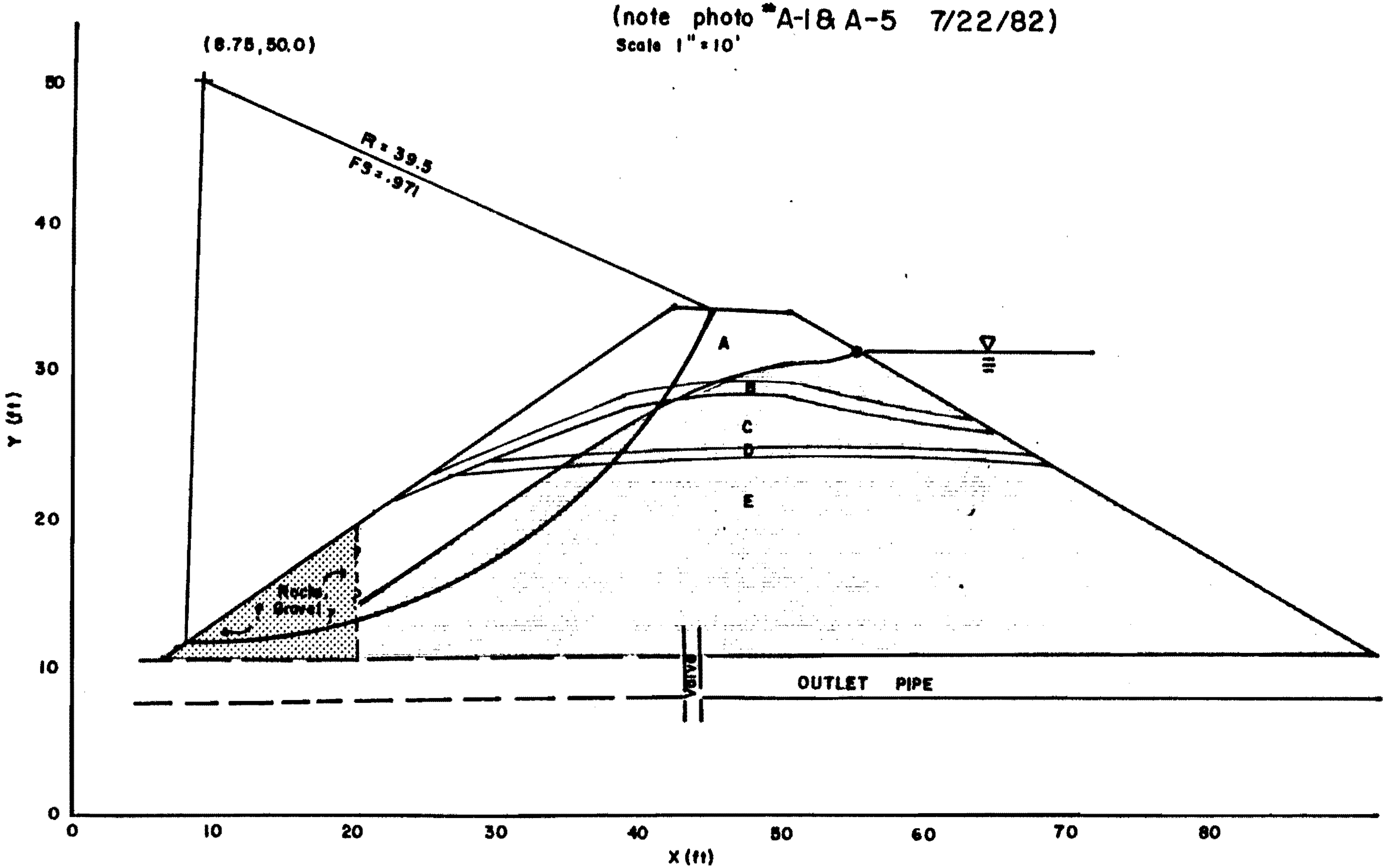


FIGURE C-5

APPENDIX D

LETTER REPORT ON CONSTRUCTION OF
LAWN LAKE RESERVOIR

T. W. JAYCOX

September 22, 1903

State of Colorado
L.G. CARPENTER
STATE ENGINEER

LAWN LAKE RESERVOIR.

Denver, Colo., Sept. 22nd, 1903.

Professor L.G.Carpenter,

O F F I C E.

Dear Sir:—

This reservoir is being made by enlarging the capacity of a natural lake, by placing an earth dam across the outlet.

