REPORT OF INDEPENDENT STUDY

IDENTIFICATION OF DEBRIS FLOWS AND SLOPE CREEP IN COPPER CANYON, SOCORRO COUNTY, NEW MEXICO

Issued to advisory committee
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Identification of Debris Flows and Slope Creep in Copper Canyon, Socorro County, New Mexico

Abstract:

Copper Canyon area is located in the Magdalena Mountains and is a branch of the Water Canyon. I identified unstable slopes in Copper Canyon, and surveyed the study area and produce an engineering geologic map of a scale of 1:1650. All of the engineering geologic symbols being used in this map is the Genesis-Lithology-Qualifier (GLQ) System from Keaton (1984). Twenty-nine samples has been collected for laboratory analyses and classified according to the Unified Soil Classification System (USCS). The geologic map of Copper Canyon is modified from Krewedl (1974). Debris flows in this area have shear strength around 1.43~1.95 kPa and they are not very fluid. The lab data reveal that void ratios of most samples are pretty high. The major reason for the slope creeping is that the soils are not well consolidated.

Introduction:

Within Socorro County, I can point out many kinds of slope failure. We often go to Water Canyon for a picnic by taking U.S. Highway 60 west and sometimes going deeper into Copper Canyon. It is very easy for us to see many phenomena of rock falls, failures, slides and flows along the road, especially in Water Canyon

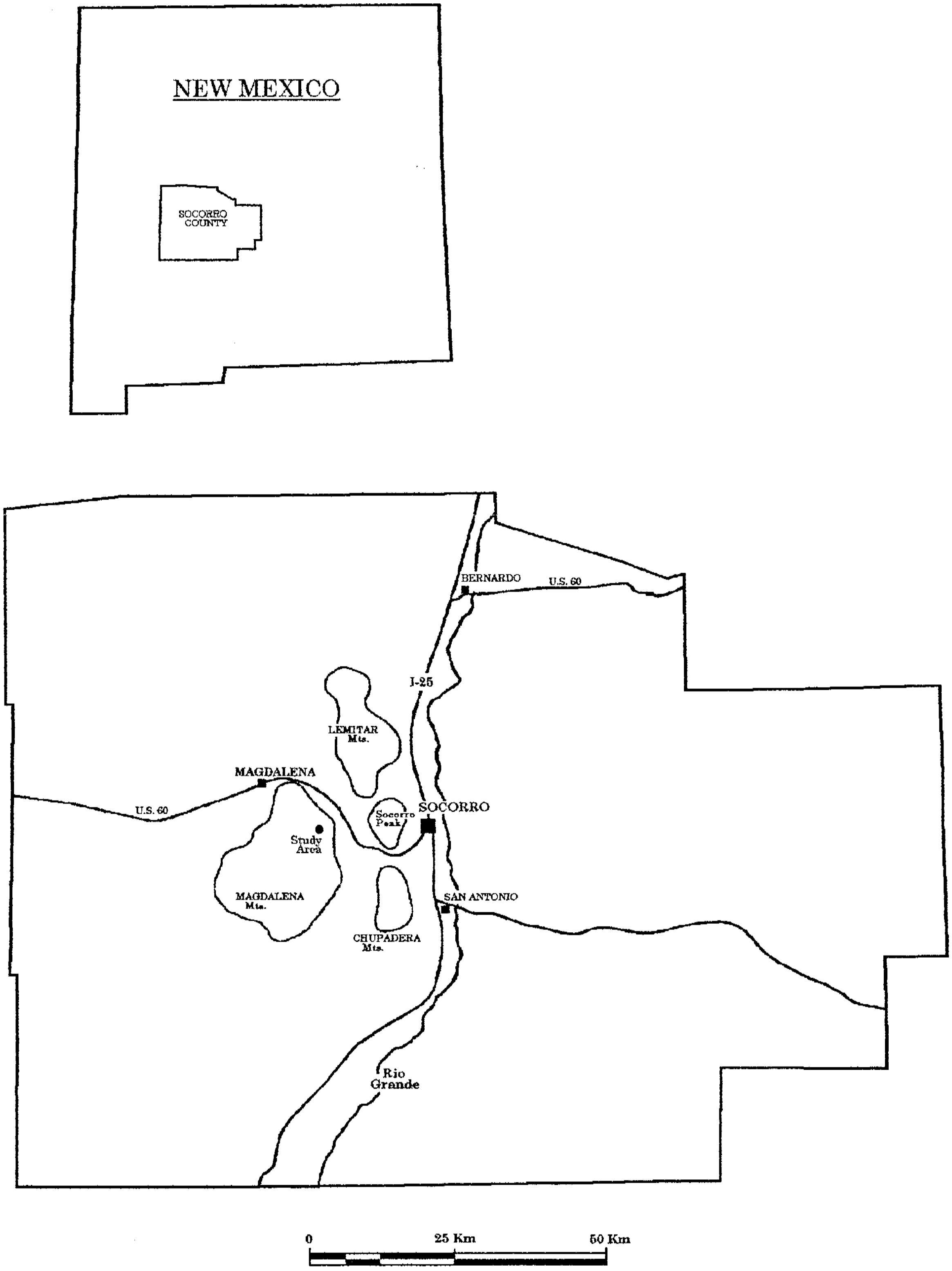


Figure 1. Study area located in the northeast of the Magdalena Mountains

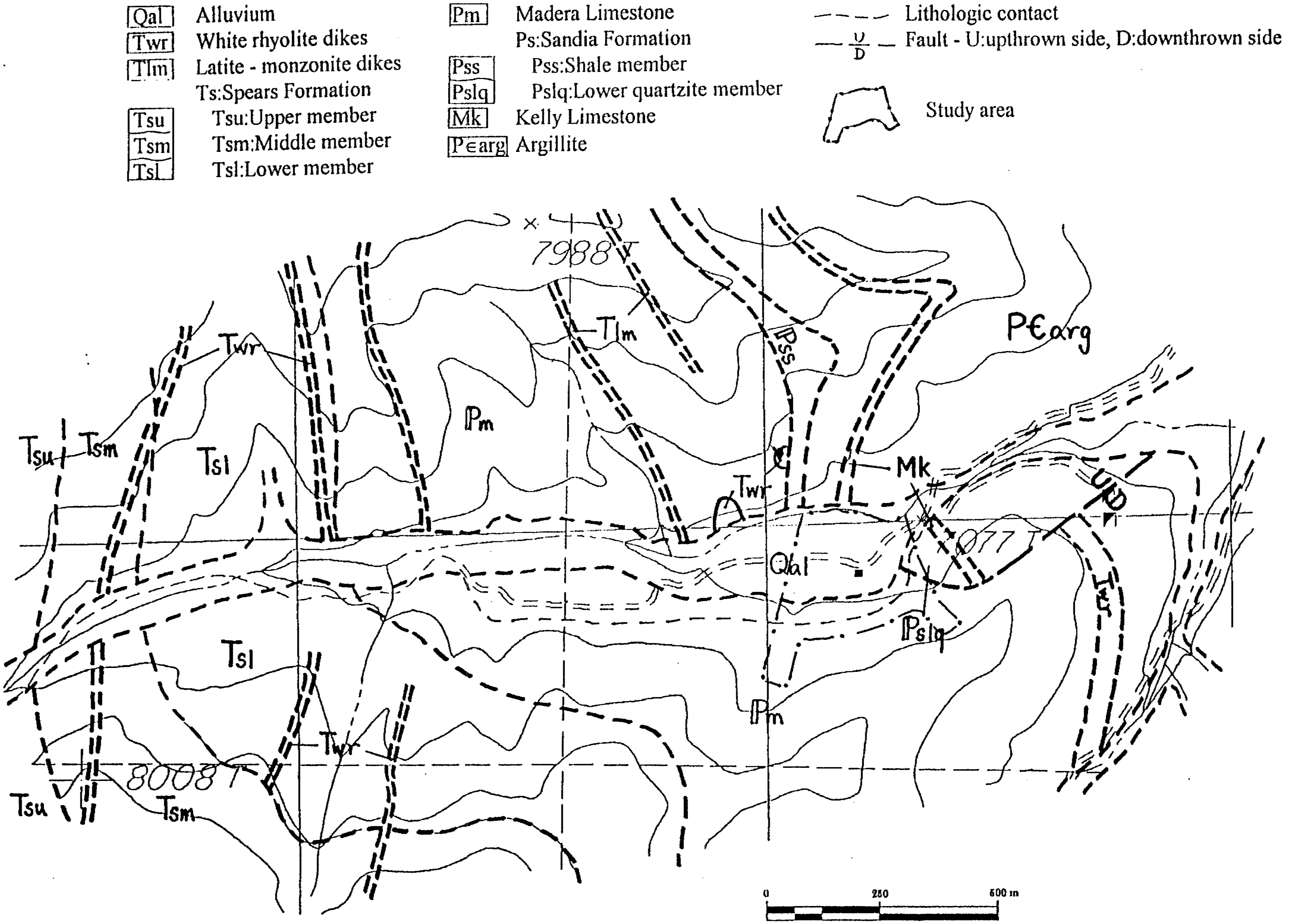


Figure 2. Geologic map of the Copper Canyon. The contour line is modified from the Magdalena 15-minute topographic quadrangles. The geology is modified from

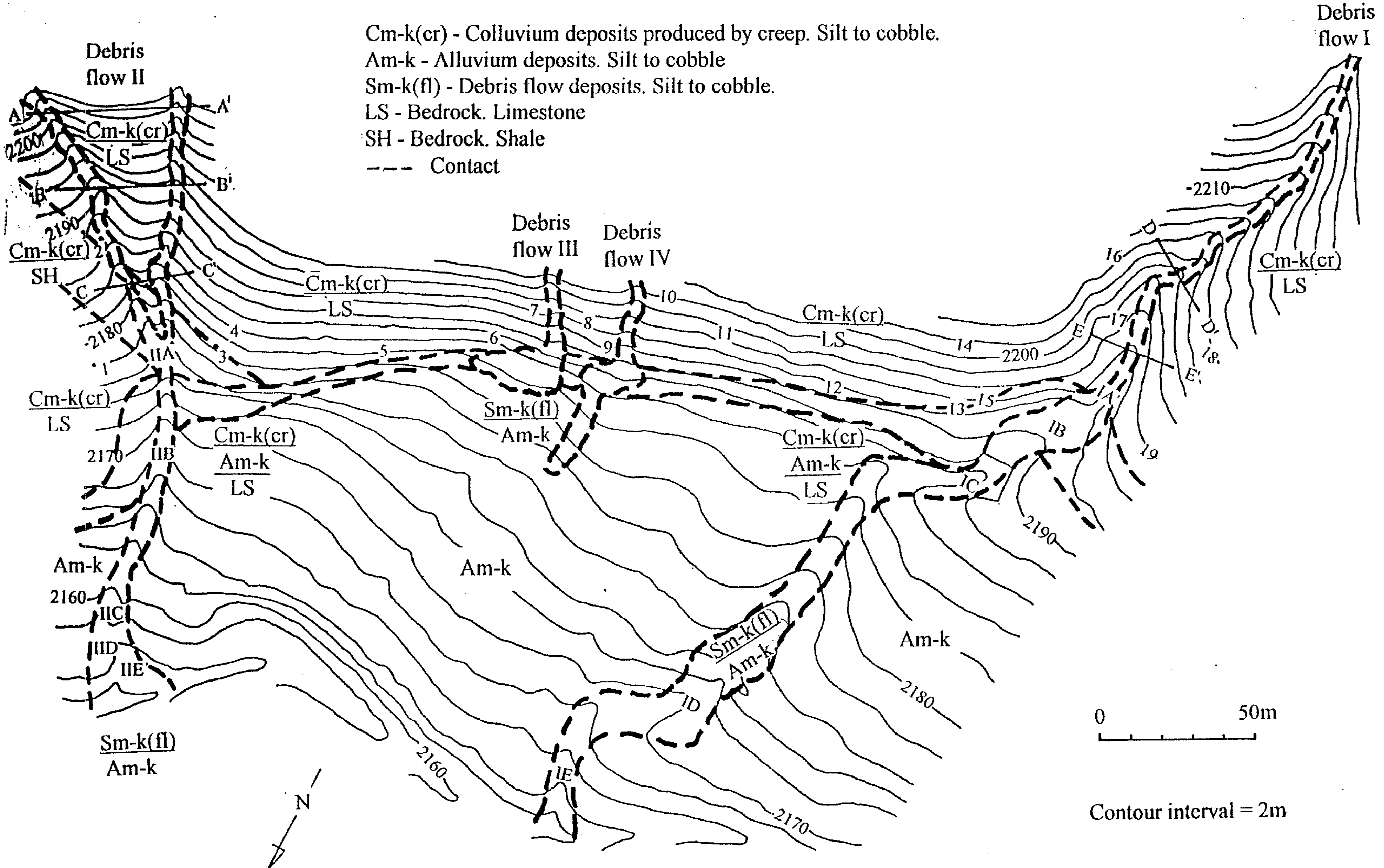


Figure 3. Engineering geologic map of the study area. All geological symbols are according to Genesis-Lithology-Qualifier (GLQ) system (Keaton, 1984).

and Copper Canyon. There is a private land about 500m x 150m in Copper Canyon. It seems that the slopes, both north and south, are unstable and we can also see several debris flows. If we want to rebuilt the houses or to use the land for any other purposes. I am curious whether the south slope will do any damage to the private property or not. The direction of this study is to identify the soil creep and to approach the major debris flows on the slopes.

Study area:

Copper Canyon is a branch of the Water Canyon which is located in the central Magdalena Mountains, Socorro County, New Mexico. This area lies in the Magdalena 15-minute topographic quadrangle. It is about twenty-two miles west of the Socorro city (Figure 1.). Access to the study area shown in Figure 2. and 3 is by U.S. Highway 60 west turning left into Water Canyon road for about 6.5km (4 miles). Then before the road reaches the camp ground, we followed the right-handed unpaved road into Copper Canyon and found that the trail is divided into three directions, the east one is access to the abandoned Buckeye Mine , the west one is to the private land and the south-then-west trail, which is called the Copper trail No. 10, is going deeper into the canyon and connecting the North Baldy trail No. 84.

Copper Canyon strikes roughly east-west and has a river flow through its north side of the bottom. Ponderosa pine is the most common vegetation in the canyon. Besides that, I also found many roses, junipers, chollas and cactuses and many kinds of unknown plants. The north slope has relatively fewer plants on it than the south slope. Because it faces against the sunshine and the vaporization is more active. The water content of the soil is lower and the plants are not easy to survive and to propagate.

The elevation range of the area in Figure 2. is about from 2100 m (6880 ft) to 2450 m (8040 ft) above sea level. The climate is not so seriously with a few exceptions in the canyon. During winter seasons, there are many chances to snow and to rain. The precipitation is abundant. They may seriously retard the field work. When the canyon is covered with snow, even four-wheel drive vehicles are hard and dangerous to get there. In addition to that, it is freeze in the canyon, especially when there is no sunshine on it. On the other hand, there is only a few periods that the temperature may higher than $40^{\circ}C(104^{\circ}F)$ in the summer seasons. I have ever seen snakes, rats and bees in the study area, so everyone should be alert when working in this field.

The area that interests me is the bottom and the south slope of the canyon. The land owner set wire fences to confine the boundary limit, and the Copper Trial No. 10 lies along the fences. The trial is indicated in the Figure 2. Most part of the slope in Copper Canyon is under creeping condition and we could also find tens of flow channels on the slope through whole canyon.

Geological Settings:

In central Magdalena Mountains, the exposed unit can be divided into four main groups. These include Precambrian argillite and granite; Mississippian to Permian limestone, shale, and sandstone; mid-Tertiary volcanic, intrusive, and sedimentary rocks; Quaternary talus, pediment gravels, and alluvial deposits (Krewedl, 1974). Precambrian rocks are the oldest ones that we can find in this area. Bowring, and others, (1983) described that the largest exposure in the Socorro area is in the Magdalena Mountains, and they crop out continuously along the eastern flank of the range from Water Canyon to the northern end of the range. Kalish (1953) described the Copper Canyon has a large area of greenstone that is first described by Gorden (1910) as "greenstone schists". The greenstone is light gray-green to dark green in color and weathers to buff or gray. The stone is argillite in Krewedl's (1974) report. The thickness in the canyon is about 300m (1000 ft). Granite lies under the argillite, both belong to Precambrian age, and also has an estimated thickness of 300m (1000 ft) (Kalish, 1953).

We can also find Kelly Limestone (Mississippian), Madera Limestone, Sandia Formation (both belong to Pennsylvanian), and the Quaternary alluvial deposit in the Copper Canyon. Sandia Formation composed abundance of shale with quartzite and limestone. Only a small exposure can be identified within study area. Madera Limestone plays a major role in the study area and it overlies the Sandia Formation. The stone is a blue-gray, fine-grained limestone and is a homogeneous sequence with black cherts (Sumner, 1980). The Kelly Limestone dips from 20° to 45° W., and varies in strike from northwest to northeast owing to the folding of the strata (Krewedl, 1974). He also described the stone as a light bluish-gray, medium-to-coarse-grained crinoidal limestone and white to gray chert bands are present. The Kelly Limestone is the most receptive host rock for sulfide mineralization. The Buckeye Mine and others are found at the Kelly-Proterozoic contact in the Kelly Limestone (Sumner, 1980).

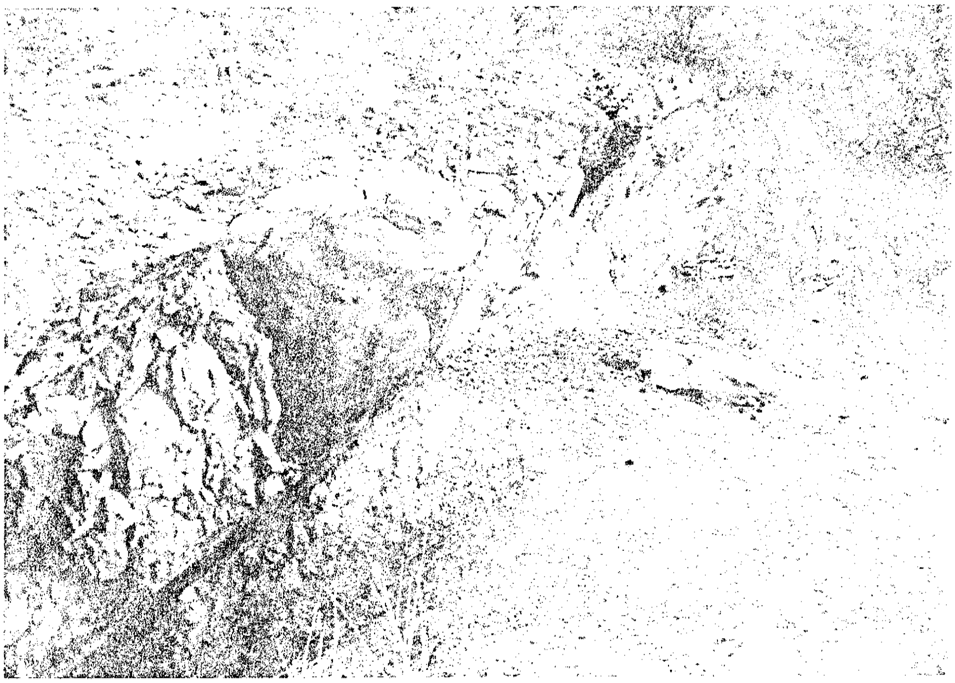


Figure 4. A small fault pass through the entrance of the abandoned Buckeye Mine.