It is situated in Section ________ Tp. ______ R. ______ W and is at timber line. The formation is moranial and appears sufficiently consolidated to form a practically tight reservoir.

A trench has been cut through the barrier to a depth that will give fourteen feet of water above the flow line of the outlet pipe to the level of the spillway. The outlet pipe is 36 inches in diameter, of 3/16 sheet steel, taper built, ~~enlargement~~ longitudinal seams double riveted, circular seams single riveted. It was brought on the ground in 12 ft. lengths, and field riveted in place in the trench. A light weight Ludlow gate valve 36 inches in diameter is placed at or near the center line of the dam; 48 feet of pipe being above and 36 feet of pipe being below the valve. This valve rests on a stone foundation, is to be placed in a solid mass of concrete across the trench, to a height to the bottom of upper casing of valve.

The pipe is placed in a concrete bed 8 inches thick across the full width of the trench, and embedded in concrete to the height of the center for its entire length, and covered with four inches of concrete, placed around the upper half, above the valve.

The pipe was leaded into the valve using hot lead, and caulked.

The embankment to be of loose rock and earth, the loose rock being stomes from the excavation for spillway, and gathered from the surface, having a slope of about 1 to 1 on the back, and steeper on the upper face, being hand placed, and a top width of five feet. The earth part is to have a slope of 4 to 1, rip-rapped, and a top width of five feet. A small portion of the loose rock part and almost none of the earth embankment was in place at the time of inspection.

The pipe and valve were in place, the concrete foundation and sides completed, and the lead poured around the pipe when I arrived on the ground.

Iola and Dyckerhoff cement were used. The work was being done by the Company, and what I saw was well done.

Instructions were given as to the method of formingthe earth embankment, and to step back the sides of the trench when filling it.

The inspection was made September 9th and 10th, 1903.

The weather was snowy and cold and probably but little more work can be done here this season.

Very respectfully,

[illegible]

[illegible]

APPENDIX E

INVESTIGATION OF THE

FAILURE OF LAWN LAKE DAM

STATEMENTS OF WITNESSES

OBTAINED BY THE

NATIONAL PARK SERVICE

746

Memorandum

To: Files

From: James D. Harpster, Public Affairs Officer

Subject: Lawn Lake Dam failure in Rocky Mountain NP

Upon learning at the Regional Office of the Lawn Lake dam failure on Thursday, July 15, 1982, five representatives of the RO drove to Estes Park and Rocky Mountain NP headquarters. The group included Jim Randall, Bill Mekeel, Ron Hermance and Curt Menefee of the Solicitor's Office.

We reached park headquarters via the Mary's Lake road through residential areas of Estes Park that had escaped all flood damage.

At park headquarters at about 12:15 p.m., we met with Superintendent Chet Brooks, Assistant Superintendent Jim Godbolt and Chief Ranger Dave Essex. They offered a recapitulation of the day's events, commencing at 6:26 a.m. when an employee of the A-1 Trash Service alerted park headquarters from the Lawn Lake trailhead that a flood emergency appeared to be heading down Roaring River and Fall River toward the Aspenglen Campground.

It appeared at the time that one Steven See of Hilbert, Wisconsin, was missing and presumed dead, and that as many as 7 or 8 other persons were unaccounted for, including 3 from the Aspenglen Campground. Two members of the park staff had suffered injuries, the worst of them a broken ankle (Jack Gartner).

Two helicopters had been chartered from Continental Divide Helicopters. Lt. Gov. Nancy Dick had been to the city and the park. Superintendent Brooks had been in touch with an aide to Representative Hank Brown, and efforts were under way to obtain bridges from the Army Corps of Engineers to provide access to areas cut off by floodwaters and by road failures.

The park staff indicated that one Donay Manson (Hansen?), a research assistant to Dave Stevens, had visited Lawn Lake on Wednesday, July 14 (the day previous) and reported that there was considerable water overflowing the dam's spillway. There apparently was no reason to be concerned for the safety of the dam at the time, however.

Bill Mekeel quoted one Alan (Allen?) Pearson (Pierson?) of the State Engineers' Office that the dam had last been inspected in August 1978.

(In a telephone call by Harpster to Mike Baugher at about 1 p.m., Baugher advised that our Washington Office reported an inspection by unidentified Soil Conservation Service employees on April 30, 1981. Further, Baugher said an individual had called him during the morning to say he (the individual) was at the dam on Thursday, July 8, and had observed three "farmer types" struggling with a valve, cursing and fuming about its stubbornness. They told him, he said, that the valve was "tricky.")

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0

LOCATION OF INCIDENT.	DATE OF INCIDENT MO DA YR
Same	0 7 1 5 8

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Donay Hanson	P.O. Box 1567, Estes Park, CO 80517

RESULTS OF INVESTIGATION

I arrived at Lawn Lake Patrol Cabin Monday, July 12, 1982 at 9:30 p.m. and stayed until approximately 3:00 p.m. Wednesday, July 14. During that time I was making observations of the bighorn sheep as part of the research for Rocky Mountain National Park. Since I was not interested in the lake or dam I did not spend much time observing the lake, dam or spillway. Wednesday morning, around 8:00, when I filled my water bottle from the spillway, I noticed that it was full and the volume of water was that of a river the size of the spillway. It was approximately a foot deep. The lake was full and, with the wind from a front that passed through, the waves were breaking on top of the dam. This lasted about an hour. As to the level of the water on the dam and any seepage or flow of water below the dam, I did not notice anything at all. Other than a rain Tuesday afternoon, there was no significant amount of precipitation during the time I was there. The ground was soggy around the lake from the runoff and the frequent rainstorms this summer.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
Donay Hanson 7/18/82	[illegible] 7/28/82

SUPPLEMENTARY CASE INCIDENT RECORD

ORGANIZATION (PARK) NAME

Rocky Mountain National Park

CASE/INCIDENT NUMBER

8	2	0	6	0	3

LOCATION OF INCIDENT

Same

DATE OF INCIDENT

MO		DA		YR	
0	7	1	5	8	2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME

Statement - Kenneth Franks

COMPLAINANT'S ADDRESS

1986 Flickinger Hill, Woorster, OH 44691

RESULTS OF INVESTIGATION

I was fishing off Spillway corner of dam last evening and quit at 8:45 P.M. Waves were 2 feet high, wind strong, a small amount of debris in spillway area, water going over spillway OK - not high. I awoke after midnight (sometime) I could hear a roar that I thought was the wind. I went to fish at 7:30 and found the dam broken. The people who camped at Lawn Lake last night are OK. One campsite is vacant -(not used.)

I saw no other hikers after a family of four- man, woman, 2 children they had water bottles only, and said they had to pick up their son at the YMCA Camp at 4P.M. We met them at Lawn Lake at 1 P.M., the last time. I think they got out O.K.

I saw no people other than those accounted for at Lawn Lake campsite this A.M.

SUBMITTED BY (SIGNATURE AND DATE)

/s/ Kenneth D. Franks

APPROVED BY (SIGNATURE AND DATE)

Laurie Shannon 7/15/82

NATIONAL PARK SERVICE

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Joanne Franks	1986 Flickinger Hill, Wooster, OH 44691

RESULTS OF INVESTIGATION

(Site #7-1 @ Lawn Lake)
We left Lawn Lake trailhead mid morning for overnight camping at Lawn Lake. We arri[illegible] approx. 2 PM & set up camp, which took an hour.

After setting up camp, we hiked up to Crystal Lake, which took an 1 1/2 hr. Stayed at Crystal for 1/2 hr., then headed down. We got caught in a rain storm, which laste[illegible] a short time. Arrived at campsite around 5 PM & started to prepare supper. My husban[illegible] went to the lake to fish. Supper finished & cleaned up by 7:30 PM. We noticed 1 othe[illegible] fellow camped nexted to us. Approx. 9 PM we turned in. During the night I heard what sounded like a freight train, & just thought a storm was whipping up, & fell back to sleep. It wasn't until approx. 7:30 AM that we realized the dam had broken. When the helicopter landed there were 3 more people appear who had also camped.

We met no one on the way to Crystal Lake.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Joanne Franks	Susan Henderson 7/15/82

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME

Rocky Mountain National Park

CASE/INCIDENT NUMBER

8	2	0	6	0	3

LOCATION OF INCIDENT.