The Spears Formation is a volcaniclastic unit composed of conglomerates, mudflow deposits, sandstones, lavas, and ash-flow tuffs of andesitic to latitic composition (Chapin and others, 1978). It is the oldest Tertiary unit found in this area and has been dated at 37-33 m.y.. The Spears Formation is the lowermost unit of the Datil Group and can be divided into three members, lower, middle, and upper. White rhyolite dikes and latite-monzonite dikes in the study area are both Tertiary intrusive rocks (Krewedl, 1974).

There is a small normal fault strikes N45°E and has dip angle of 33° across the entrance of the Buckeye Mine (Figure 4.). Buckeye Mine belongs to the Water Canyon mining district. Kalish (1953) described that Buckeye Mine has copper, lead, silver, and some gold mineralization and it was abandoned in 1901 because that the lower pit was filled with groundwater. The most recent activity was an attempt by Vernon F. Foy in the 1940's and 1950's to develop the Buckeye Mine, but it had only small amount of unprofitable production. North (1983) informed that the ore deposits of the Water Canyon district include some skarn, vein and replacement deposits associated with Tertiary intrusive rocks, as well as some deposits in faults between the Precambrian and Paleozoic rocks. The deposits in Copper Canyon are replacement deposits in Paleozoic limestone.

Engineering geologic map:

Engineering geologic map use different kind of symbols from conventional geologic map. I started learning how to create an engineering geologic map after Dr. Haneberg, who is one of my advisors, introduced the Genesis-Lithology-Qualifier (GLQ) system to me.

The GLQ system is proposed by Keaton (1984). The following paragraphs are abstracted from Keaton's paper to introduce the system and explain all the symbols being used in this report.

The Genesis-Lithology-Qualifier (GLQ) system of engineering geology mapping symbols, and the elements of the system were first described by the originator, Richard W. Galster. Keaton (1980) compiled a data sheet describing Galster's system and proposed a few additions to it. The chief difference between the GLQ system and most conventional geologic mapping systems is in the detail given to unconsolidated surficial materials (soils in the engineering sense). Most conventional geologic maps are constructed to portray the stratigraphic and structural relationships of bedrock units.

In many engineering applications, the age of geologic materials is either unimportant or so important that conventional symbols are not sufficient, so age terms are not included in the GLQ system. The GLQ system consists of symbols which have engineering significance as well as similarity to the Unified Soil Classification System (USCS) in engineering use, and the same material in different regions will be represented by the same symbol.

The general formula for symbols representing surficial materials can be stated as:

eAb(c)(d)

where A = Genetic symbol; usually single capital letter.

b = Lithology symbol; one or more lower case letters.

(c) = Qualifier symbol, if desirable; one or more lower case letters in parentheses.

(d) = Thickness, if applicable; Arabic number with feet or meter symbol in parentheses.

e = Modifier symbol, if applicable; one or more lower case letters to denote deposits of critical engineering and construction significance.

All symbols for surficial materials must have at a minimum a genetic symbol and a lithologic symbol. The genetic symbols include followings:

A - Alluvial C - Colluvial E - Eolian F - Fill (man-made)
G - Glacial L - Lacustrine M - Marine
R - Residual S - Slide V - Volcanic

Virtually all surficial materials may be classified by one of these genetic symbols. In some cases, interbeded materials can be denoted as, for instances, A/C means alluvial and colluvial deposits or G/L means glacial and lacustrine deposits. Occasionally, deposits of combined origin or uncertainty can be designated by a hyphen, for example: "A-C" or " R-C".

The most abundant or significant lithologic symbols are:

c - clay m - silt s - sand g - gravel
k - cobbles b - boulders r - rock rubble t - trash or debris
e - erratic blocks o - organic material p - peat
d - diatomaceous material

Commonly, a number of grain sizes are present in s single deposits. You can abbreviate with the use of a hyphen: "m-b" means constituents from silt to boulders and "rm-g" means signify rock rubbles in a matrix composed of silt, sand, and gravel.

Qualifier symbols are the followings:

1. For alluvial: (f)-fan morphology (fp)-present flood plain (te)-terrace (df)-debris fan (p)-pediment deposits
2. For colluvial: (sw)-slope wash (ta)-talus (cr)-creep deposits
3. For eolian: (l)-loess (d)-dune morphology
4. For fill deposits (u)-uncompacted (e)-engineered
5. For glacial deposits: (es)-esker (t)-till (ic)-ice contact (m)-moraine (k)-kame (o)-outwash
6. For lacustrine and marine:(b)-beach (ma)-marsh (de)-delta (ti)-tide lands
7. For residual deposits: (sa)-saprolite
8. For slide deposits:(ro)-rotational (ls)-lateral spread (fl)-flow (tr)-translational (sl)-slump
9. For volcanic deposits: (a)-ash (cl)clinker (pu)-pumice (ci)-cinders

Qualifier symbols may be used if noteworthy qualities are present and are generally unique for each genetic classification.

There are only three modifier symbols proposed, they are: c - cemented, e - expansive, and h - hydrocompactible. As indicated former, these symbols precede the genetic symbol. For example, "hAmcs(f)" means "hydrocompactible alluvial sandy, clayey silt in an alluvial fan".

Besides the surficial materials, the bedrock materials also got a formula as:

cAA(b)

where AA = Rock type symbol; usually one set of two capital letters representing geologic "shorthand".

(b) = Thickness, if applicable; Arabic number with feet or meter symbol in parentheses

c = Modifier symbol, if applicable; one or more lower case letter.

The use of this formula is similar to the above, for example, "QT" is quartzite, "SS" is sandstone, "BA" is basalt, and so on. "SS/SH" signifies interbeded sandstone and shale. But you have to be careful that "SS-ST" denotes "silty sandstone to sandy siltstone" and "$\frac{SS}{ST}$" means "sandstone over siltstone".

The symbols appear on Figure 3. follow the rules that are described above.

1. Cm-k(cr) - This is the deposits produced by creep on the slope. We classified this kind of deposits as colluvium. It contains silt, sand, gravel and cobbles.
2. Am-k - This is the alluvial deposits and is equal to the geologic symbol "Qal". It also contains silt, sand, gravel and cobbles.

3. Sm-k(fl) - Main debris flow deposits. It is classified as "slide". The deposits contain silt, sand, gravel, and cobbles.

Erosion factors:

In Copper Canyon, we can see that soil erosions are proceeding in debris flow channels (Figure 5.), creeping slopes, and also in the private land (Figure 6.). That may change the shapes of the flow channels, accelerate the rates of slope creep, and affect the shape of the land. Figure. 5 and 6 show the erosion channels formed after rains and snows in the winter of 1993-94.

Soil erosions can be proceeded through many ways, such as wind erosion, rainfall and snowfall erosions, groundwater erosion, and so on. Gray and Leiser (1982) described control factors for both rainfall and wind erosions and in their paper, they also mentioned about how the vegetation plays a role against erosion.

For rainfall erosion:
1. Climate - storm intensity and duration
2. Soil - inherent erodibility
3. Topography - length and steepness of slope
4. Vegetation - type and extent of cover

For wind erosion:
1. Climate - temperature, rainfall distribution, wind velocity and direction.
2. Soil - texture, particle size, moisture content, surface roughness.

Figure 5. Soil erosion in the debris flow channel I. It formed after snow this winter

Figure 6. Erosion channels in the private land formed after snow and rain this winter

3. Vegetation - type, height and density of cover, seasonal distribution.

Vegetation offers the best long-term protection against surficial erosion on slopes and provides some degree against shallow mass-movement. Vegetation prevents surficial rainfall erosion by:

1. Binding and restraining soil particles in place.
2. Filtering soil particles out of runoff.
3. Intercepting raindrops.
4. Retarding velocity of runoff.
5. Maintaining infiltration.

Debris flows:

There is complete gradation from debris slides to debris flows, depending on water content, mobility, and character of movement. The term "debris flow" defined as containing a relatively higher percentage of coarse fragments than mud flow does and it commonly results from unusually heavy precipitation or from thaw of snow or frozen soil (Varnes 1978). Flows usually follow preexisting drainageways, and they are often of high density so the large boulders can be rolled along.

Rahn (1986) also made some descriptions about debris flow. According to some classifications, debris flow is a coarse-grained earth flow and mud flow is a fine-grained one. Debris-flow deposits typically have 50 % of the solids larger than sand, and they contain 90% by weight solids, and have densities of 2-2.5 g/cm^3. The deposit consists of clayey matrix containing large angular boulders and rubble.

Debris flows could happen anywhere in the mountain range and would do a fatal harm to people and their properties. I think that is why so many geologists and engineers are interested in studying characteristics of debris flows and anxiously trying to predict when and where it will fail. Within the study area, we can see four obviously debris flow channels (marked as I., II., III. and IV. in the Figure 3), and many minor ones. I found that the owner built a concrete dam near the place where I collected sample IC and is between IB and IC. I think it probably to reduce or to prevent the damage.

It is very important for us to get familiar with the properties of debris flows. Such as the densities of the deposits and clasts, critical thickness of the deposit, slope angels, shear strength, cohesion values and friction angles. Because a flow is just like carrying itself through a channel for a long distance and then settle down as a deposit. Knowing the properties may help ourselves to become aware of the flowing process. Before we can calculate the value of shear stress k at the time it stopped flowing, we have to determine the density of each debris-flow deposit first. The method being used here is from Johnson and Rodine (1984) as follows:

STEP 1. Sample a representative volume of debris-flow deposit and separate coarse clasts (greater than about 10 mm diameter) from fine material. Determine the volume V_c of coarse clasts by measuring dimensions and computing volumes or by displacing a volumetric fluid.

STEP 2. Determine the average density ρ_c of coarse clasts. Generally select samples of different rock types and determine their densities in the laboratory.

STEP 3. Admix water in small increments to all the fine fraction (containing clasts smaller than about 10 mm diameter) of the sample until it becomes mobile. Then determine the density ρ_f of the reconstituted fine fraction by measuring the weight of a known volume.

STEP 4. Determine the total volume V_f of the reconstituted fine fraction.

STEP 5. The density of the reconstituted fluid debris ρ_d, including the coarse clasts, is then:

$$\rho_d = \rho_f + \left[\frac{V_c}{(V_c + V_f)}\right](\rho_c - \rho_f)$$

Now we find the densities, we have two ways approaching to the shear stress k (dn/cm^2) values by using the equations below and they are also from Johnson and Rodine (1984).

(I) use the thickness of the debris flow deposit

$$k = T_k * \gamma_d * \mathrm{Sin}(\delta)$$

where k is the shear strength. the unit is $dn/cm^2 = 0.1$ pascal

T_k is the thickness of the debris flow deposit. the unit is cm

δ is the slope angel of the deposit.

$\gamma_d = \rho_d g$ is the unit weight of the reconstituted debris. the unit is dn/cm^3

If the flow channel is roughly semicircular, then $T_k = R_k/2$

R_k is the radius of the channel.

If the flow channel is roughly rectangular or semi-elliptical in cross-section,

then $$T_k = \frac{0.5W_c}{\left(W_c/2D_c\right)^2 + 1} = \frac{D_c}{\left(2D_c/W_c\right)^2 + 1}$$

W_c is the critical width and D_c is the critical depth.

(II) measure the unusually large clasts in the debris flow deposit

$$k = 0.219\,h\,(\gamma_b - n\,\gamma_d)$$

where h is the height of the large block. the unit is cm

n is the volume fraction submerged in the deposit.

γ_d is the same as above.

γ_b is the density of the large block.

After we collect and calculate all data through upper procedures, we can use the data and the graph in Figure 7. to obtain the values of cohesive strength C and friction angle ϕ.

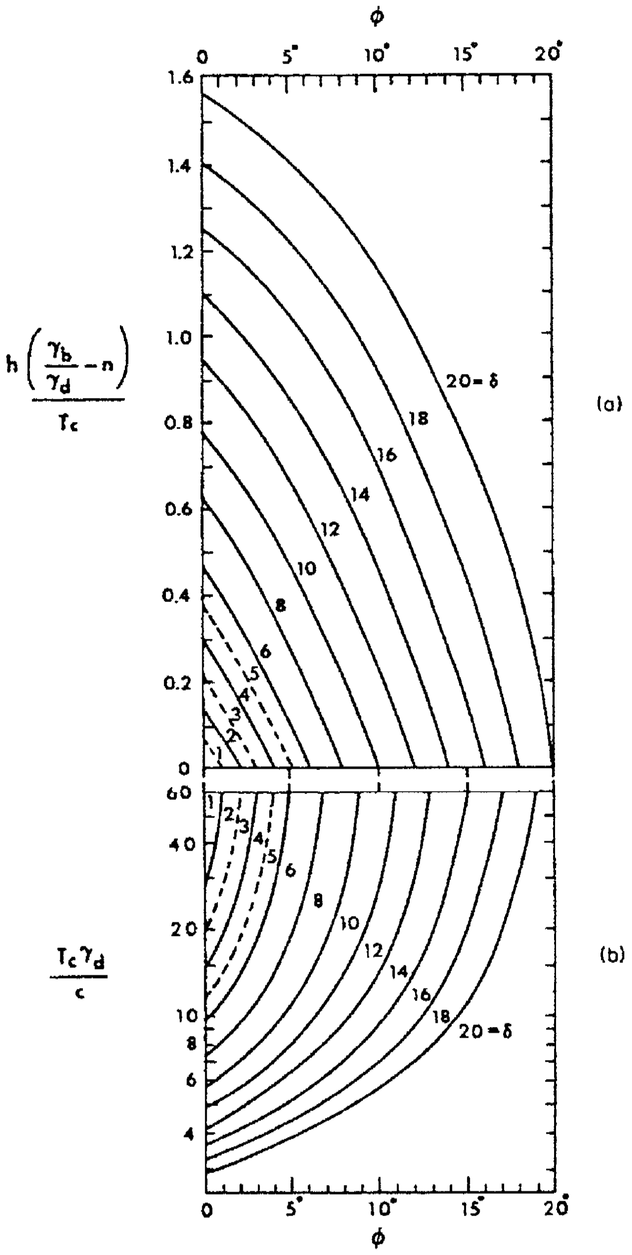


Figure 7. Graphs used to compute C and ϕ.

STEP 1. Calculate the value of $\frac{h(\frac{\gamma_b}{\gamma_d}-n)}{T}$ first.

STEP 2. From upper part (a) of Figure 7., use slope angle δ and the value in step1 to find ϕ value.

STEP 3. From lower part (b) of Figure 7., use ϕ value obtaining from step 2 and δ to find a value which is equal to $\frac{T_c \gamma_d}{C}$.

STEP 4. Use the value and the equation from above to calculate the value of C.

Cohesion is the shearing strength of the soil. It is affected by the mutual attraction of particles due to molecular forces and presence of moisture films (Rahn, 1986). Cohesion may vary from 0 pascal in dry sand or wet silt to 10^5 pascal in very stiff clays. And internal friction is the resistance to sliding within the soil mass. Gravel and sand impart high internal friction, and it will increase with sand and gravel content. The stability of the slope is affected largely by these two factors.

$\tau = c + \sigma \tan \phi$ where σ is the normal stress
τ is the shear stress

The equation is known as Coulomb's equation and is worldwidely used.

When considering stability of the slope, we can use friction angle and slope angle to calculate the factor of safety. The slope has to be an infinite and homogeneous soil mass.

$F = \tan \phi / \tan \beta$ for dry slope
$F = 0.5 \tan \phi / \tan \beta$ for fully saturated slope

where F = Factor of safety

ϕ = friction angle

β = slope angle

Laboratory studies:

In order to calculate the shear strength, friction angle, and cohesive strength of each debris flow, I simply collected 5 samples each for debris flow I & II and only 2 samples each for debris flow III & IV. Because the deposits of flow III & IV were disturbed and the boundaries are not easy to confine. Some data could not be obtained and I just measured densities, estimated the larger clasts of them and include these two sets for comparison.

I was able to get only 2 undisturbed samples of the debris flows, so the void ratios of most samples cannot be determined. Through laboratory works, all of the samples were analyzed and classified according to the Unified Soil Classification System (USCS, Appendix 1). The densities of all samples range from 2.29 - 2.53 g/cm^3. Because the fine fractions (particles pass sieve No. 200 which is 0.074 mm) of all samples are less than 5%. I didn't run the Atteberg's' limit tests on most of them. Table 1 & 2 give the summaries of the laboratory works and the detail analysis results are referred to appendix 2. Samples IA & IIE have Cc values very close to 1.0 and they meet all the other requirements, so I classified them into GW & SW.

Table 3., 4. and 5. below, show the data and results from the laboratory and field. Densities of I & II are the mean values from table 1 & 2.

Table 1. Geotechnical properties of the samples collected from debris flow I. and classified according to the Unified Soil Classification System

Sample No.	Undisturbed (Y/N)	Void ratio	Fines[1] (weight %)	Cc[2]	Cu[3]	Moisture content %	Density of debris[4]	Atterberg limits		Plasticity Index	USCS Class
								Plastic	Liquid		
IA	N	---	1.6	0.9	18.1	11.4	2.39	---	---	---	GW
IB	N	---	0.8	1.6	18.0	7.9	2.45	---	---	---	GW
IC	N	---	4.3	0.8	14.2	20.4	2.29	---	26.9	---	SP
ID	N	---	3.7	0.7	30.9	17.7	2.32	---	---	---	SP
IE	N	---	1.5	0.8	21.2	13.2	2.49	---	---	---	GP

Table 2. Geotechnical properties of the samples collected from debris flow II. and classified according to the Unified Soil Classification System

Sample No.	Undisturbed (Y/N)	Void ratio	Fines[1] (weight %)	Cc[2]	Cu[3]	Moisture content %	Density of debris[4]	Atterberg limits		Plasticity Index	USCS Class
								Plastic	Liquid		
IIA	Y	1.2	1.1	1.4	19.0	14.0	2.49	---	---	---	GW
IIB	N	---	3.7	0.7	13.1	16.3	2.33	---	24.6	---	SP
IIC	N	---	2.1	0.4	119.0	7.1	2.53	---	---	---	GP
IID	Y	1.0	1.6	0.3	47.5	13.6	2.41	---	---	---	GP
IIE	N	---	2.6	0.9	22.8	12.4	2.43	---	---	---	SW

1. Soil particles pass the No.200 (0.074 mm) sieve.
2. Cc = cofficient of curvature = $(D_{30})^2 / [(D_{10})(D_{60})]$.
3. Cu = cofficient of uniformity = $(D_{60})/(D_{10})$.
4. The unit of the density is g/cm^3.

Table 3. Summaries of four debris flows using method (I) to get k values

DEBRIS FLOW	I	II	III	IV
ρd (g/cm^3)	2.39	2.44	2.40	2.35
γd	2345	2394	2354	2305
Tk(cm)	65	55	---	---
δ	6.5	8.5	---	---
Sin δ	0.1132	0.1478	---	---
k (dn/cm^2)	17300	19500	---	---

Table 4. Summaries of four debris flows using method (II) to get k values

DEBRIS FLOW	I	II	III	IV
γd	2345	2394	2354	2305
ρb (g/cm^3)	2.62	2.55	2.64	2.64
γb	2570	2502	2590	2590
n	0.4	0.40	0.25	0.25
h(cm)	40	45	35	35
k (dn/cm^2)	14300	15200	15300	15400

The k value is correspond with the flowing rate of the debris flow. If it is quite fluid then the value of k is small. So we might say that debris flow I. is the slowest. Practically, in this result, four k values are around 1.43 kPa ~ 1.54 kPa, and they should be the same.

Table 5. C and ϕ calculated from Figure 7.

DEBRIS FLOW	I	II	III	IV
ϕ	2.4	1.0	---	---
C	13000	15000	---	---

3
3

Figure 8. Shows the deposits of debris flow I between the Copper Trial No.10 and the dam. The pillars of the wire fence had flushed away.