Same

DATE OF INCIDENT

MO		DA		YR	
0	7	1	5	8	2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME

Statement- Debra J. Franks

COMPLAINANT'S ADDRESS

29 Millhaven Ct., Richmond, VI 23233

RESULTS OF INVESTIGATION

We left lawn lake Trailhead at 10:05 AM 7/14/82: parents, brother (23), brother's girlfriend (-23), myself. Slowly hiked up trail with frequent rest stops. People passed on the way: one young male on way out with fishing pole (no pack) low in hike (still in aspen); middle aged male fishing in creek farther up; family of four (father, mother, two children of elementary age) on way up to lake for day hike (said they had to be back to YMCA by 4:30-saw them at 12:30PM still on way up); single male on way up to lawn for overnight; man and woman on way down (we passed them at 12:30PM); two young men at lake at dam looking like they were there just for day hike; family of three (small child, husband, wife) also camped at lake. Reached campsite 2PM, set up camp. Hiked up to Crystal Lakes and back to camp by 5PM. Cooked supper, father fished, in bed 8:30 PM. Sometime after 9:30(10?) heard extra roar (we thought was wind). Slept - didn't know lake was gone until up at 8:00 AM.

SUBMITTED BY (SIGNATURE AND DATE)

/s/ Debra Joanne Franks 7/15/82

APPROVED BY (SIGNATURE AND DATE)

Lawson McKinley 07/15/82

SUPPLEMENTARY CASE INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Kerry Franks	1986 Flickinger Hill, Wooster, OH 44691

RESULTS OF INVESTIGATION

Camped @ Lawn Lake 7/14 w/Franks party.

At 2-4 AM (7/15) I awoke and heard a roar. At that time I assumed it was just wind, however, I thought it strange that the tent was not fluttering.

In the morning (8-9 AM) I saw the dam had broken. Camp was packed up and left via helicopter.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Kerry Franks 7/15	Susan Henderson 7/15/82

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Thomas Gunning	878 S. Dexter #302, Denver, CO 80222

RESULTS OF INVESTIGATION

Started at Lawn Lake trail head 10:30 am 7-14-82. Met several parties coming down the trail as I was going up. Met party of husband & wife & two children (about 10 yr. old). They were hiking for the day. Also met them at lake they were heading back down (about 2:30 pm) Their son was climbing Baker w/ the YMCA. Also met party of 5 that also camped at Lawn Lake. Arrived at Lake at 2:30 pm. Met 2 young met at dam (I believe they were from Illinois). They were getting ready to head to the bottom.

I woke up at 3:30 am (7-15-82) & heard a roaring noise (which I assume was the river after the dam broke) I got up at 6:50 am & noticed the Lake was lower. I went to the dam, seeing it was washed out. Met Dave Bux at dam & watched the river washing out the river bed.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Thomas A. Gunning 7/15/82	Susan Henderson 7/15/82

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT MO DA YR
Same	07 15 82

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Jeanne Jones	650 Prospect St. Shreve, OH 44676

RESULTS OF INVESTIGATION

We arrived at the campsite at about 2:10 & set up camp. We then hiked up to Crystal Lake at got back - 5:30. Ate supper, went to bed. About 9:30 we were talking about the noise which sounded like high winds to them but it sounded like a distant waterfall to me. During the night I woke up periodically & the noise had increased but there was no wind hitting the tent. At 8:00 we checked out the path; the dam broke right where the spillway had been. -100 feet away from the break was a big rusty wheel lodged among some rocks & 1/4 mile away was a big metal cylinder lodged among some pine trees on the left bank. The helicopters then began to circle.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Jeanne Jones 6/15/82	Laurie Shannon 7/15/82

NATIONAL PARK SERVICE

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3
LOCATION OF INCIDENT	**DATE OF INCIDENT** MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Maggie Box	1510 N. Choctaw Ave. Claremore, OK

RESULTS OF INVESTIGATION

We started out Monday to Roaring River Camp site. Camped there Mon & Tue nights. Started up the trail on Wed around 10 a.m. Saw nothing unusual. We pasted a party of four (man women 2 teenage girls) on the trail. Near the last switch backs. The man told my husband they were going to camp where ever because they were tired. My husband got up around 6 a.m. Thurs morning to walk. He saw the dam had broken. He took pictures of the water levels. At 6 a.m. the sound from our campsite was like a train engine.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Maggie Helton Box 7/15/82	Susan Henderson 7/15/82

SUPPLEMENTARY CASE INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Ann E. McMann	P.O. Box 179, Coos Bay, OR 97420