Descriptions:

Debris flow I. probably had ever did any damages to this area. Because the land owner built a concrete dam to obstruct the flow, and the retaining wall to keep the slope stable. The difference of the deposit inside and outside the dam is about 2.0-2.5 meters. If we look downstream from the dam, it is not easy to confine the channel boundary. I suppose that the former debris flow happened a long time ago, and most of the land is covered with grass, but we can still observe larger clasts scattered. The channel is deeper and larger than all the others in this area. After the channel across the trail in the land, the deposits become more obvious to distinguish. Many more large clasts were found in the channel that finally reaches the river.

Then we look upstream from the dam, the deposit is thicker and is more distinctive just inside the dam. We can see the channel, the lateral deposit ridge and the snout. The debris flow destroyed the pillars of the fences that is along the Copper Trail No.10 (Figure 8). I believe that after the dam had been built and the fences had been set, there was debris flow that had ever happened at least once. There are some but not much volcanic rocks scattered along the channel deposit. The rocks are reddish brown and look very conspicuously. If we trace the channel upstream from the trail, we may found many locations that show deeper caves and larger vertical differences. The soils flushed away and the bed rocks were exposed. Entire flow channel is meandering, and many sharp curvatures along the channel. Figure 9. shows two cross-sections of debris flow I. The estimated soil layers are not very thick and we can see the bed rock is limestone.

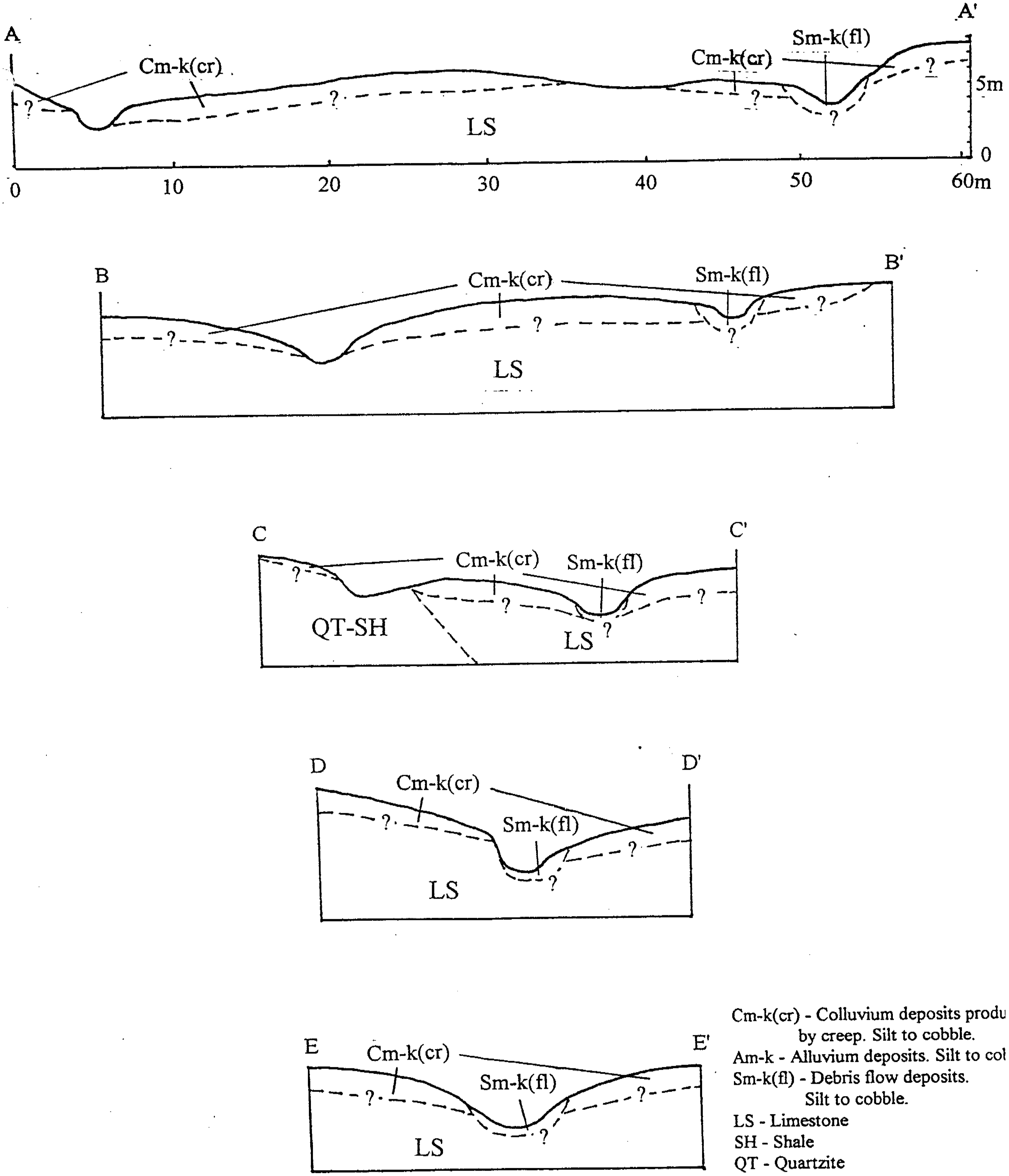


Figure 9. Cross sections perpendicular to the channel of debris flow I & II, AA', BB' and CC' are in the flow I, and DD' and EE' are in the flow II. All scales are the same.

Debris flow II. looks more interesting, the bed rocks exposed because of the debris flow took away the soil and we can identify the contact of Kelly Limestone, Sandia Formation and Madera Limestone. Although the deposit near the river doesn't preserve very well, we can merely identify some ambiguous boundary and collect samples for laboratory test. It looks like an alluvium fan deposit, partly covers with grass and larger clasts dispersed. The pillars of the wire fences near the trail were also demolished by debris flow.

When we take a look at the upstream of the flow, there are two channels from different directions (Figure 10). They combine with each other at about 7 meters before the channel across the trial. The one at the right-handed side is steeper but smoother and the other at the left-handed side is more released but more zigzag. The two contacts of three formations can be seen in the left-handed channel. When we trace the left channel upstream, it has many places that have larger vertical differences and we meet first exposed bed rock is Kelly Limestone followed by Sandia shale which is more fragmental than the others, and then is Madera Limestone. Figure 9. also have three cross-sections of debris flow II. We can see the relative positions of two channels

Debris flow III. looks very similar to debris flow IV. The channel flowed northward as all the others but while it encountered the iron fences it turned eastward along the trial for about 13 m. and then went downward again. It is because of the trial is steeper here.

After the channels flow through the fences, both of the channels and the deposits are not so obviously to recognize. I think that materials of the debris flow

Figure 10. Deposits of the debris flow II at the site of two channels combined each other.

were disturbed and trapped by fences and trees, so only part of them kept going and then settled down as deposits.

Debris flow IV. is not so large in comparison with flow I. and II. But we still can see the lateral deposit in the channel very clearly at certain spots. Just like the debris flow III, when the flow went downward and met the trial, the channel was disturbed and part of the flow was trapped by the iron fences and trees. Some flowed through and some settled down on the trial. That's the reason why the deposit on the trial is very clearly. But through people's destruction, it is not easy to preserve completely. The width of the deposit on the trial is about 8.5 m. I estimate that the fences have a largest separation of 1.0 m and the trees in the channel are deformed. The flow went far more than flow III and very near the abandoned house.

Creeps:

Creep as described in the "Glossary of Geology", which is edited by Gary, McAfee and Wolf (1972), is the slow, gradual, more or less continuous, non-recoverable (permanent) deformation sustained by ice, soil, and rock materials under gravitational body stresses. Soil-creep is the best-known and most widely distributed type of slow flowage in nature. The deformation rate on a hillside depends not only on climate conditions and angle of slope but also on type of soil, parent material, and many other factors (Sharpe, 1960).

Hansen (1984) defined by its velocity, owing to the slow nature of the movement. There are usually three types of creep:

1. Seasonal creep, or movement within the depth of soil affected by seasonal changes in soil moisture and soil temperature;

2. Continuous creep, where shear stress exceeds the strength of the material;

3. Progressive creep, which is associated with slopes reaching the point of failure by other mass movements.

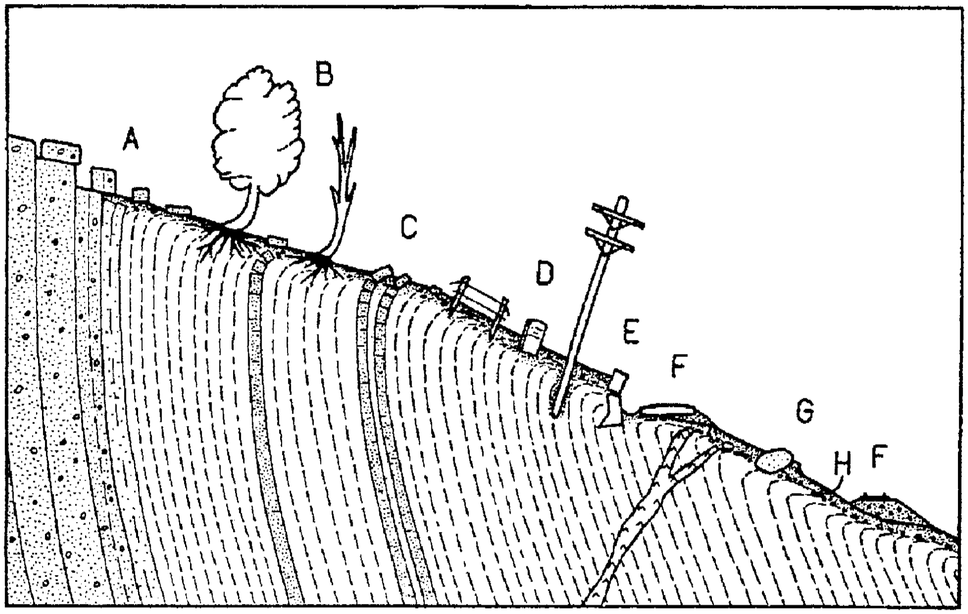


Fig. 11. A typical model of the slope creeps

Figure 11. is a typical model from Sharpe (1960). It indicates many common evidences that we usually use to identify soil creeps. (A) Moved joint blocks; (B) trees with curved trunks concave upslope; (C) downslope bending and drag of

bedded rock, weathered veins, etc., also present beneath soil elsewhere on the slope; (D) displaced posts, poles, and monuments; (E) broken or displaced retaining walls and foundations; (F) roads and railroads moved out of alignment; (G) turf rolls downslope from creeping boulders; (H) stone-line at approximate base of creeping soil.

The movement of creep is not so instant and prominent and it could probably take a period of time to be noticeable. People usually ignore where creep may exist and they even don't know about the reason why their possessions were wounded.

Evidences:

Through field observation, we found that both slopes of the canyon are unstable, especially in the south slope. A large range of area is creeping and the bottom of the canyon as well. We have discovered many phenomena listed below to prove the slope is creeping.

1. All of the trees on the south slope through entirely canyon look like the one shown in Figure 11. No matter what they are big trees or small ones, their trunks near the roots grow curved. Because trees have the tendency growing against gravity and toward sunshine, their trunks always straight upward. The slope is creeping downward now, and there are forces push aside the trunks, but the roots stay where they are, so all trunks become like this. Some of them are seriously curved (Figure 12).

Figure 12. The trunk near the roots of the tree is seriously curved.

Figure 13. When the roots can not resist against the creep, it fell down

2. During the study time, I walked through whole canyon along the trial periodically. I had ever seen trees fell down to the ground, but not quite often. It seemed to happen at which creep is more active (Figure 13). I noticed that everytime after it had heavy snow or rain, there probably had tree(s) fell down. Water pulled the trigger to the unstable slope. The latest two fallen trees that I noticed were between the dates of Jan. 27 and Feb. 17.

3. After trees fell down, they would leave holes there. It won't take "creep" a lot of time to recover them. I tried to estimate two holes of them. First one, it has 30cm in diameter and 15cm in depth when I noticed it, and it only took creep three months or so to get the hole back to normal with the help of rain. The second is a bigger one which has 80cm in diameter and 40cm in depth, and it is getting smaller day by day.

4. Almost all pillars of the wire fence which is used by the land owner to confine the property boundary are found to have a certain degree of tilt and separation. The pillars of the cattle pen at front of the house are also inclined, but they don't seem seriously as the ones on the slope.

5. The rains and snows may help creeping whether they are small or heavy because the water content of the soil would get higher and even saturated. Once the soil became mobile, it is easier to creep or to flow. Everytime after it rained or snowed, I detected some small scars on the slope.

6. The side-wall of the abandoned house has deformed, because there was soils pushing on it . I measured the difference between inside and outside of the wall is about 1.2 meter (Figure 14). Such phenomenon indicates that creep is

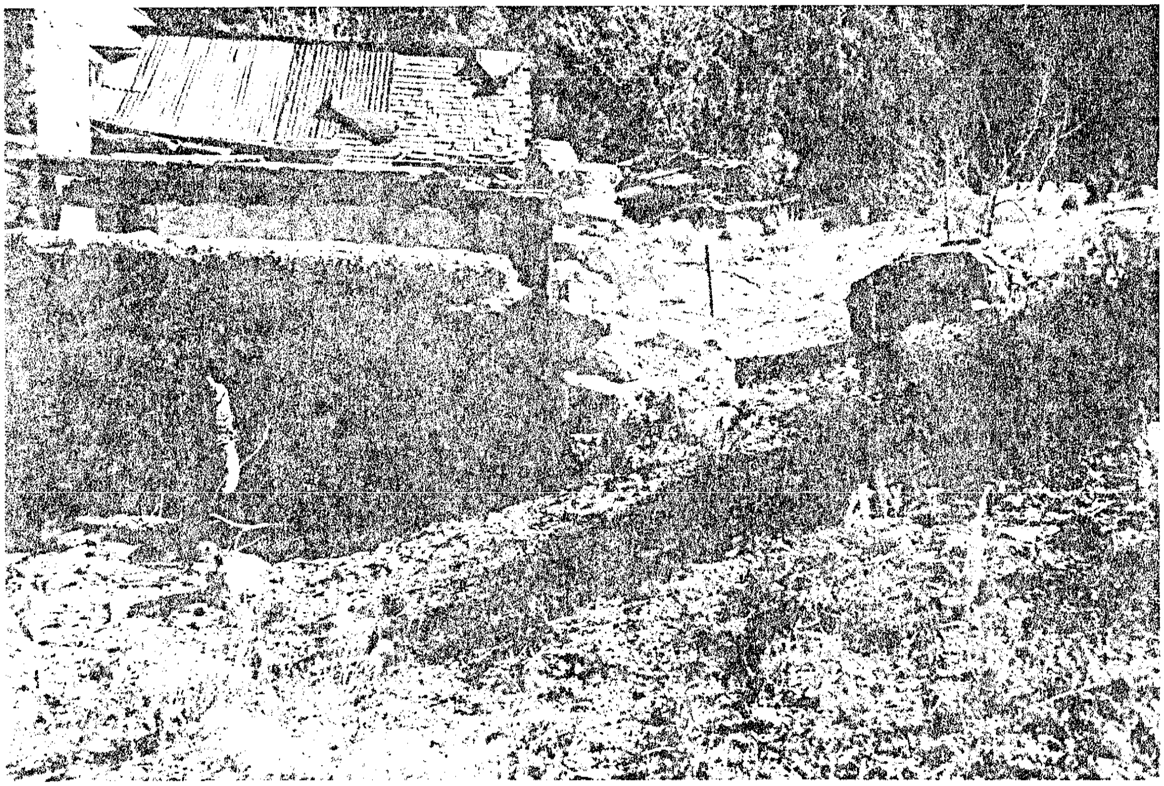


Figure 14. The land on both sides of the wall is quite different in height.

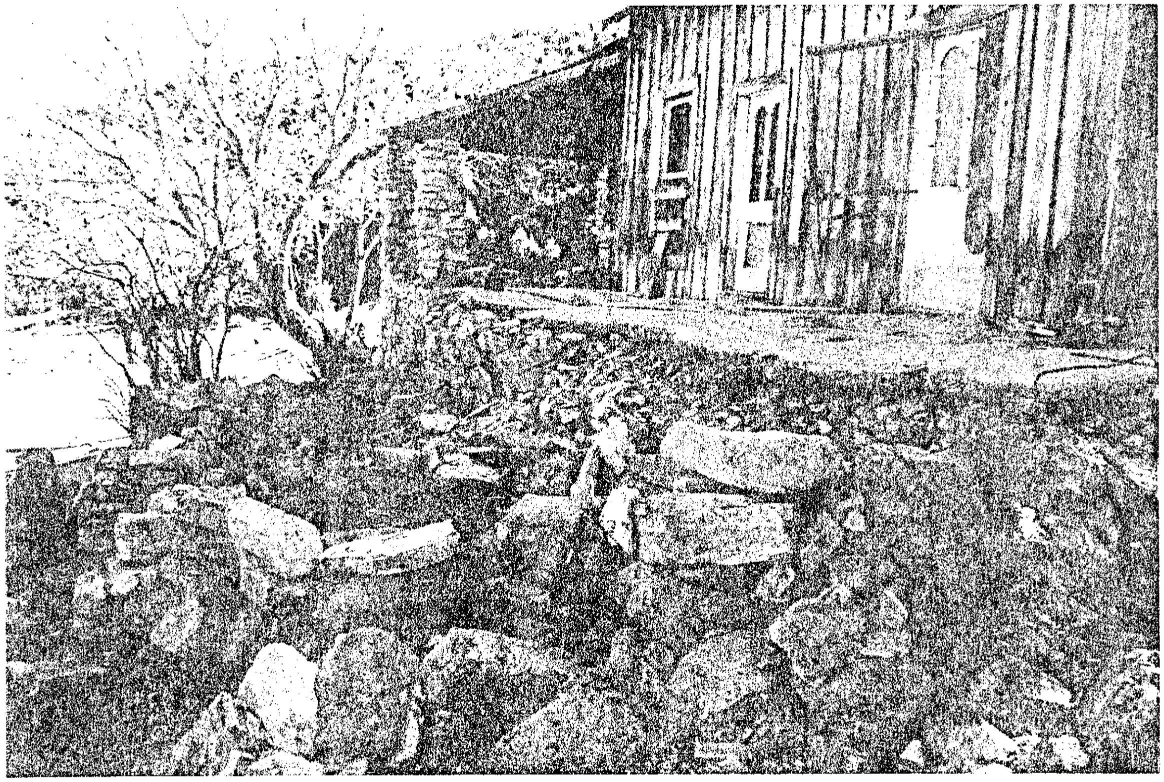


Figure 15. The tree is bend and the base is deformed.

proceeding. I also found that the base of the house has a large separation and the wall of the base is partly failed. It proves that the whole house is moving parallel because of creep (Figure 15).

7. Creep also occurs at the deposit of debris flow III. and IV. just inside the fences. Because they have larger slope angles there combined with the creep of the slope themselves. I think that the deposit was not so dense is one of the reasons and it would promote the creep rate.

Field and laboratory studies:

Since the whole area is unstable and doesn't move equally, it is not easy for me to measure the exact movement of the slope. In order to estimate the approximate rate of the deformation, I randomly choose three points on the slope (these points are near the places where I collected sample marked as No. 5, 8 and 12 in the Figure 3.) and set symbols for observation and record. I used three steel sticks and originally I pushed them into slope and kept them straight upward. I measured each point to a stationary point respectively and record their changes periodically.

According to the data and phenomenon that I got from field, the most active place should be around the range between debris flow III. and IV. I estimate the deformation rate is about 12.0 cm per year.