RESULTS OF INVESTIGATION

I was camping with Margaret Brault and early in the morn. Margaret awakened me by saying "What's that noise?" - listened a moment and could only think it must be thunder - I unzipped tent flap & Margaret saw a "Wall" of water and said it's a flash flood and I could only see a dark portion of the river coming downriver above us. I grabbed my sweater & Margaret & I ran out of the tent & ran to higher ground above us. We stopped up higher on the hill to turn around & watch the river, mud & rocks "boiling" past us & filling portions of the flat part of Roaring River C.G. We looked back and could see the tent & packs were untouched - we waited longer - trees were falling, rocks were making great noise - then when things seemed to be stabler (possibly 45'-60'??) we went back to the tent site and gradually hauled part of gear to higher ground. We looked toward C.S.#1 (saw nothing, saw no one - walked up to overlook above the Horseshoe Park - watched helicopters, park service trucks thru bincos - went back for packs (Margaret went back 1st) & decided to wait above RR.C.S. area in case Park Service came there - about 11 AM 2 men camping at Up. Chipm came thru - we all four walked to flat river bed - too fast to cross - all four went back up Ypsilon Trail to clearing above Valley - walked downhill clearing area - saw Park Ser. persons on E. side of river - told us to go downstream - walked to flat bottom valley - met there by 2 Park Serv. men & 1 women - arranged copter to take us to Park Hdqtrs.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Ann E. McMann 7/15/82	Laurie Shannon 7/15/82

SUPPLEMENTARY CASE INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3
LOCATION OF INCIDENT	**DATE OF INCIDENT** MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Daniel Sumita	6047 S. Campbell, Chicago, IL 60629

RESULTS OF INVESTIGATION

Hiking from the Lawn Lake trailhead up to the Ypsilon Creek Campsite our party encountered two twenty year old males w/backpacks in shorts (no shirts) who passed us up on the trail. Later walking toward us (at the trailhead) we passed one single male hiker, later another single male, and then a group of four (two females and 2 males. Once at the trail split we passed 3 males and a female sitting on the bridge. Once at the campsite we built a fire had dinner and went to bed. At about 6:20 AM all in our party was awakened by a loud tree breaking thunder, by the time we looked out the first surge of water was 50 feet from our tent sending trees crash downward along/w tons of earth and boulders water and debris also reached our tent as we scrambled uphill with the first pieces of gear we could grab when we finally realized the danger was over near our tent we pulled our gear and tent up the hill and watched the destruction.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Daniel Sumita 7/15/82	Laurie Shannon 7/15/82

NATIONAL PARK SERVICE

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3
LOCATION OF INCIDENT	**DATE OF INCIDENT** (MO DA YR)
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Laurie Shannon	Moraine Route, Box 1994 Estes Park, CO 80517

RESULTS OF INVESTIGATION

On 07/15/82 while on my lieu day, I was called out by Ranger Fiala at 0700 hrs. to respond to the rescue cache because of the dam breaking at Lawn Lake. At approx. 0800 hrs. I was requested to interview Steven Cashman at Headquarters. Cashman had been camping at Roaring River Campsite #1 in the Lawn Lake drainage when the flood occurred. Cashman stated that he had been up at daybreak drinking coffee, and his partner Steven See was asleep when he heard a loud roar. The roar continued growing louder when Cashman looked up and saw trees snapping, boulders and a wall of water coming down the drainage. He stated that he ran for higher ground. He stated when he looked back the tent with See in it was gone and the area had been destroyed by the flood. Cashman hiked down the west side of Roaring River and when reached the Endovalley Road, he walked west until he found a bridge to cross and then proceeded east until he contacted a Ranger who transported him to Headquarters. When I interviewed Cashman he was extremely upset and was somewhat hostile about answering questions. We asked Cashman to please wait until 12:00 hrs. noon before making any phone calls. Cashman was then transported to an apartment in the Park Annex for rest. He was later [redacted] by Ranger Henderson.

I interviewed all the other campers evacuated from the Lawn Lake drainage with the assistance of Rangers Henderson and McKinley. As the campers were evacuated by helicopter they were brought in groups to us at Headquarters. We had each of them fill out statements (344's) as well as making notes on a separate piece of paper which was attached to the statement. We asked questions from all trying to account for all campers or hikers who might have been in the drainage on 7-14-82 to 7-15-82. We basically followed the format of Who, What, When, Where, How and Why during the interviews. Most of the campers were cooperative but did not have alot of information. After the interview they were given transportation if needed. After the interviews we were fairly confident that we had accounted for all the campers in the drainage with the exception of any illegal campers who might have been up the drainage. After obtaining a list of all the people the campers had encountered during the day, we then asked them to relate their account of the flood.

I was clear at 1600 hrs.

On 07-16-82 I participated as a searcher in Ranger Powers search group. We searched from Aspenglen Campground down to approx 1-1/2 miles below the Park boundary along Fall River. Nothing was found.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
Laurie Shannon 07/15/82	[illegible] 8/2/8[illegible]

NATIONAL PARK SERVICE

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME Rocky Mountain National Park	CASE/INCIDENT NUMBER 8 2 0 6 0 3
LOCATION OF INCIDENT Same	DATE OF INCIDENT MO DA YR 0 7 1 5 8 2
NATURE OF INCIDENT Flood	
COMPLAINANT'S NAME Statement - Steven R. Cashman	COMPLAINANT'S ADDRESS 829 West Franklin Appleton, WI 54911

RESULTS OF INVESTIGATION

Went to bed last night about 10:00. We both woke up cause we couldn't sleep. We talked for a while and went back to sleep. This was around 3:00. I woke up early this morning & woke Steve up. he was to tired to get up. I bilt a fire & made coffee. I started to hear a sound like an air plane. Also there were loud booms. It got louder and louder. I thought it was breaking the sound beareyer. I kept looking for a plane but couldn't see one. I got suspicious and started to look up stream. I saw trees crashing over and a wall of water coming down. I started to run as fast as I could for high ground. There was a defining roar. I fell and got up and kept running. I stood on high ground and watched it wipe out our camp sight. It knocked everything In it path over Steve didn't stand a chance. I watched for 15 minutes and then started down the Mt. for help.

I got to the road on the oposit side of the river from the car. I walked back and forth for about an hour. Then I walked up the valley and around they other river at the picknick area. I walked along the mt sides till I saw a rangers truck about 1/2 mile away. I ran to It and told him what happened. If we would of been warned what to whatch for I could of woke Steve up. He would still be alive.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Steven R. Cashman 7/15/82	Laurie Shannon 7/15/82

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT (MO DA YR)
Same	07 15 82

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Rick Krainas	7808 S. Homan, Chicago, IL 60652

RESULTS OF INVESTIGATION

At 11:15(A.M.) 7-14-82 we headed up Long Lake trailhead. We made many stops and it took us 4 1/2 hrs. Along the way we saw many hikers but very few backpackers. The backpackers we saw were 2 ladies (In early 40's) and 4 men who were trailworkers.

When we arrived at camp we setup and did some exploring. We ate and went to bed early. We were awakened at approximately 6:00(A.M.) by a loud thundering noise. We looked out the tent and saw waves about 25-30 ft. carrying trees and rocks everywhere. We began to bring all valuables to high land. Then we saw other campers hiking around making sure everybody's OK. Then there were 4 rescuers who gathered everybody to a helicopter landing spot.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Rick Krainas 7/15/82	Larry McKinley 07/15/82

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3
LOCATION OF INCIDENT	**DATE OF INCIDENT** MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Robert C. Kendall	2448 W. Balmoral Chicago, IL 60625

RESULTS OF INVESTIGATION

Left for Lawn Lake Trail 11:15 AM. Made it to Ypsilon Creek Site #1 about 4:30 PM. Set up camp and ate 7:30 PM. Went to bed 9:00-9:30PM. Awoke at 5:50 AM and began to hear what sounded like thunder then came crashing noises and we all looked out a saw a 25-30' wall of water seything throu the trees, probably 100 yds away. We ran to higher ground and watched. This was 6:00 AM. We watched the total destruction of the creek for 3 hours, then about 11:30 AM the trail rangers came and got us all in one place, for the copters to pick us up - about 1 PM.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ RC Kendall 7/15/82	Laurie Shannon 7/15/82

SUPPLEMENTARY CASE INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3
LOCATION OF INCIDENT.	**DATE OF INCIDENT** MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Steve Wilde	605 Glendale Glenview, IL 60025

RESULTS OF INVESTIGATION

At about 6:15 AM I awoke to the sound of trees smashing and water rushing. We looked to the river and saw trees and water rushing by. We went to the lower campsites and saw that everyone was fine. We went back to our campsite and saw Wheelers trail cre They yelled across the river to stay still and wait. Some time later they came dow the other side of the river. They collected people from the lower campsites and we went to a spot where the helicopter could pick us up.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Steve Wilde 7/15/82	Laurie Shannon 7/15/82