The deformation rate of the point which is between debris flow II and III is 10.2 cm per year. And the rate for west-side of the slope which is in the middle of debris flow I and IV is 8.8 cm per year.

Table 6. Geotechnical properties of the samples collected from creeping slope within the study area and classified according to the Unified Soil Classification System.

Sample No.	Undisturbed (Y/N)	Void ratio	Fines[1] (weight %)	Cc[2]	Cu[3]	Moisture content %	Dry density of sample[4]	Atterberg limits		Plasticity Index	USCS Class
								Plastic	Liquid		
18	Y	1.6	1.7	1.0	7.3	15.5	0.91	---	---	---	SW
19	Y	1.7	1.9	1.2	7.2	18.2	1.07	---	---	---	SW
1	Y	1.1	1.9	1.0	12.7	12.6	1.22	---	---	---	SW
8	Y	1.5	2.0	1.1	5.3	17.6	1.07	---	---	---	SP
4	Y	1.6	2.2	1.0	6.8	12.1	1.14	---	---	---	SW
10	Y	1.2	2.3	1.0	7.0	12.1	1.02	---	---	---	SW
3	Y	1.6	2.6	1.1	5.9	10.8	1.10	---	---	---	SW
13	Y	1.0	2.9	1.0	8.2	12.9	1.19	---	---	---	SW
11	Y	1.0	3.0	0.9	9.7	13.8	1.05	---	---	---	SW
17	Y	1.3	3.5	1.1	12.9	26.1	1.08	---	---	---	SW
14	Y	1.7	3.8	1.1	6.4	15.7	0.96	---	---	---	SW
9	Y	1.5	4.3	1.0	7.5	27.8	1.02	---	---	---	SW
15	Y	1.5	4.6	1.0	8.2	17.6	1.09	---	---	---	SW
6	Y	1.1	4.9	0.9	8.7	26.0	0.95	---	31.3	---	SW
12	Y	1.3	6.6	1.2	5.0	18.6	1.20	27.7	46.3	18.6	SP-SM
5	Y	1.3	8.0	0.5	8.9	21.8	1.41	29.7	39.5	9.8	SP-SM
16	Y	1.5	9.3	0.6	8.8	26.6	0.73	29.3	40.4	11.1	SP-SM
7	Y	1.2	10.2	0.5	21.1	15.5	1.16	22.4	28.3	5.9	SP-SM
2	Y	1.4	15.7	1.1	3.3	24.4	1.37	26.8	35.1	8.3	SM

1. Soil particles pass the No.200 (0.074 mm) sieve.
2. Cc = cofficient of curvature = $(D_{30})^2 / [(D_{10})(D_{60})]$.
3. Cu = cofficient of uniformity = $(D_{60})/(D_{10})$.
4. The unit of the density is g/cm^3.

From the creeping slope, I collected 19 undisturbed samples for laboratory analysis. The results show the properties including void ratio, particles distribution, dry density, Atterberg's limits, and moisture content. The same as debris flows samples, each sample was analyzed and classified according to the Unified Soil Classification System (USCS). Table 6. shows the summaries of the laboratory analyses results. And the detail soil samples distributions are in the appendix 3. I did the same thing as samples IA & IIE. Samples No. 6 & 11 have Cc values close to 1.0 and sample No. 3 has Cu value close to 6.0, so they all classified as SW.

We can see that most of the void ratios are pretty high. Holtz and Kovacs (1981) suggested that normally, typical values of void ratios for sands may range from 0.4 to about 1.0 and for clays vary from 0.3 to 1.5 and even higher for some organic soils. According to lab results, I calculate the mean value of the dry density, which is defined as weight of dry soils divide by total volume of the undisturbed sample, is around 1.08 g/cm^3. It is pretty low. All these mean that soils of the slope are very very loose.

Some of the samples have relatively higher moisture content. Because I collected these samples only one week after the snow melted and some are just under trees where the sunshine barely reached. I collected samples of debris flows at just one more week later and I was fortunate to collect the samples because it rained the very next day.

We can roughly divide all samples into two groups: the fine fractions over 5% and less than 5%. Sample No. 5, 7, 12, 15, and 2, they are classified as SP-SM or SM , and all the others are SW with an exception of No. 8. The fine fractions ranging from 1.7% to 15.7% are largely depending on the depth where I digged the hole and collected the sample. I think that is because the slope is creeping. The soil is shearing and all of the particles chafe against one another. The deeper it goes into, the larger the forces are.

Discussion:

Many trees that are grown in the middle of the channel or debris deposits look like the trees in the creeping slope whose trunks are bend. The reasons for both situations are not the same. As I have mentioned above, the reason for trees whose trunk is curve in the slope is their tendency of growing anti-gravity and photo-sensitivity, and for the trees in the channel is the materials of the debris flow pushed them. Trees in the debris flow must have grown before debris flow(s) happened.

The ten samples collected from debris flows deposits are not all classified as GW or GP. ID & IIE are very close to GP & GW respectively, they all contain nearly 50% of grain size larger than No. 4 sieve (4.76mm in diameter). IC & IIB were collected at the middle segment of the channel, and they do not match Rahn's (1986) description (which is in the second paragraph under the title of debris flows, says the typical debris flow deposit has 50 % of the solids larger than sand), and maybe they are not typical enough to be the samples of the deposits.

When I tried to create table 6, I considered arranging the samples according to the percentage of fine fraction each sample instead of the sample numbers. The benefit of arrange in this way is that all of the SW & SP samples, SP-SM samples and SM sample are group together respectively, and it is easy to compare with each other.

In USCS, the requirements of GW (well-graded gravels with little or no fine) are $Cu > 4$ and $3 \geq Cu \geq 1$, and for SW (well-graded sands with little or no fine) are $Cu > 6$ and $3 \geq Cu \geq 1$. Several samples don't completely meet all of these, but very close to. What I considered is when I analyzed the samples and plotted the data into a semi-log figure, I am not skillful at that and everything might not accurately be done. Besides that, I also examine the curves in the semi-log figures to make sure the curves are smooth. So I loose the rules a little bit and classified them.

According to Coulomb's model, only when friction angle $\phi \geq$ slope angle δ the slope is stable. In table 5, ϕ for debris flow I is 2.4° and for debris flow II is 1.0°, both are smaller than their slope angles. So the ϕ values for debris I and II are possible.

In Table 3., some data are missing because the channels and deposits of the flow III. and IV. had been disturbed. It's very difficult for me to collect what I need for the table. So I neglected the C and ϕ.

Only when trees and other plants are big enough and their roots go through the creep layer and reach the bed rocks, they could promote the stability of the slope. Otherwise, I don't think it will help a lot. On the contrary, their weight will add to the slope and make it slip down.

The deformation rates for three places may use as references. Because I don't have a precise tool to measure the deformation and I am not exactly sure the points that chose as fixed are really firm.

Through the study in the copper canyon during past several months, I get familiar with many characteristics about debris flow and several methods in the field. I also testify that the south slope is as active as what I expected. Snows and rains would do a large help to the creep. Besides these, I've learned that the whole study area is unstable. If the owner wants to rebuilt the houses or to develop for another purpose, the most important is to prevent the damages that would cause by creeps and debris flows.

Acknowledgments:

I really appreciate my advisors, Dr. William C. Haneberg, Dr. Peter S. Mozley, and Dr. Laurel B. Goodwin, for offering consultations and references. They also reviewed the report for accuracy and help me for improvement. And I wish to thank Dr. Kalman I. Oravecz for offering the tools I need, to Dr. Aimone for the lab use, and to Terrence Ho and Vincent Lin for helping me in surveying the study area.

References:

Barnes, J. W. 1981, Basic geological mapping: The Geological Society of London, Wales

Bowring, S. A., Kent, S. C., and Sumner, W. 1983, Geology and U-Pb geochronology of Proterozoic rocks in the vicinity of Socorro, New Mexico, in New Mexico Geological Society Guidebook, 34th field conference, Socorro Region II, 1983, p. 137.

Brunsden, D., and Prior, D. B. 1984, Slope instability: John Wiley and Sons, New York, pp. 290-310.

Chapin, C. E., Chamberlin, R. M., Osburn, G, R., and White, D. W. 1978, Exploration framework of the Socorro geothermal area, New Mexico, in Chapin, C. E. and Elston, W. E., eds., Field guide to selected cauldrons and mining districts of the Datil-Mogollon volcanic field, New Mexico: New Mexico Geological Society Special Publication No. 7, pp. 114-129.

Costa, J. E., and Wieczorek, G. F. 1987, Debris flow / Avalanches: process, recognition, and mitigation: The Geological Society of America, Colorado.

Gary, M., Mcafee, Jr. R., and Wolf, C. L. 1972, Glossary of Geology: p. 164.

Gray, D. H., and Leiser, A. T. 1982, Biotechnical slope protection and erosion control: Van Nostrand Reinhold Company, New York, pp. 10-13, 37-39.

Ho, C. S. 1981, Physical geology: Wu Nan Book Co., Taiwan, pp. 173-193.

Holtz, R. D., and Kovacs, W. D. 1981, An introduction to geotechnical engineering, Prentice-Hall, Inc., New Jersey, p.12.

Kalish, P. 1953, Geology of the Water Canyon area, Magdalena Mountains, Socorro County, New Mexico: New Mexico Institute of Mining and Technology, unpublished M. S. thesis,

Keaton, J. R. 1984, Genesis-Lithology-Qualifier (GLQ) system of engineering geology mapping symbols: Bulletin of the Association of Engineering Geologists Vol. XXI, No. 3, pp. 355-364.

Krewedl, D. A. 1974, Geology of the central Magdalena Mountains, Socorro County, New Mexico: University of Arizona, unpublished Ph.. D. dissertation,

North, R. M. 1983, History and geology of the precious metal occurrences in Socorro County, New Mexico, in New Mexico Geological Society Guidebook, 34th field conference, Socorro Region II, 1983, pp. 265-266.

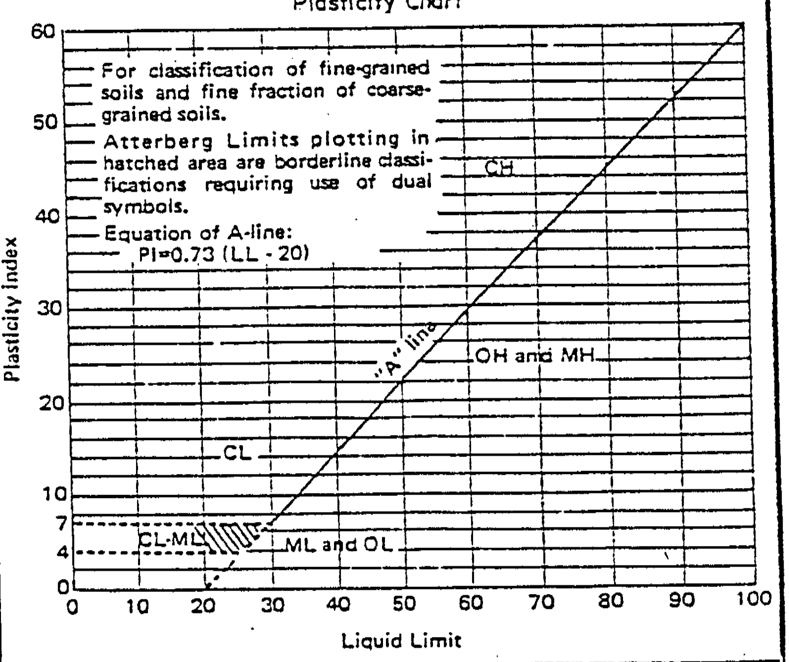
Rahn, P. H. 1986, Engineering geology, An environmental approach: Elsevier Science Publishing Co., Inc., New York, pp. 147-181.

Sharpe, S. C. F. 1960, Landslides and related phenomena: Pageant Books, Inc., New Jersey, pp. 21-48, 127-128.

Sumner, W. 1980, Geology of the Water Canyon - Jordan Canyon area, Socorro County, New Mexico: New Mexico Institute of Mining and Technology, unpublished M. S. thesis,

Appendix 1

UNIFIED SOIL CLASSIFICATION SYSTEM

jor divisions			Group symbols		Typical names	Laboratory classification criteria		
	Gravels (More than half of coarse fraction larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 per cent . . . . GW, GP, SW, SP More than 12 per cent . . . . GM, GC, SM, SC 5 to 12 per cent . . . . *Borderline* cases requiring dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM	d	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols.
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
than half of material is smaller than No. 200 sieve	Silts and clays (Liquid limit less than 50)		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart 		
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL		Organic silts and organic silty clays of low plasticity			
	Silts and clays (Liquid limit greater than 50)		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity, organic silts			
	Highly organic soils		Pt		Peat and other highly organic soils	SOIL TESTING SERVICES, INC. NORTHBROOK ILLINOIS 60062		

For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg Limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line:
PI=0.73 (LL - 20)

Appendix 2

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. IA

Total wt in grams of sample, W_s = 680.6 g

Wt in grams of material > No. 4 sieve = 354.8 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	53.7	7.9		92.2
0.500	12.7	1/2-in.	97.3	14.3		77.9
0.375	9.52	3/8-in.	73.1	10.7		67.2
0.250	6.35	No. 3	74.8	11.0		56.2
0.187	4.76	No. 4	55.9	8.2		48.0
		Pan				
0.132	3.36	No. 6	42.6	6.3		41.7
0.094	2.38	No. 8				
0.079	2.00	No. 14	101.9	15.0		26.7
0.047	1.19	No. 16				
0.033	0.84	No. 20	62.5	9.2		17.5
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	69.9	10.3		7.2
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	23.2	3.4		3.8
0.0041	0.105	No. 140	8.3	1.2		2.6
0.0029	0.074	No. 200	6.5	1.0		1.6
		Pan	10.9	1.6		
Total weight in grams			680.6			

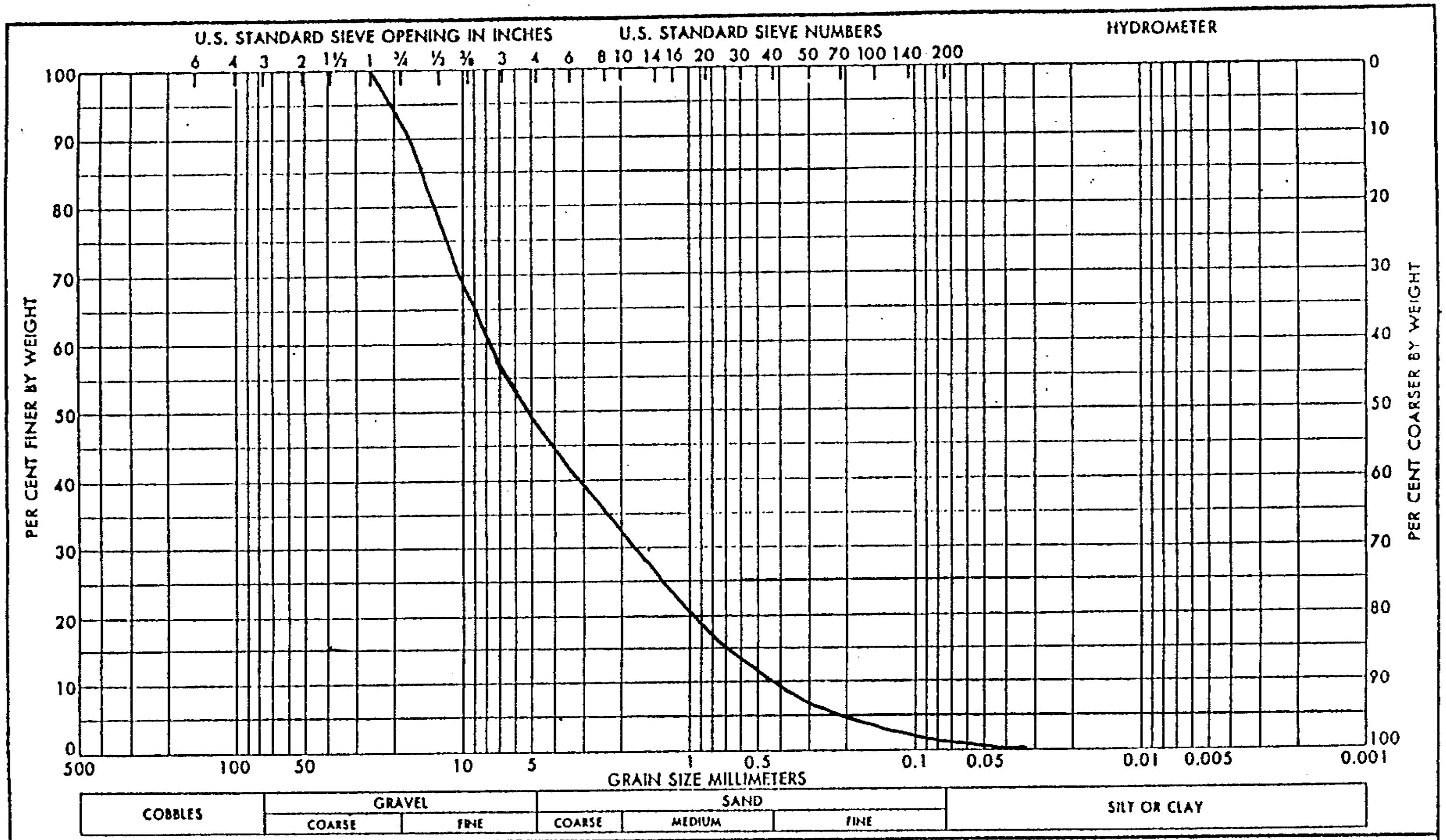
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
		GW				
IA						
D_{10}	0.43					
D_{30}	1.7	Cu= 18.1				
D_{60}	7.8	Cc= 0.9				

GRADATION CURVES

PROJECT

AREA

BORING NO.