NATIONAL PARK SERVICE

SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3

LOCATION OF INCIDENT	DATE OF INCIDENT MO DA YR
Same	0 7 1 5 8 2

NATURE OF INCIDENT

Flood

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS
Statement - Tim Wood	1756 Henley St. Glenview Ill 60025

RESULTS OF INVESTIGATION

I woke up at 6:15 and the ground was shaking. I heard some trees braking I got out off the tent and saw a wall of water rushing down the river. I wached the water for till the ranger came. I saw them akrost the river. They told us to stay there. They come about two hours later. We went to a clearing and wated for the Helakopter. Then they took us to the ranger station.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)
/s/ Tim Wood 7/15/82	Laurie Shannon 7/15/82

SUPPLEMENTARY CASE INCIDENT RECORD

ORGANIZATION (PARK) NAME: Rocky Mountain National Park

CASE INCIDENT NUMBER: 8 2 0 6 0 3

DATE OF INCIDENT: MO 0 7 DA 1 5 YR 8 2

LOCATION OF INCIDENT: same

NATURE OF INCIDENT: Flood -

COMPLAINANT'S NAME: statement -Stephen W. Gillette

COMPLAINANT'S ADDRESS: Box 2162 Estes Park, CO 80517

RESULTS OF INVESTIGATION

Approx. 6:18, arrived at Lawn Lake Trailhead to empty 4 cans. Getting out of my truck I hear a very deafening noise. Looking, I see dirt in the air. Decided that a jet was crashing and to go up the road to confirm.

About 30 yds from Roaring River Bridge I notice some water and debris (logs and limbs) on road. Stopping and looking up-hill I see trees and rocks being thrown into the air. Truck in reverse to the Endovalley winter closure gate - turn around to go to trailhead emergency phone. Notice Blazer (Michigan plates) entering off 34. Decided to block road and run to phone.

6:22, call dispatch - ask whats going on up Endovalley? I think a lake or something just burst. There is a massive landslide - I have the road blocked. I'm the A-1 Trash Driver. Get Dan Davis down here. Not going to let anyone up the road till Dan gets here.

Ranger Shultz arrive where I have my truck blocking access. Shultz and I proceed to the Endovalley winter closure gate. He ask me to lock it. He is on the radio. We both then go to the bridge on 34. While there, I see much more water and Debri[s] After getting to the bridge I see an Knee high wall of water and debris coming to bridge. I tell Shultz that I will block the road with some blockades that I have observed up the road. I do this and by the time I finish--water is coming over the road--I go on with my business

SUBMITTED BY (SIGNATURE AND DATE): Stephen W. Gillette 7-22-82

APPROVED BY (SIGNATURE AND DATE): David [illegible] 8/2/82

ORM 10-343
(Rev. 3-73)

United States Department of the Interior
NATIONAL PARK SERVICE
CASE INCIDENT RECORD

ORGANIZATION CODE: 1	2. ORGANIZATION (PARK) NAME: Rocky Mountain National Park	3. LOCATION CODE:	4. CASE/INCIDENT NO.: 8 2 0 6 0 3
LOCATION OF INCIDENT: oaring River/Fall River Drainages	6. WHEN DID IT OCCUR? MO. 07 DAY 15 YR. 82	24 HOUR TIME: HRS. 06 MIN. 26	7. DAY OF WEEK: 5
OFFENSE/INCIDENT CODE:	9. NATURE OF INCIDENT: Lawn Lake Dam Failure	10. HOW REPORTED: Telephone	
1. REPORTED BY: teven Gillette	12. ADDRESS: AI Trash Service, Estes Park, CO	13. PHONE: HOME / BUSINESS 586-5740	
4. RECEIVED BY: ispatch Center	15. WHEN RECEIVED: DATE 07/15/82	16. TIME BROADCAST: 0627	
7. INVESTIGATED BY: ann Shultz - Park Ranger	18. OFFICER/RANGER NO.:	19. WHEN INVESTIGATED: DATE 07/15 TIME 0628	DISPOSITION 20.:

	21. INVOLVED PERSONS	22. ADDRESS	23. PHONE	24. SEX	25. RACE	26. AGE	27. DATE OF BIRTH
1							
2							
3							
4							

28. DETAILS OF INCIDENT

ometime around daybreak on Thursday morning, July 15, 1982, the Lawn Lake Dam failed, eleasing 820 acre feet of water into the Roaring River drainage. The resulting water, ock, and debris, which emptied into the Horseshoe Park area, was first reported at :26 am by an AI Trash Service employee who was enroute to pick up trash in the ndovalley area. Park Rangers immediately began to respond to the Horseshoe Park area nd the Estes Park Police Department was notified of the situation at 6:43 am. Park isitors were evacuated from Horseshoe Park and a Park Ranger was dispatched to spenglen Campground to evacuate campers from the walk-in campsites along the river, otification being completed by 7:12 am. Park Rangers also notified the Operator of ascade Cottages of impending flood conditions. During this period of time employees t Park Headquarters were compiling a list of registered campers in backcountry ampsites at Lawn Lake and along the Roaring River drainage and obtaining a helicopter ith which to carry out rescue operations in these backcountry areas. At 7:30 am a escue team started up into the Roaring River drainage on foot to attempt contact with urvivors. At this time flood waters draining Horseshoe Park began to flow over the ascade Dam. At 7:43 am the Cascade Dam went out, creating a crest flood down the Fall iver alongside the Aspenglen Campground area. Sometime prior to this crest moving ownstream, eye witnesses in the campground observed three persons who had previously een evacuated from the walk-in river campsites reenter the evacuated area by walking ver a foot bridge which was completely covered by water. These three individuals were pparantly swept away as the flood crest from the Cascade Dam failure moved through the

29. QUANTITY	30. PROPERTY STOLEN OR DAMAGED	31. ESTIMATED VALUE	RECOVERED 32. DATE	33. VALUE

34. PROPERTY CODE OF HIGHEST VALUE | 35. TOTAL | 00 | 36. TOTAL | 00

INVESTIGATED BY (Signature and Date) [signature]

APPROVED BY (Signature and Date) [signature] 7/..

FORM NO. 10-344
(Rev. 3-73)

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
SUPPLEMENTARY CASE/INCIDENT RECORD

ORGANIZATION (PARK) NAME	CASE/INCIDENT NUMBER
Rocky Mountain National Park	8 2 0 6 0 3
LOCATION OF INCIDENT	**DATE OF INCIDENT** (MO DA YR)
Roaring River/Fall River Drainages	0 7 1 5 8 2

NATURE OF INCIDENT

Lawn Lake Dam Failure

COMPLAINANT'S NAME	COMPLAINANT'S ADDRESS

RESULTS OF INVESTIGATION

river campsites area to a height of several feet. This crest also took out the entrance road into Aspenglen Campground preventing any further vehicle or foot access across the road bridge. At this time another rescue team was started into the campground on foot from the Deer Ridge Junction area, reaching the campground in approximately one half hour. This team reported a lot of water running throuhgout the campground to a depth of 5 or 6 inches in places but no life threatening situations with the exception of three persons who reportedly went back into the river campsites area. This crew then began to search for these missing persons along both sides of the river below the campground, continuing their efforts throughout the afternoon. The rescue team moving up the Roaring River drainage reported contacts with stranded campers on the west side of the river at several locations. These stranded campers were advised to stay put until other rescue personnel could move down the drainage from above and make contact with them. At 8:44 am, a helicopter began transporting rescue personnel into the Lawn Lake area to contact campers at the lake and also to begin hiking down both sides of the drainage to contact survivors. At 8:49 am a report was received from the rescue team moving up the drainage that they had been informed by a camper at the Roaring River campsites that he had observed a companion get swept away in his tent. This was the first report of a possible fatality in the Roaring River drainage. After transporting rescue personnel into the Lawn Lake area the helicopter began flying survivors out to Horseshoe Park as rescue personnel were able to conduct them to suitable helipad locations. At 11:17 am, a second helicopter began assisting in transportation of survivors, search and rescue personnel and carrying out aerial reconnaisance. After all survivors were located and transported to safety, rescue personnel intensified recovery searches in the Horseshoe Park area and along the Fall River below Aspenglen Campground for known missing persons, continuing the searches throughout the remainder of the day. During the afternoon, additional Ranger personnel along with food and supplies were delivered by helicopter into the Aspenglen Campground area. By midnight the National Park Service had constructed an emergency road into the campground from the south side of the river. Only four individuals left that night, the rest indicating they would rather wait until morning to drive out. Three Park Rangers (one a Para-Medic) spent the night in the campground to provide security and emergency medical attention if needed. One hundred chicken dinners were delivered to the campground that evening. The following morning campers began an organized evacuation of the campground.

SUBMITTED BY (SIGNATURE AND DATE)	APPROVED BY (SIGNATURE AND DATE)

End of Document