DATE

SIEVE ANALYSIS

Date ______

Project ______

Boring No. ______ Sample No. IB

Total wt in grams of sample, W_s = 1082.3g | Wt in grams of material > No. 4 sieve = 753.7 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				100.0
1.00	25.4	1-in.	114	10.5		89.5
0.750	19.1	3/4-in.	238.2	22.0		67.5
0.500	12.7	1/2-in.	216.6	20.0		47.5
0.375	9.52	3/8-in.	62.3	5.8		41.7
0.250	6.35	No. 3	79.4	7.3		34.4
0.187	4.76	No. 4	43.2	4.0		30.4
		Pan				
0.132	3.36	No. 6	49.2	4.5		25.9
0.094	2.38	No. 8				
0.079	2.00	No. 14	109.5	10.1		15.8
0.047	1.19	No. 16				
0.033	0.84	No. 20	66.8	6.2		9.6
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	64.7	6.0		3.6
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	18.0	1.7		1.9
0.0041	0.105	No. 140	6.5	0.6		1.3
0.0029	0.074	No. 200	5.2	0.5		0.8
		Pan	8.7	0.8		
Total weight in grams			1082.3			

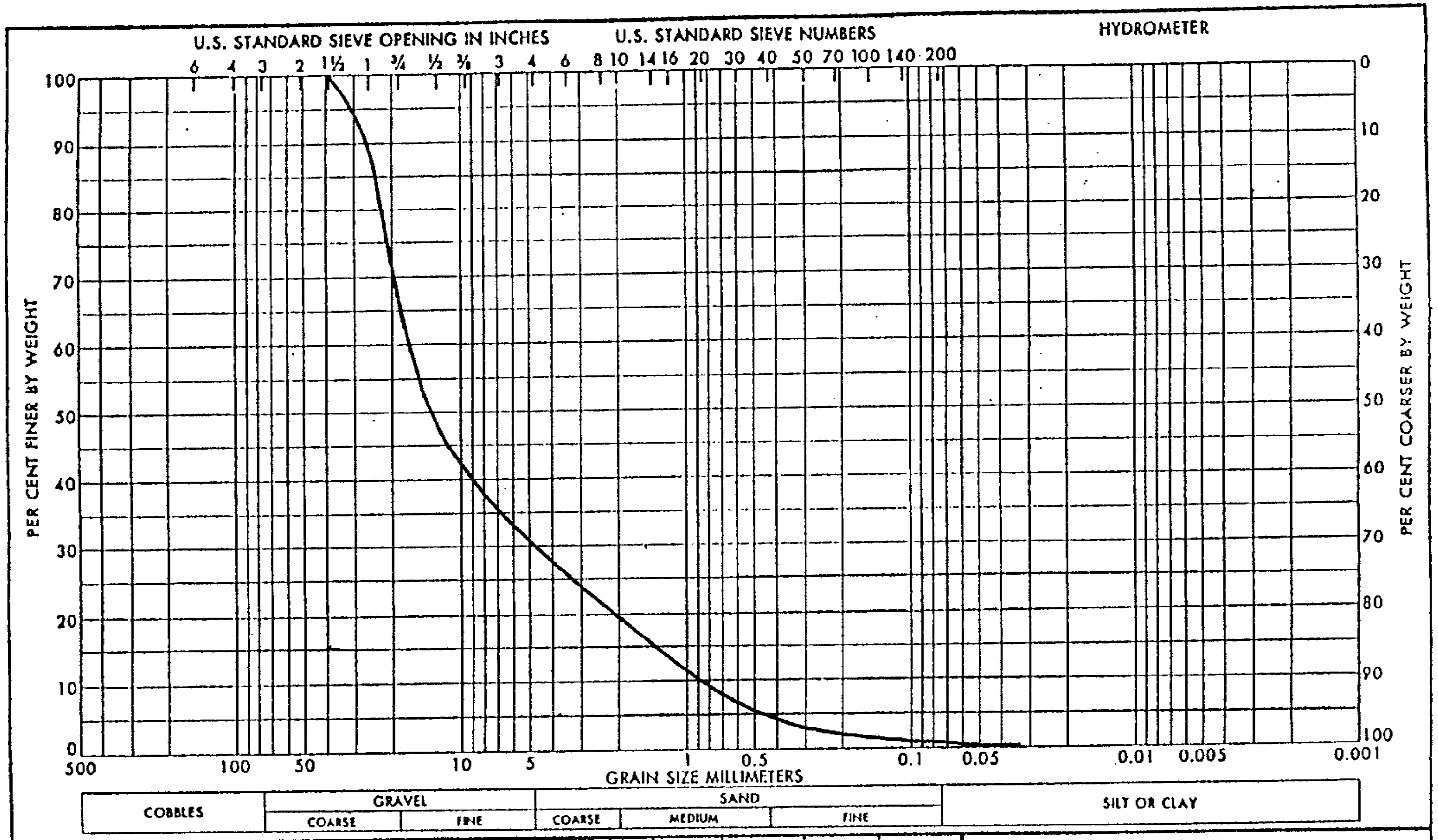
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IB		GW				
D_{10}	0.89					
D_{30}	48	$C_u = 18.0$				
D_{60}	16	$C_c = 1.6$				

GRADATION CURVES

PROJECT

AREA

BORING NO.

DATE

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. IC

Total wt in grams of sample, W_s = 699.1 g	Wt in grams of material > No. 4 sieve = 182.3 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	26.7	3.8		96.2
0.500	12.7	1/2-in.	69.4	9.9		86.3
0.375	9.52	3/8-in.	24.9	3.6		82.7
0.250	6.35	No. 3	41.2	5.9		76.8
0.187	4.76	No. 4	20.1	2.9		73.9
		Pan				
0.132	3.36	No. 6	25.0	3.6		70.3
0.094	2.38	No. 8				
0.079	2.00	No. 14	98.8	14.1		56.2
0.047	1.19	No. 16				
0.033	0.84	No. 20	69.0	9.9		46.3
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	163.4	23.4		22.9
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	61.7	8.8		14.1
0.0041	0.105	No. 140	41.7	6.0		8.1
0.0029	0.074	No. 200	26.9	3.8		4.3
		Pan	30.3	4.3		
Total weight in grams			699.1			

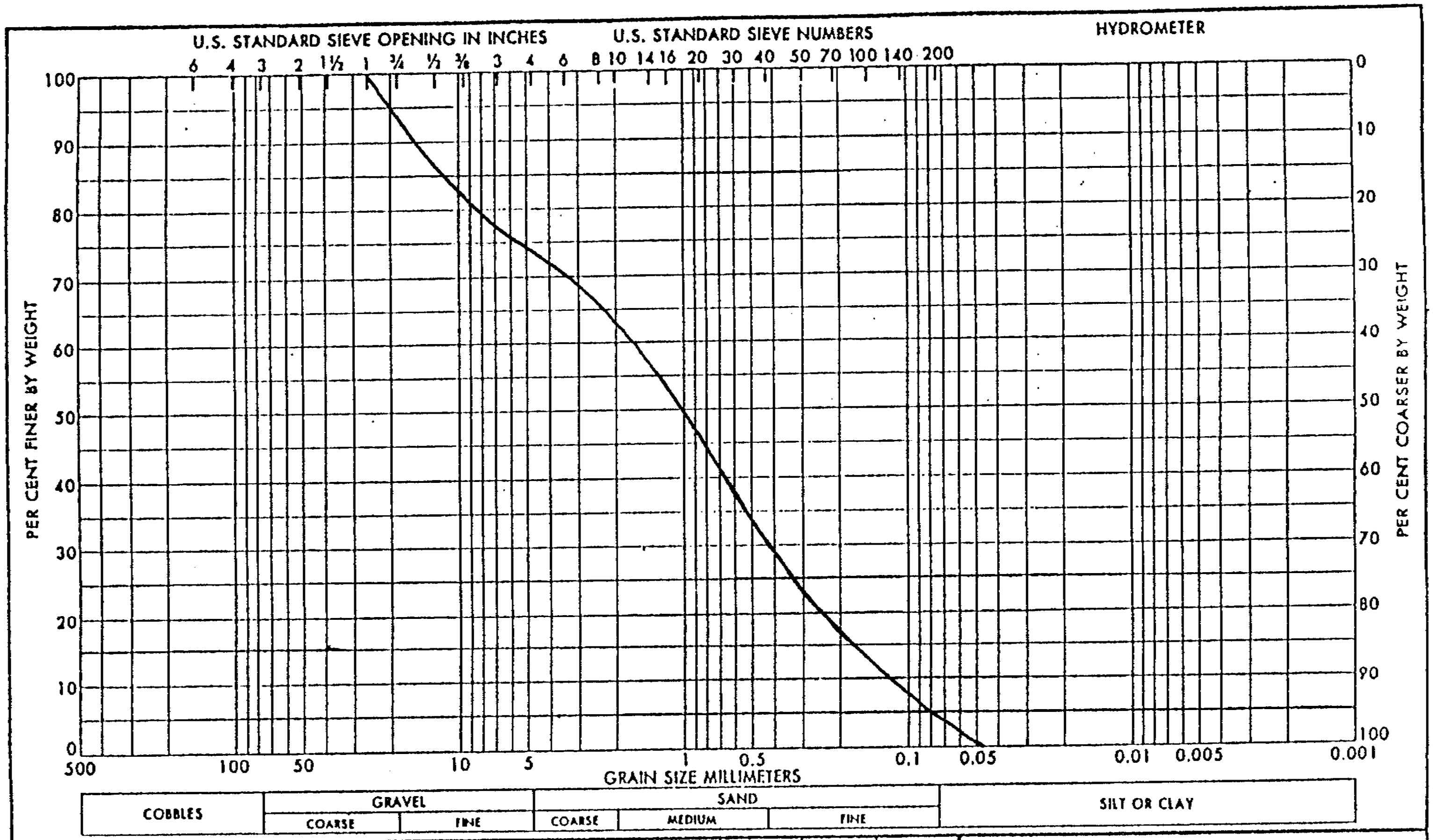
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IC		SP		269		
D_{10}	0.12					
D_{30}	0.41	C_u = 14.2				
D_{60}	1.7	C_c = 0.8				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. ID

Total wt in grams of sample, W_s = 649.5 g

Wt in grams of material > No. 4 sieve = 323.3 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	78.3	12.1		88.0
0.500	12.7	1/2-in.	55.6	8.6		79.4
0.375	9.52	3/8-in.	69.4	10.7		68.7
0.250	6.35	No. 3	66.7	10.3		58.4
0.187	4.76	No. 4	53.3	8.2		50.2
		Pan				
0.132	3.36	No. 6	50.4	7.8		42.4
0.094	2.38	No. 8				
0.079	2.00	No. 14	59.1	9.1		33.3
0.047	1.19	No. 16				
0.033	0.84	No. 20	42.7	6.6		26.7
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	93.6	14.4		12.3
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	28.8	4.4		7.9
0.0041	0.105	No. 140	9.9	1.5		6.4
0.0029	0.074	No. 200	17.4	2.7		3.7
		Pan	24.3	3.7		
Total weight in grams			649.5			

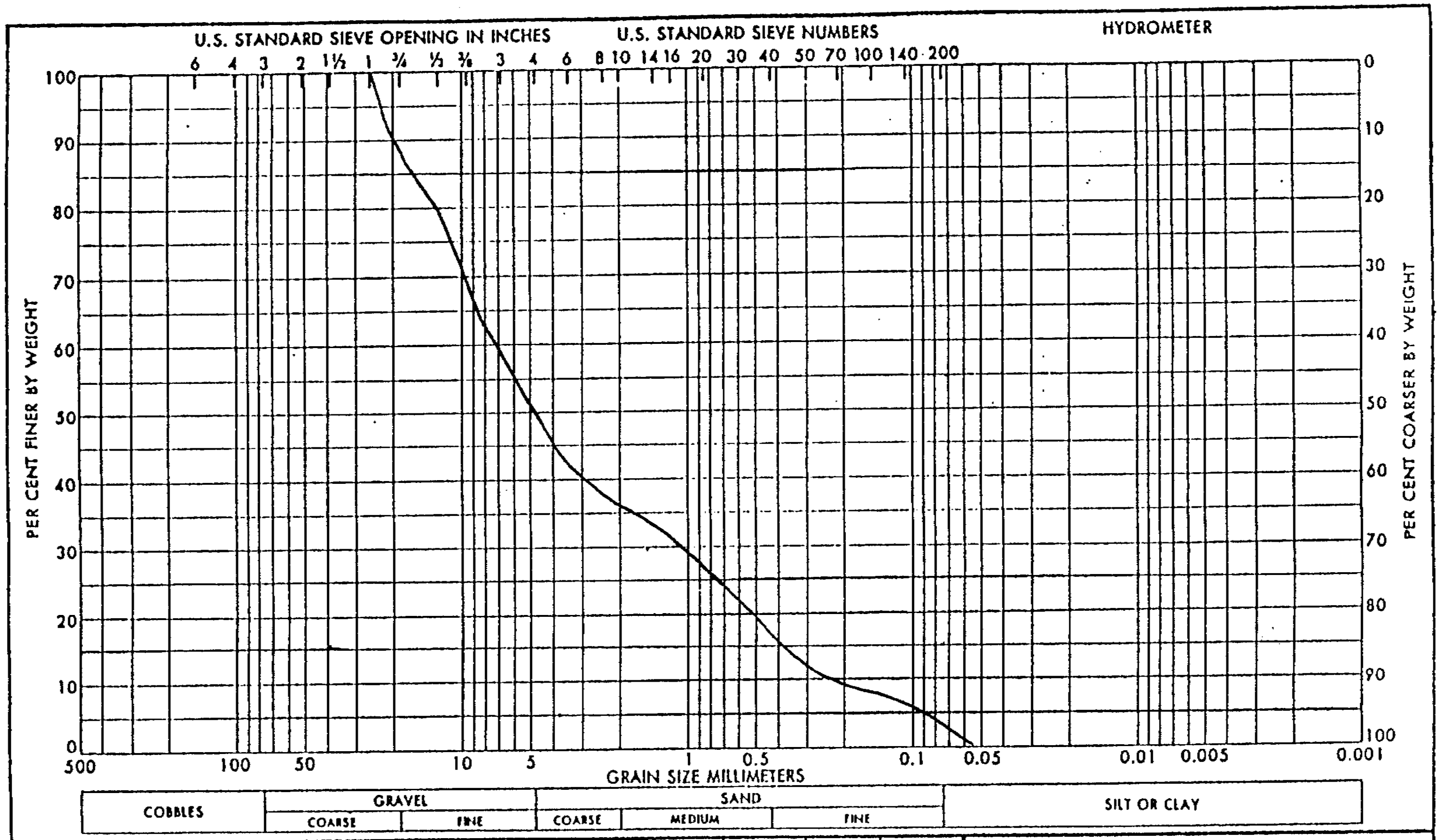
Partial percent retained = $\dfrac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$

Total percent retained = $\dfrac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
ID		SP				
D_{10}	0.23					
D_{30}	1.1	C_u = 30.9				
D_{60}	7.1	C_c = 0.7				

GRADATION CURVES

PROJECT

AREA

BORING NO.

DATE

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. IE

Total wt in grams of sample, W_s = 677.2g	Wt in grams of material > No. 4 sieve = 344.6g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	49.0	7.2		92.7
0.500	12.7	1/2-in.	82.6	12.2		80.5
0.375	9.52	3/8-in.	71.4	10.5		70.0
0.250	6.35	No. 3	79.7	11.8		58.2
0.187	4.76	No. 4	61.9	9.1		49.1
		Pan				
0.132	3.36	No. 6	50.1	7.4		41.7
0.094	2.38	No. 8				
0.079	2.00	No. 14	83.4	12.3		29.4
0.047	1.19	No. 16				
0.033	0.84	No. 20	51.7	7.6		21.8
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	88.5	13.1		8.7
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	27.3	4.0		4.7
0.0041	0.105	No. 140	11.1	1.6		3.1
0.0029	0.074	No. 200	10.6	1.6		1.5
		Pan	9.9	1.5		
Total weight in grams			677.2			

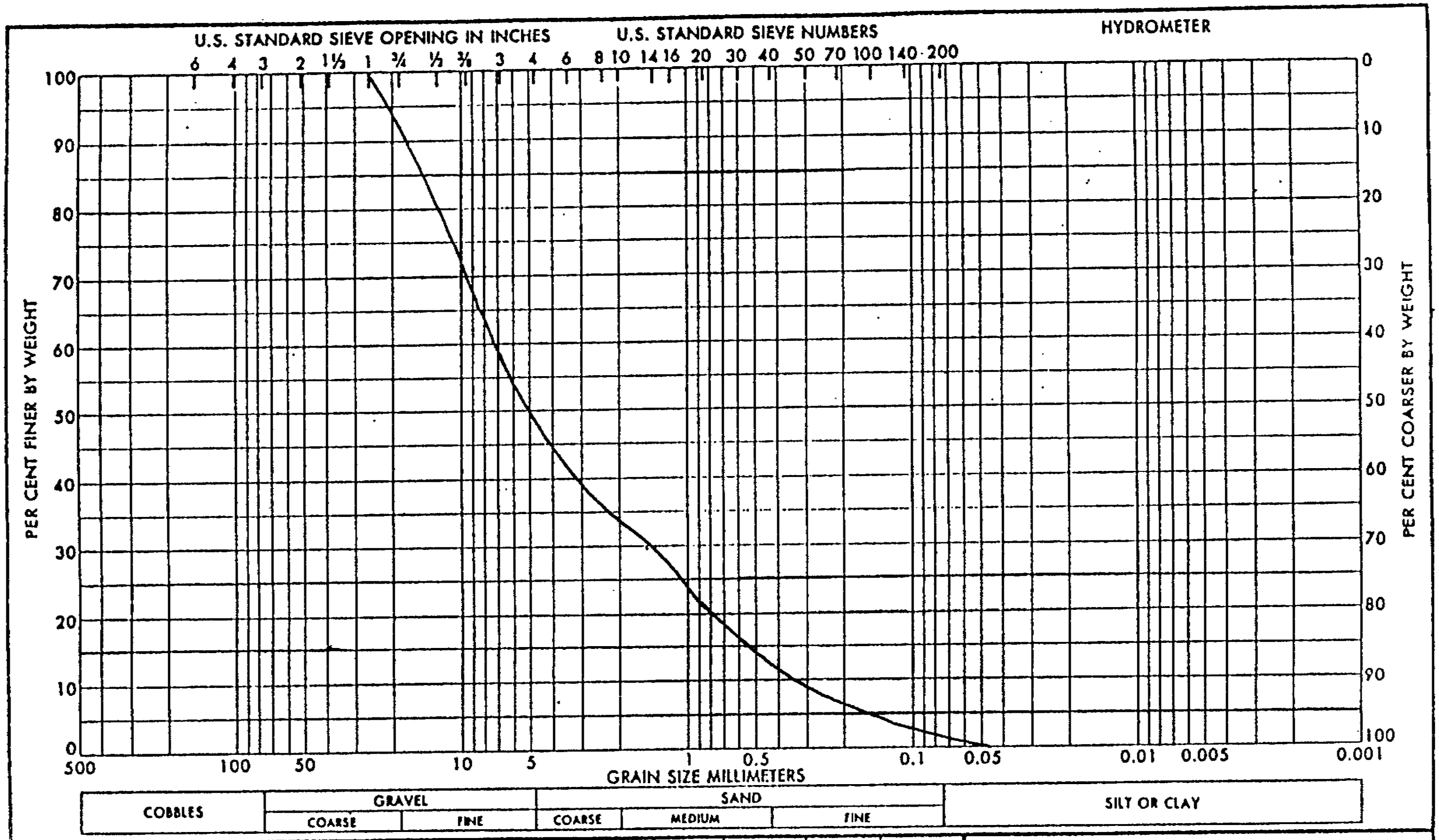
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IE		GP				
D_{10}	0.34					
D_{30}	1.4	$C_u = 21.2$				
D_{60}	7.2	$C_c = 0.8$				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ______

Project ______

Boring No. ______ Sample No. IIA

Total wt in grams of sample, W_s = 145.2 g

Wt in grams of material > No. 4 sieve = 88.1 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	23.3	16.0		83.9
0.500	12.7	1/2-in.	18.7	12.9		71.0
0.375	9.52	3/8-in.	13.1	9.0		62.0
0.250	6.35	No. 3	18.9	13.0		49.0
0.187	4.76	No. 4	14.1	9.7		39.3
		Pan				
0.132	3.36	No. 6	5.7	3.9		35.4
0.094	2.38	No. 8				
0.079	2.00	No. 14	19.2	13.2		22.2
0.047	1.19	No. 16				
0.033	0.84	No. 20	10.5	7.2		15.0
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	14.1	9.7		5.3
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	4.0	2.8		2.5
0.0041	0.105	No. 140	0.9	0.6		1.9
0.0029	0.074	No. 200	1.1	0.8		1.1
		Pan	1.6	1.1		
Total weight in grams			145.2			

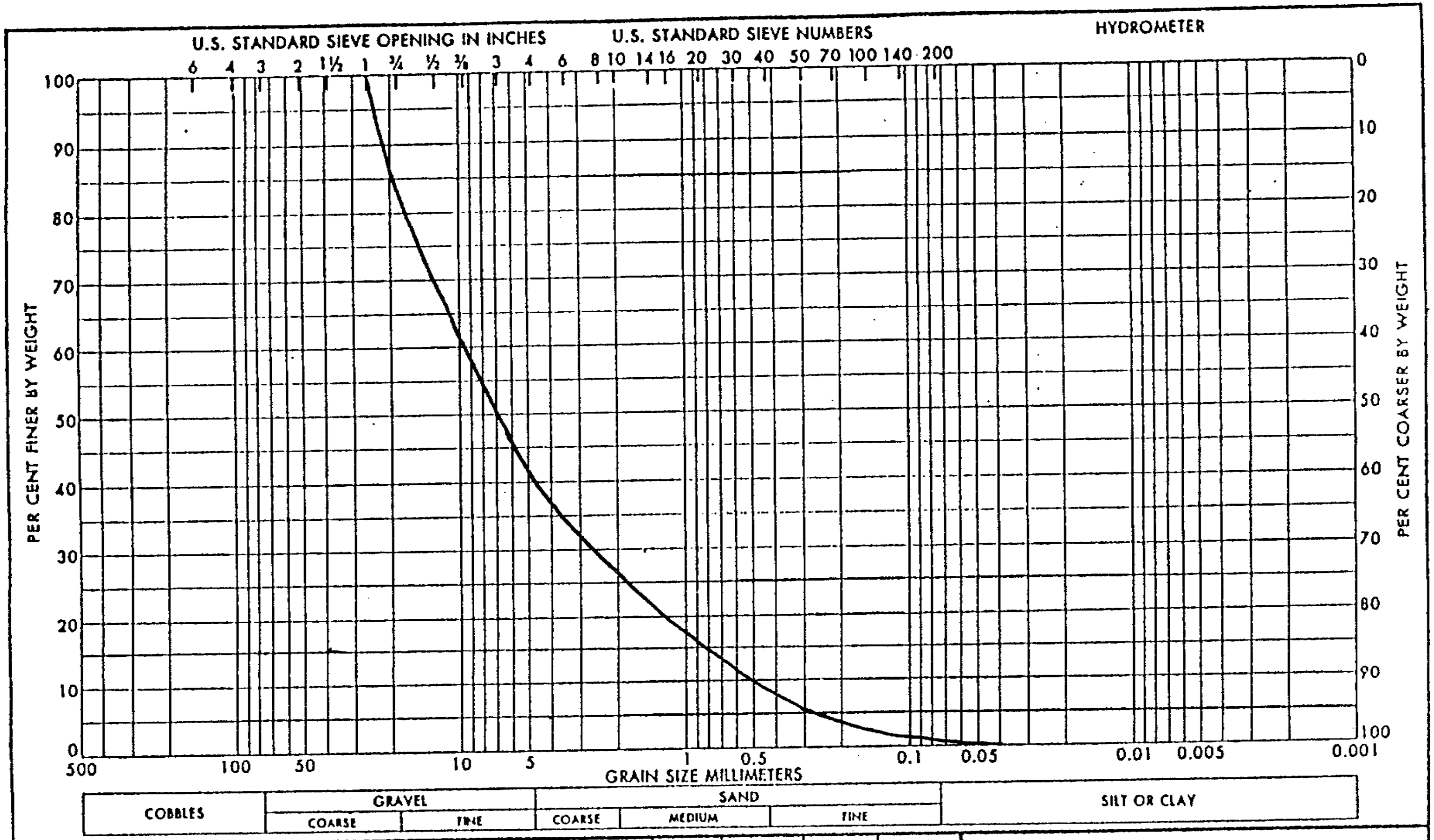
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IIA		GW				
D_{10}	0.5					
D_{30}	2.6	$C_u = 19.0$				
D_{60}	9.5	$C_c = 1.4$				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ______________

Project ______________

Boring No. ______________ Sample No. IB

Total wt in grams of sample, W_s = 692.7 g

Wt in grams of material > No. 4 sieve = 189.3g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	59.2	8.5		91.4
0.500	12.7	1/2-in.	33.4	4.8		86.6
0.375	9.52	3/8-in.	28.6	4.1		82.5
0.250	6.35	No. 3	38.3	5.5		77.0
0.187	4.76	No. 4	29.8	4.3		72.7
		Pan				
0.132	3.36	No. 6	26.3	3.8		68.9
0.094	2.38	No. 8				
0.079	2.00	No. 14	87.6	12.6		56.3
0.047	1.19	No. 16				
0.033	0.84	No. 20	75.4	10.9		45.4
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	152.1	22.0		23.4
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	73.2	10.6		12.8
0.0041	0.105	No. 140	35.5	5.1		7.7
0.0029	0.074	No. 200	27.7	4.0		3.7
		Pan	25.6	3.7		
Total weight in grams			692.7			

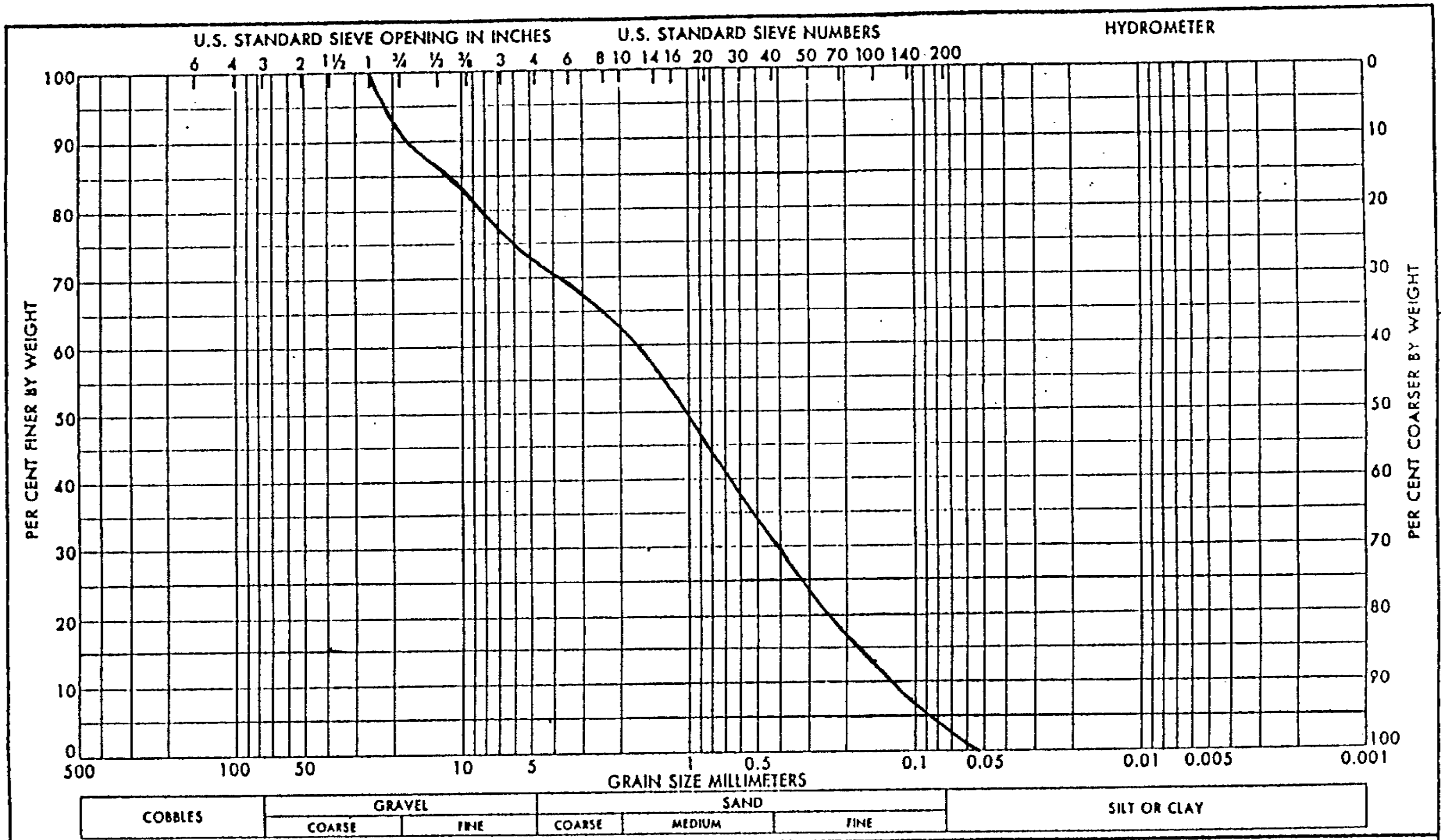
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______________ Computed by ______________ Checked by ______________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IIB		SP		24.6		
D_{10}	0.13					
D_{30}	0.405	C_u = 13.1				
D_{60}	1.7	C_c = 0.7				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date

Project

Boring No. Sample No. IIC

Total wt in grams of sample, W_s = 1145.0

Wt in grams of material > No. 4 sieve = 661.0 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				100.0
1.50		1-1/2-in.	350.6	30.6		69.3
1.00	25.4	1-in.	92.7	8.1		61.2
0.750	19.1	3/4-in.	44.8	3.9		57.3
0.500	12.7	1/2-in.	79.9	7.0		50.3
0.375	9.52	3/8-in.	24.0	2.1		48.2
0.250	6.35	No. 3	36.1	3.2		45.0
0.187	4.76	No. 4	32.9	2.9		42.1
		Pan				
0.132	3.36	No. 6	34.8	3.0		39.1
0.094	2.38	No. 8				
0.079	2.00	No. 14	98.6	8.6		30.5
0.047	1.19	No. 16				
0.033	0.84	No. 20	57.5	5.0		25.5
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	143.6	12.5		13.0
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	65.7	5.7		7.3
0.0041	0.105	No. 140	37.0	3.2		4.1
0.0029	0.074	No. 200	22.8	2.0		2.1
		Pan	24.0	2.1		
Total weight in grams			1145.0			

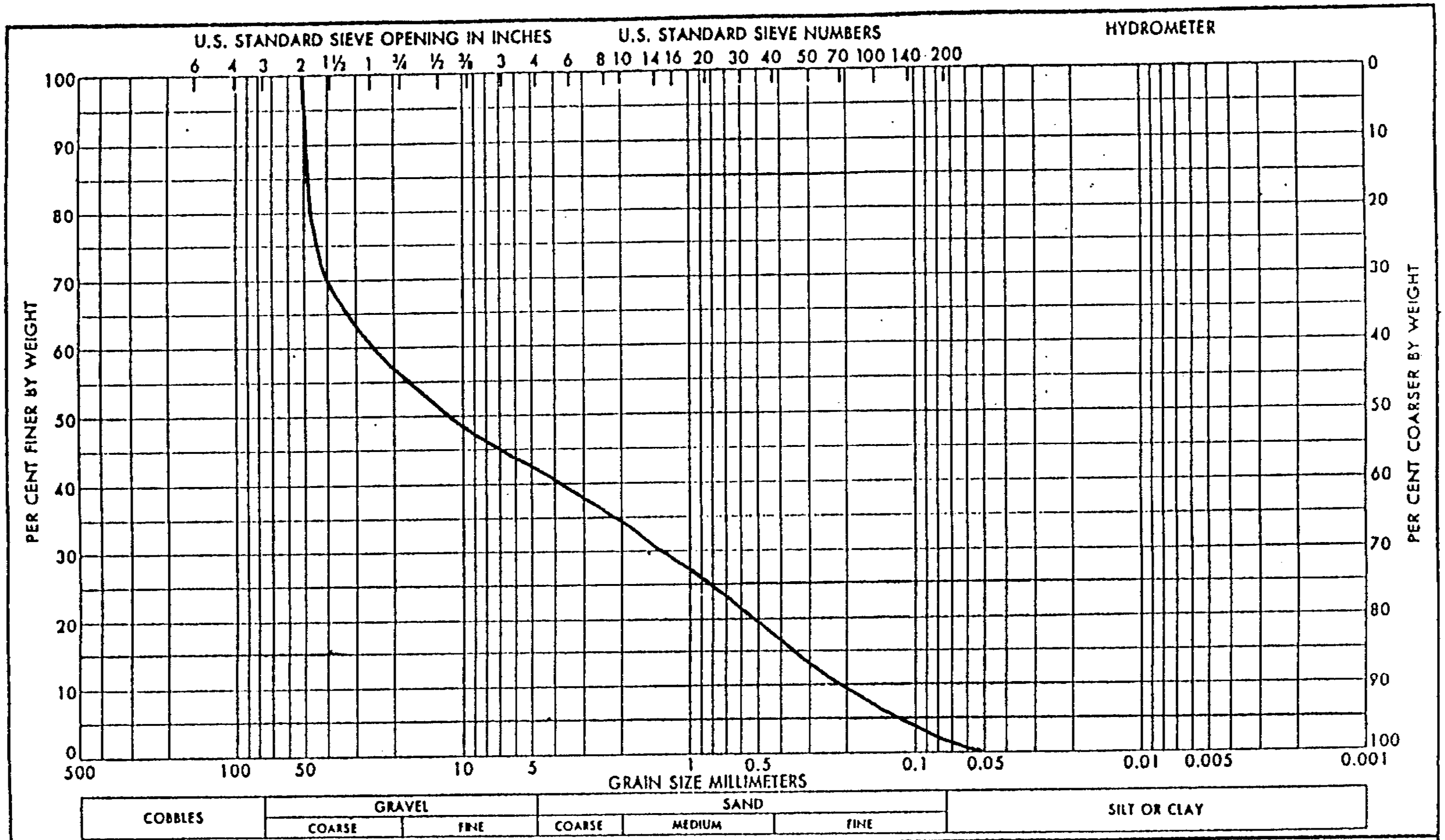
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician Computed by Checked by



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IIC		GP				
D_{10}	0.21					
D_{30}	1.4	Cu = 119.0				
D_{60}	25	Cc = 0.4				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. IID

Total wt in grams of sample, W_s = 205.8 g

Wt in grams of material > No. 4 sieve = 111.8 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	82.1	39.9		60.2
0.500	12.7	1/2-in.	17.4	8.5		51.7
0.375	9.52	3/8-in.	4.7	2.3		49.4
0.250	6.35	No. 3	2.0	1.0		48.4
0.187	4.76	No. 4	5.6	2.7		45.7
		Pan				
0.132	3.36	No. 6	5.2	2.5		43.2
0.094	2.38	No. 8				
0.079	2.00	No. 14	29.3	14.2		29.0
0.047	1.19	No. 16				
0.033	0.84	No. 20	19.7	9.6		19.4
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	24.2	11.8		7.6
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	7.5	3.6		4.0
0.0041	0.105	No. 140	2.7	1.3		2.7
0.0029	0.074	No. 200	2.2	1.1		1.6
		Pan	3.2	1.6		
Total weight in grams			205.8			

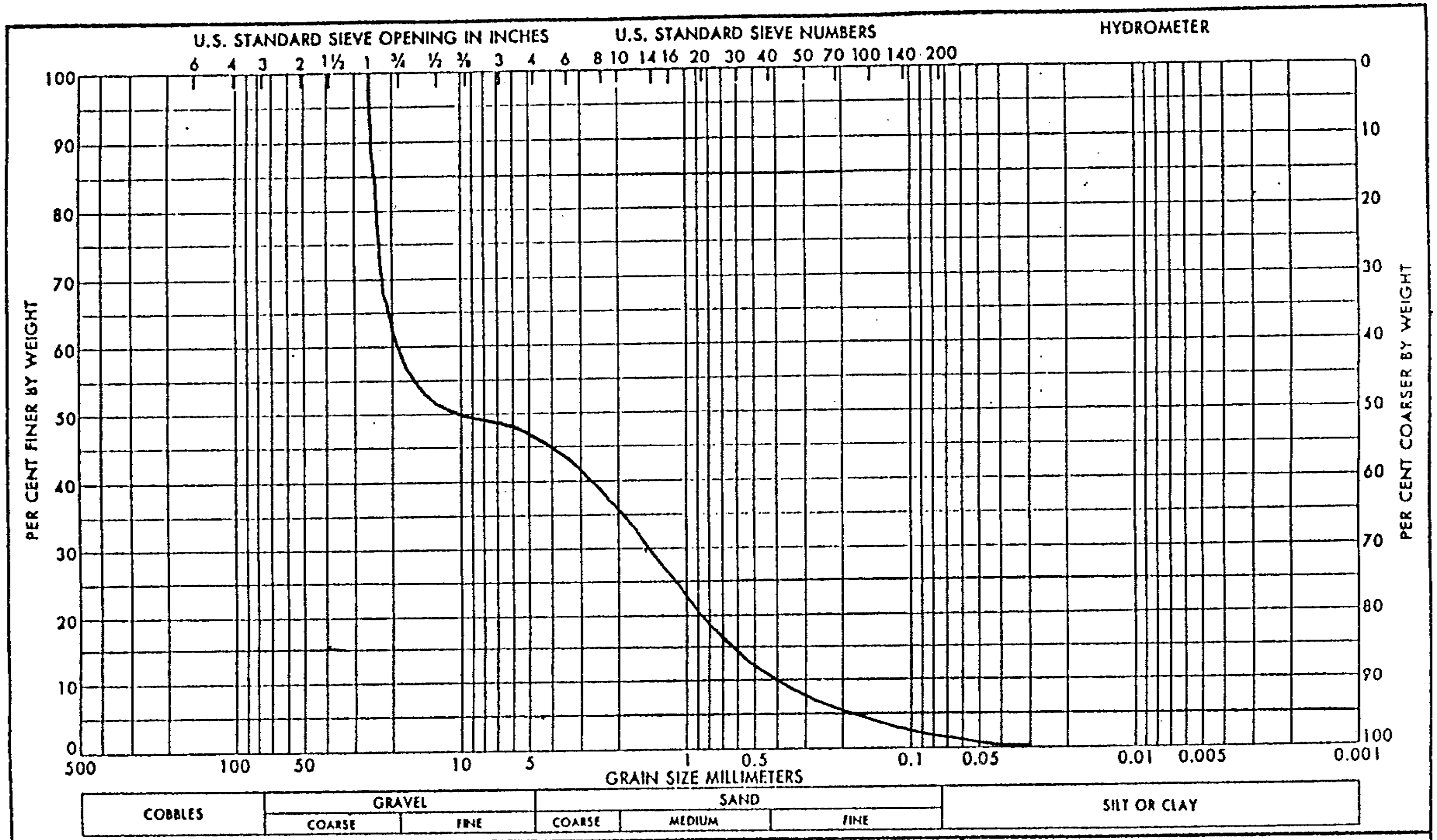
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
ID		GP				
D_{10}	0.4					
D_{30}	1.5	$C_u = 47.5$				
D_{60}	19.0	$C_c = 0.3$				

PROJECT

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BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ______________

Project ______________

Boring No. ______________ Sample No. IIE

Total wt in grams of sample, W_s = 509.8 g

Wt in grams of material > No. 4 sieve = 244.0 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	31.6	6.2		93.7
0.500	12.7	1/2-in.	71.0	13.9		79.8
0.375	9.52	3/8-in.	44.4	8.7		71.1
0.250	6.35	No. 3	57.3	11.2		59.9
0.187	4.76	No. 4	39.7	7.8		52.1
		Pan				
0.132	3.36	No. 6	34.7	6.8		45.3
0.094	2.38	No. 8				
0.079	2.00	No. 14	68.5	13.4		31.9
0.047	1.19	No. 16				
0.033	0.84	No. 20	31.1	6.1		25.8
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	77.7	15.2		10.6
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	21.6	4.2		6.4
0.0041	0.105	No. 140	10.1	2.0		4.4
0.0029	0.074	No. 200	9.0	1.8		2.6
		Pan	13.1	2.6		
Total weight in grams			509.8			

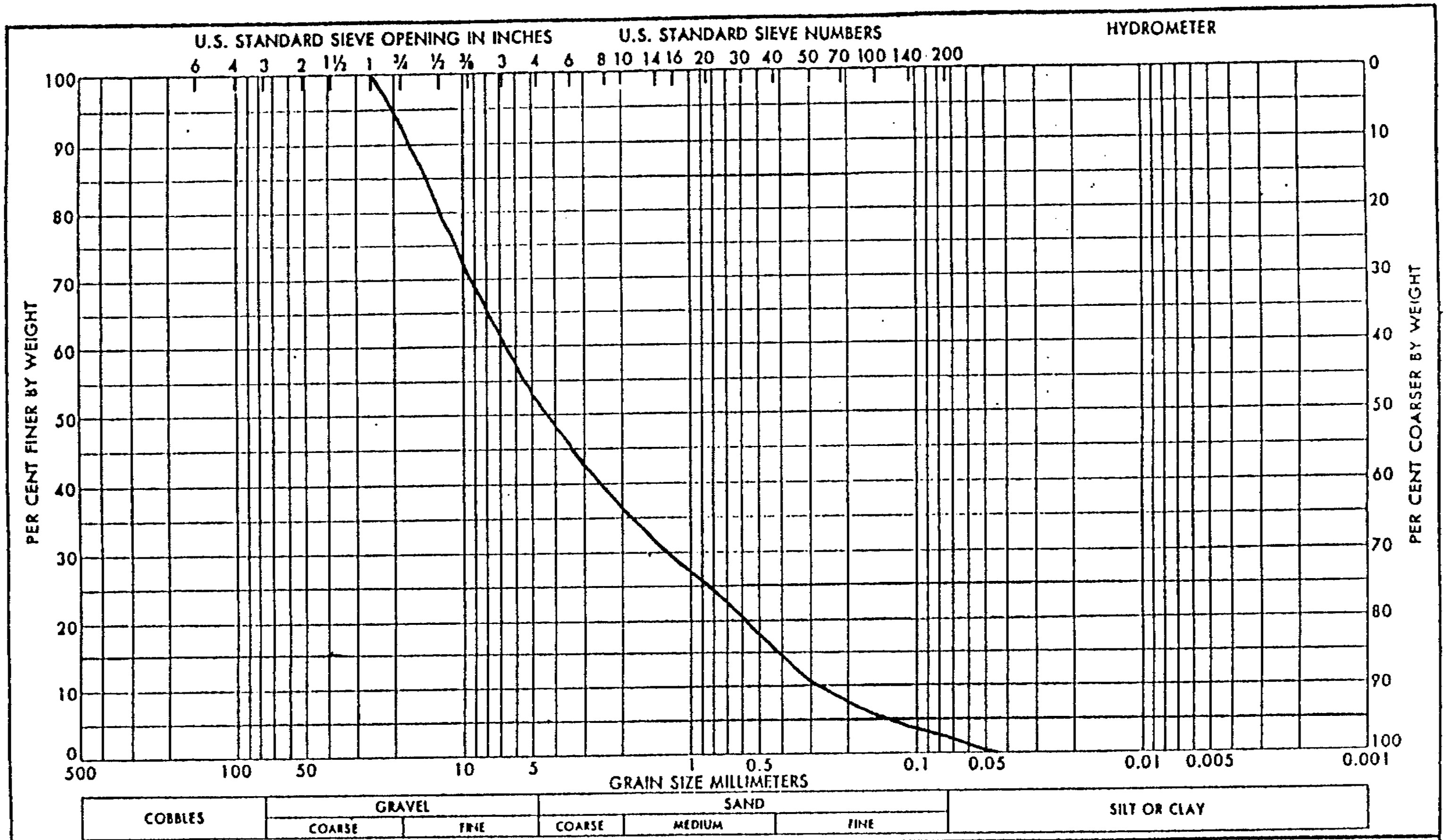
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______________ Computed by ______________ Checked by ______________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
IIE		SW				
D10	0.29					
D30	1.3	Cu= 22.8				
D60	6.6	Cc= 0.9				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

Appendix 3

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 1

Total wt in grams of sample, W_s = 184.1 g | Wt in grams of material > No. 4 sieve = 66.1 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	22.8	12.4		87.6
0.375	9.52	3/8-in.	13.3	7.2		80.4
0.250	6.35	No. 3	19.9	10.8		69.6
0.187	4.76	No. 4	10.1	5.5		64.1
		Pan				
0.132	3.36	No. 6	11.4	6.2		57.9
0.094	2.38	No. 8				
0.079	2.00	No. 14	41.2	22.4		35.5
0.047	1.19	No. 16				
0.033	0.84	No. 20	18.7	10.2		25.3
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	28.7	15.6		9.7
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	9.4	5.1		4.6
0.0041	0.105	No. 140	2.8	1.5		3.1
0.0029	0.074	No. 200	2.3	1.2		1.9
		Pan	3.5	1.9		
Total weight in grams			184.1			

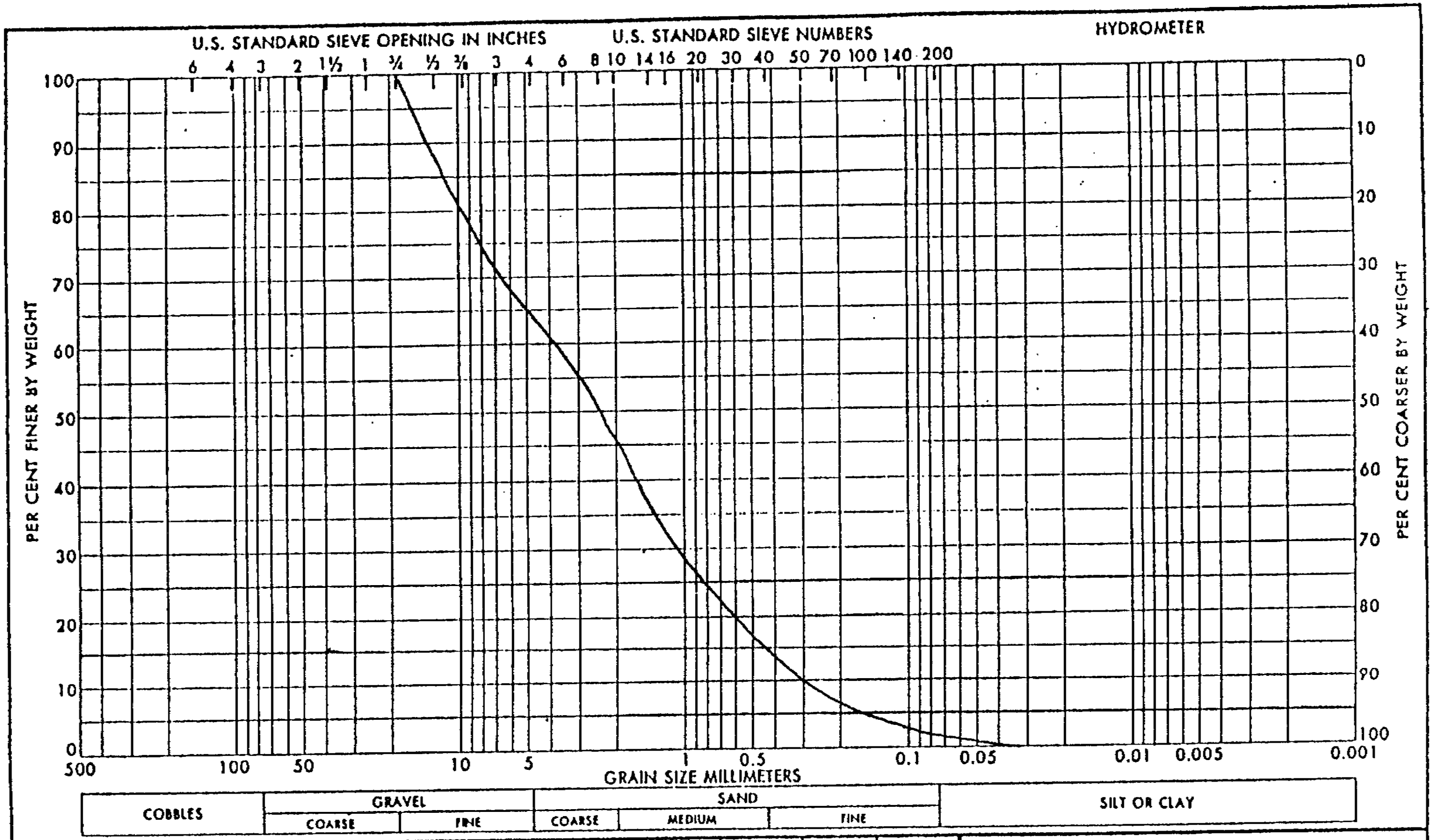
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
1		SW				
D_{10}	0.3					
D_{30}	1.05	$C_u = 12.7$				
D_{60}	3.8	$C_c = 1.0$				

PROJECT

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SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 2

Total wt in grams of sample, W_s = 231.3 g | Wt in grams of material > No. 4 sieve = 5.0 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				
0.375	9.52	3/8-in.				100.0
0.250	6.35	No. 3	0.5	0.2		99.7
0.187	4.76	No. 4	4.5	1.9		97.8
		Pan				
0.132	3.36	No. 6	3.3	1.4		96.4
0.094	2.38	No. 8				
0.079	2.00	No. 14	8.7	3.8		92.6
0.047	1.19	No. 16				
0.033	0.84	No. 20				
0.023	0.59	No. 30	9.3	4.0		88.6
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	37.3	16.1		72.5
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	54.0	23.3		49.2
0.0041	0.105	No. 140	54.8	23.7		25.5
0.0029	0.074	No. 200	22.6	9.8		15.7
		Pan	36.3	15.7		
Total weight in grams			231.3			

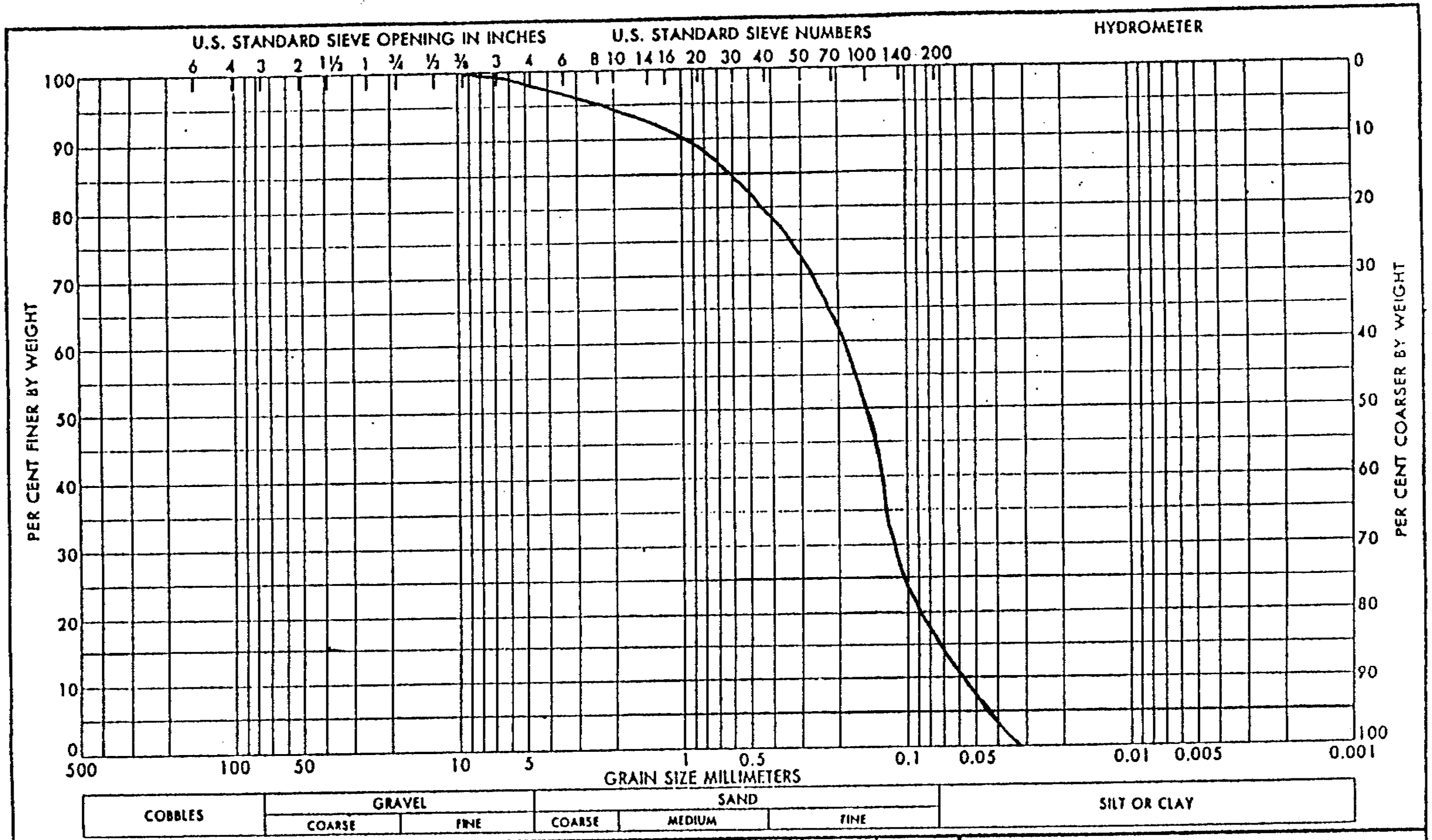
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	PL	LL	PI
2		SM		26.8	35.1	8.3
D_{10}	0.058					
D_{30}	0.11	$C_u = 3.3$				
D_{60}	0.19	$C_c = 1.1$				

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Project ____________

Boring No. ____________ Sample No. 3

Total wt in grams of sample, W_s = 178.4 g

Wt in grams of material > No. 4 sieve = 23.8 g.

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				100.0
0.375	9.52	3/8-in.	10.4	5.8		94.1
0.250	6.35	No. 3	6.5	3.6		90.5
0.187	4.76	No. 4	6.9	3.9		86.6
		Pan				
0.132	3.36	No. 6	7.6	4.3		82.3
0.094	2.38	No. 8				
0.079	2.00	No. 14	32.8	18.4		63.9
0.047	1.19	No. 16				
0.033	0.84	No. 20	29.6	16.6		47.3
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	58.5	32.8		145
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	141	7.9		6.6
0.0041	0.105	No. 140	4.0	2.2		4.4
0.0029	0.074	No. 200	3.3	1.8		2.6
		Pan	4.7	2.6		
Total weight in grams			178.4			

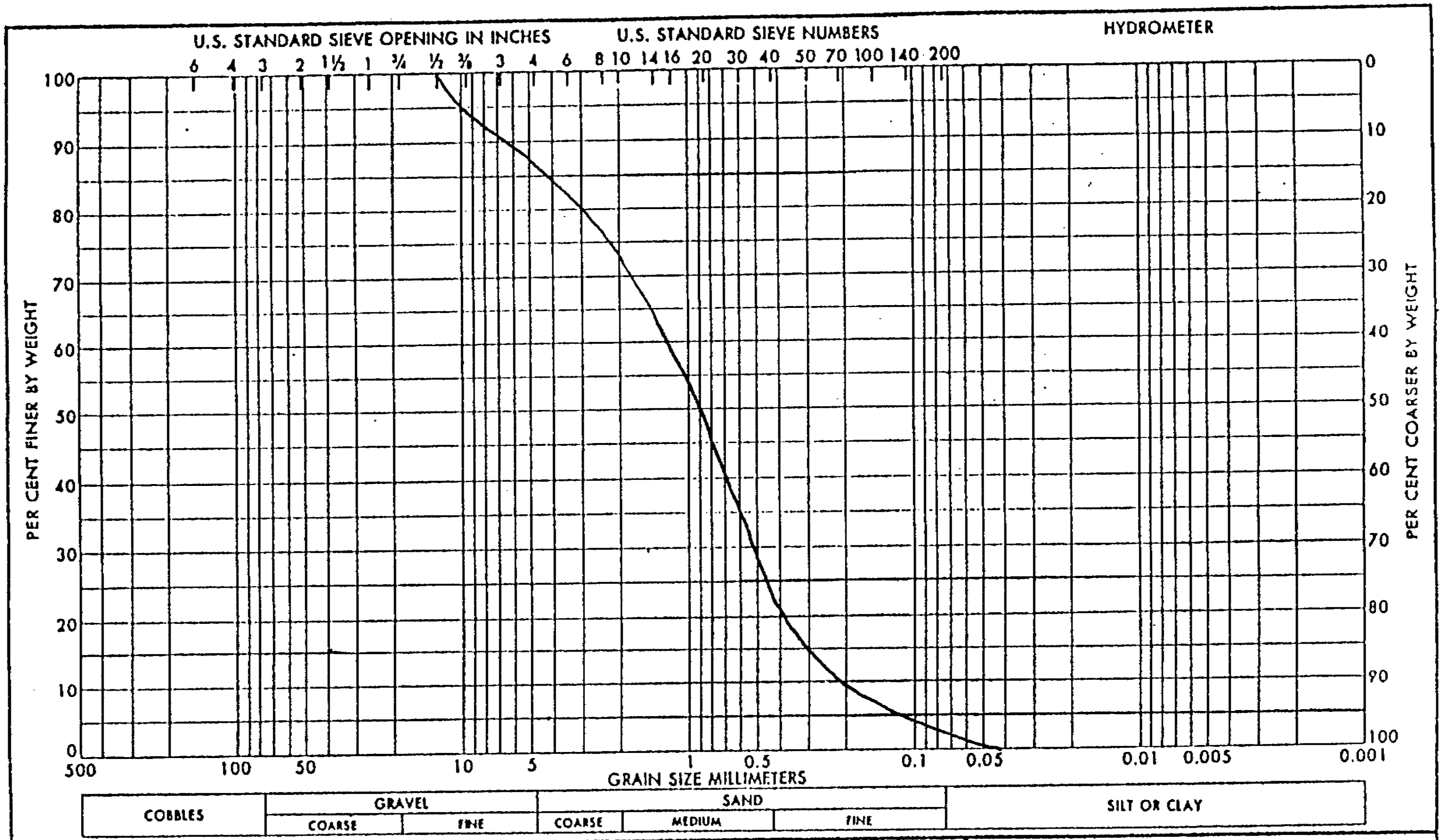
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
3		SW				
D_{10}	0.205					
D_{30}	0.51	C_u = 5.9				
D_{60}	1.2	C_c = 1.1				

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Project ______________________________

Boring No. ______________________ Sample No. 4

Total wt in grams of sample, W_s = 167.2 g | Wt in grams of material > No. 4 sieve = 23.8 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				100.0
0.375	9.52	3/8-in.	8.1	4.8		95.1
0.250	6.35	No. 3	8.8	5.3		89.8
0.187	4.76	No. 4	6.9	4.1		85.7
		Pan				
0.132	3.36	No. 6	7.4	4.4		81.3
0.094	2.38	No. 8				
0.079	2.00	No. 14	34.9	20.9		60.4
0.047	1.19	No. 16				
0.033	0.84	No. 20	27.3	16.3		44.1
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	49.4	29.5		14.6
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	14.1	8.4		6.2
0.0041	0.105	No. 140	3.9	2.3		3.9
0.0029	0.074	No. 200	2.8	1.7		2.2
		Pan	3.6	2.2		
Total weight in grams			167.2			

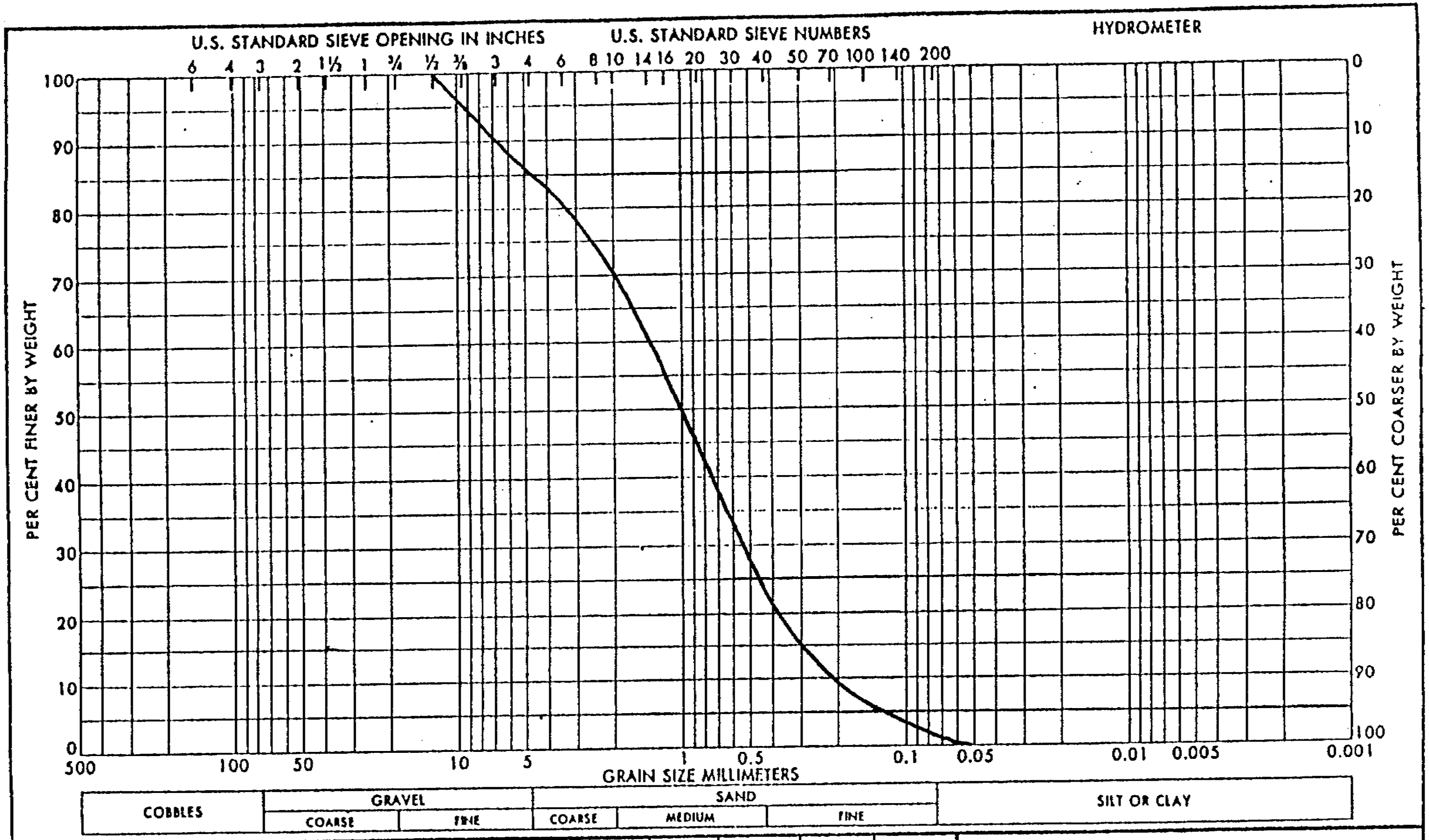
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______________ Computed by ______________ Checked by ______________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
4		SW				
D_{10}	0.205					
D_{30}	0.53	$C_u = 6.8$				
D_{60}	1.4	$C_c = 1.0$				

GRADATION CURVES

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SIEVE ANALYSIS

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Boring No. Sample No. 5

Total wt in grams of sample, W_s = 239.0 g	Wt in grams of material > No. 4 sieve = 57.4 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	41.2	17.2		82.9
0.500	12.7	1/2-in.	4.0	1.7		81.2
0.375	9.52	3/8-in.	3.1	1.3		79.9
0.250	6.35	No. 3	5.1	2.1		77.8
0.187	4.76	No. 4	4.0	1.7		76.1
		Pan				
0.132	3.36	No. 6	4.5	1.9		74.2
0.094	2.38	No. 8				
0.079	2.00	No. 14	6.1	2.6		71.6
0.047	1.19	No. 16				
0.033	0.84	No. 20	19.6	8.2		63.4
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	48.9	20.5		42.9
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	35.5	14.9		28.0
0.0041	0.105	No. 140	24.6	10.3		17.7
0.0029	0.074	No. 200	23.3	9.7		8.0
		Pan	19.1	8.0		
Total weight in grams			239.0			

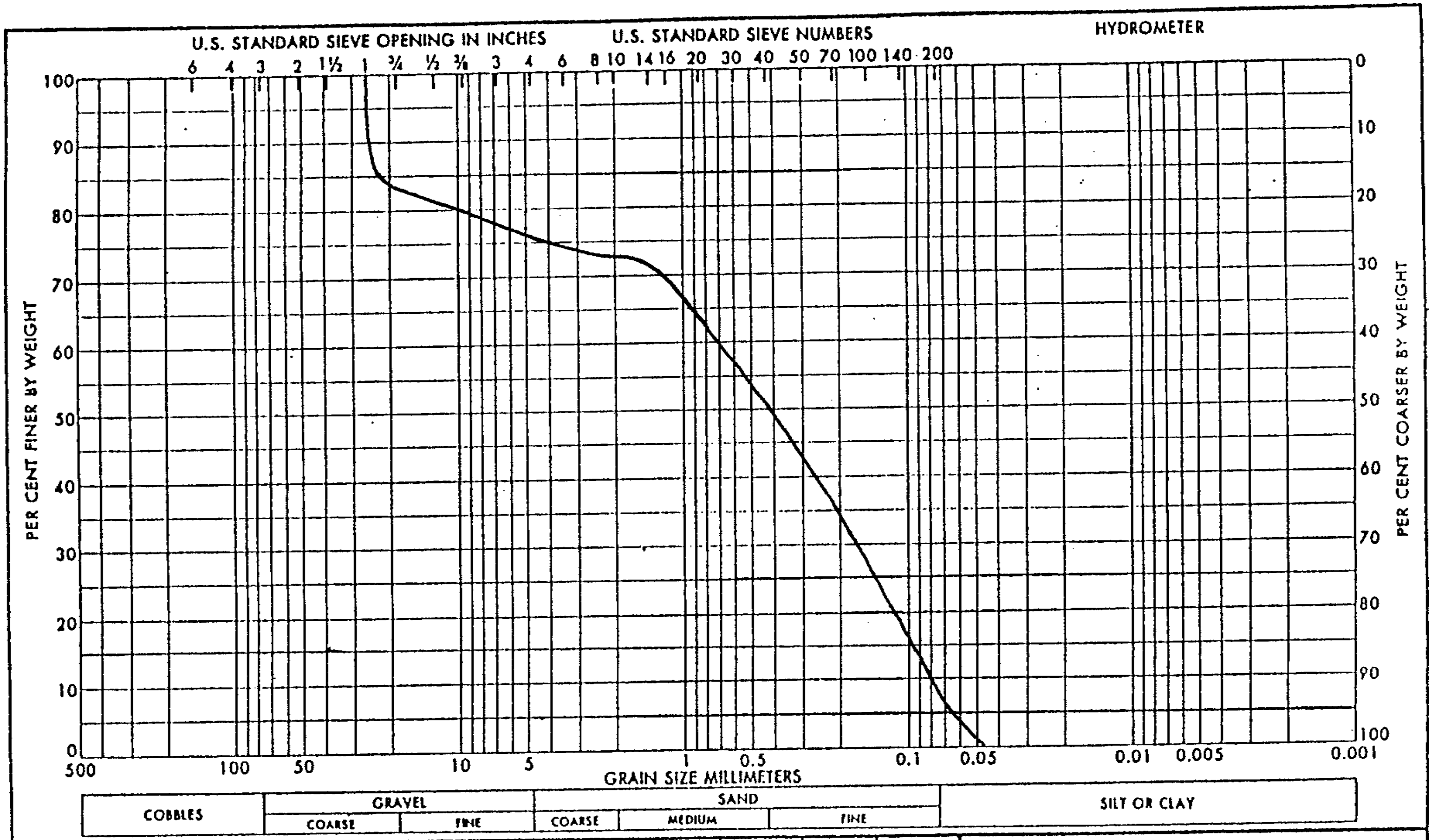
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	PL	LL	PI
		SP-SM		29.7	39.5	9.8
5						
D_{10}	0.08					
D_{30}	0.17	$C_u = 8.9$				
D_{60}	0.71	$C_c = 0.5$				

GRADATION CURVES

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Date ____________

Project ____________

Boring No. ____________ Sample No. 6

Total wt in grams of sample, W_s = 149.1 g | Wt in grams of material > No. 4 sieve = 36.8 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	21.2	14.2		85.9
0.375	9.52	3/8-in.	6.5	4.4		81.5
0.250	6.35	No. 3	5.2	3.5		78.0
0.187	4.76	No. 4	3.9	2.6		75.4
		Pan				
0.132	3.36	No. 6	2.6	1.7		73.7
0.094	2.38	No. 8				
0.079	2.00	No. 14	11.3	7.6		66.1
0.047	1.19	No. 16				
0.033	0.84	No. 20	12.5	8.4		57.7
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	43.4	29.1		28.6
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	20.7	13.9		14.7
0.0041	0.105	No. 140	8.0	5.4		9.3
0.0029	0.074	No. 200	6.5	4.4		4.9
		Pan	7.3	4.9		
Total weight in grams			149.1			

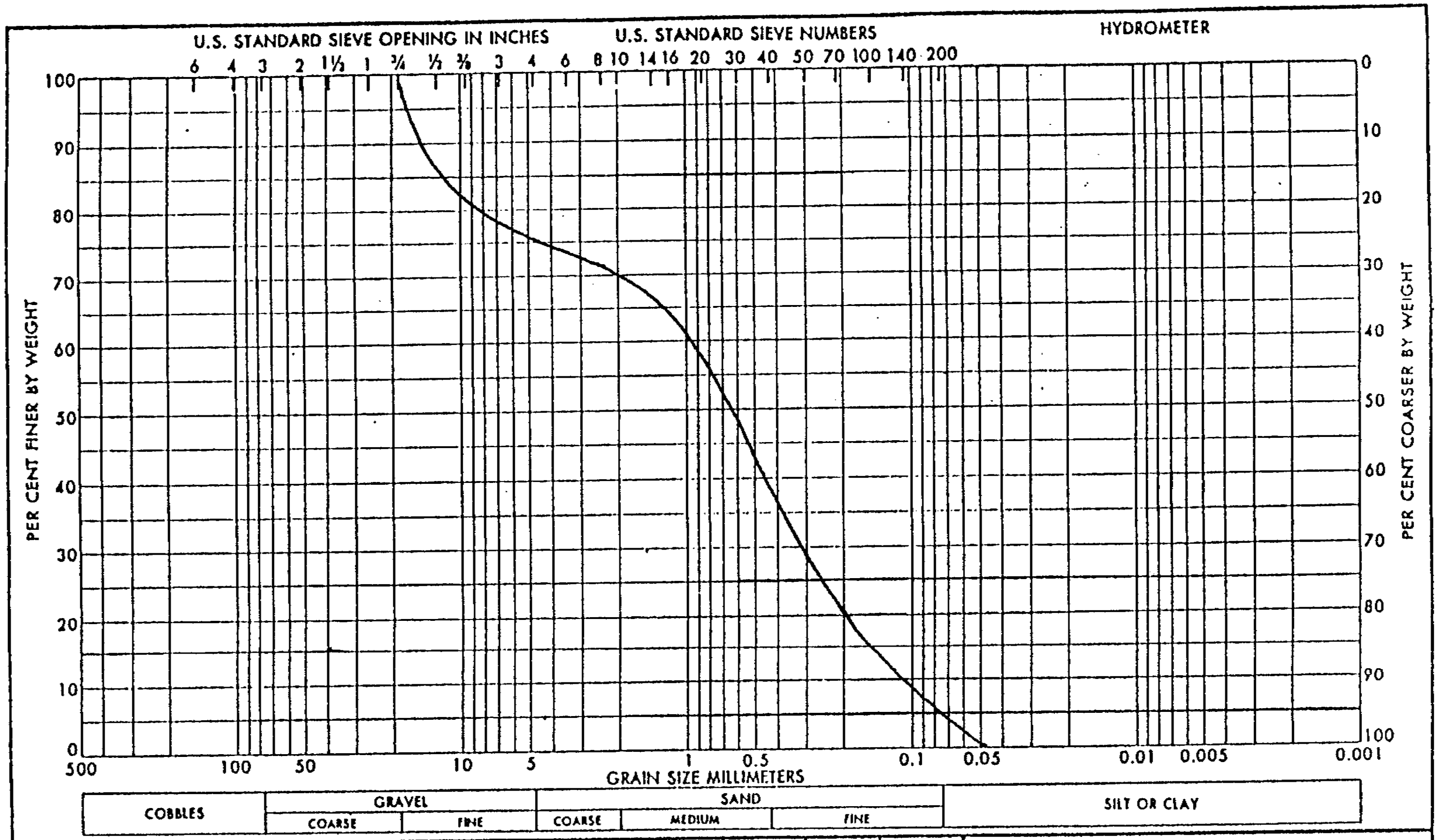
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
6		SW		31.3		
D_{10}	0.11					
D_{30}	0.31	$C_u = 8.7$				
D_{60}	0.96	$C_c = 0.9$				

GRADATION CURVES

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SIEVE ANALYSIS

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Project ______

Boring No. ______ Sample No. 7

Total wt in grams of sample, W_s = 187.1 g

Wt in grams of material > No. 4 sieve = 59.0 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	37.1	19.8		80.1
0.500	12.7	1/2-in.	7.3	3.9		76.2
0.375	9.52	3/8-in.	6.8	3.6		72.6
0.250	6.35	No. 3	2.2	1.2		71.4
0.187	4.76	No. 4	5.6	3.0		68.4
		Pan				
0.132	3.36	No. 6	4.5	2.4		66.0
0.094	2.38	No. 8				
0.079	2.00	No. 14	12.7	6.8		59.2
0.047	1.19	No. 16				
0.033	0.84	No. 20	7.9	4.2		55.0
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	35.6	19.0		36.0
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	25.8	13.8		22.2
0.0041	0.105	No. 140	12.0	6.4		15.8
0.0029	0.074	No. 200	10.5	5.6		10.2
		Pan	19.1	10.2		
Total weight in grams			187.1			

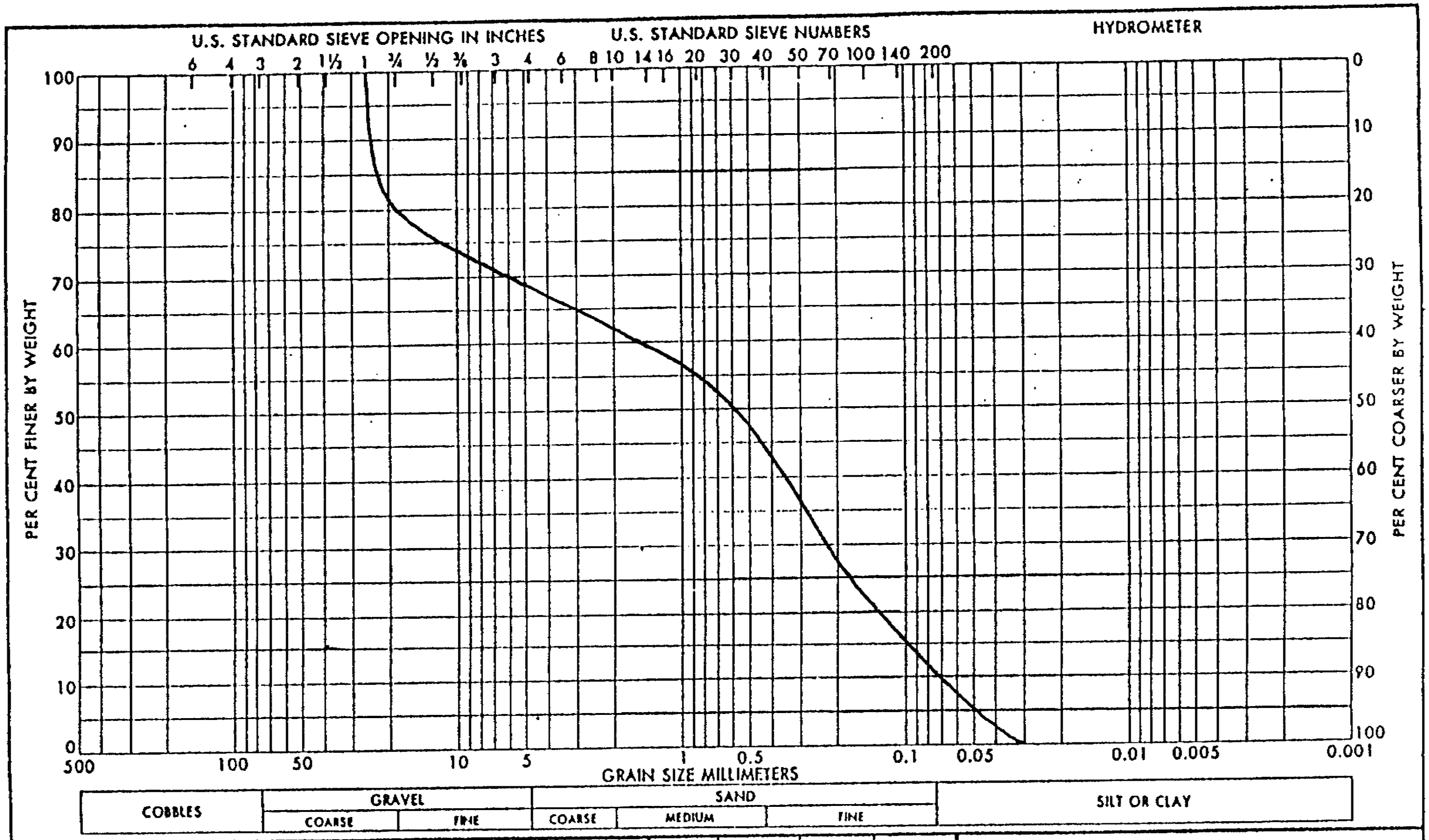
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
7		SP-SM		28.3	22.4	5.9
D_{10}	0.071					
D_{30}	0.22	C_u = 21.1				
D_{60}	1.5	C_c = 0.5				

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Boring No. Sample No. 8

Total wt in grams of sample, W_s = 172.4g

Wt in grams of material > No. 4 sieve = 35.6g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	8.8	5.1		94.9
0.375	9.52	3/8-in.	11.9	6.9		88.0
0.250	6.35	No. 3	10.0	5.8		82.2
0.187	4.76	No. 4	4.9	2.8		79.4
		Pan				
0.132	3.36	No. 6	7.6	4.4		75.0
0.094	2.38	No. 8				
0.079	2.00	No. 14	11.2	6.5		68.5
0.047	1.19	No. 16				
0.033	0.84	No. 20	33.8	19.6		48.9
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	56.7	32.9		16.0
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	16.3	9.5		6.5
0.0041	0.105	No. 140	4.6	2.7		3.8
0.0029	0.074	No. 200	3.1	1.8		2.0
		Pan	3.5	2.0		
Total weight in grams			172.4			

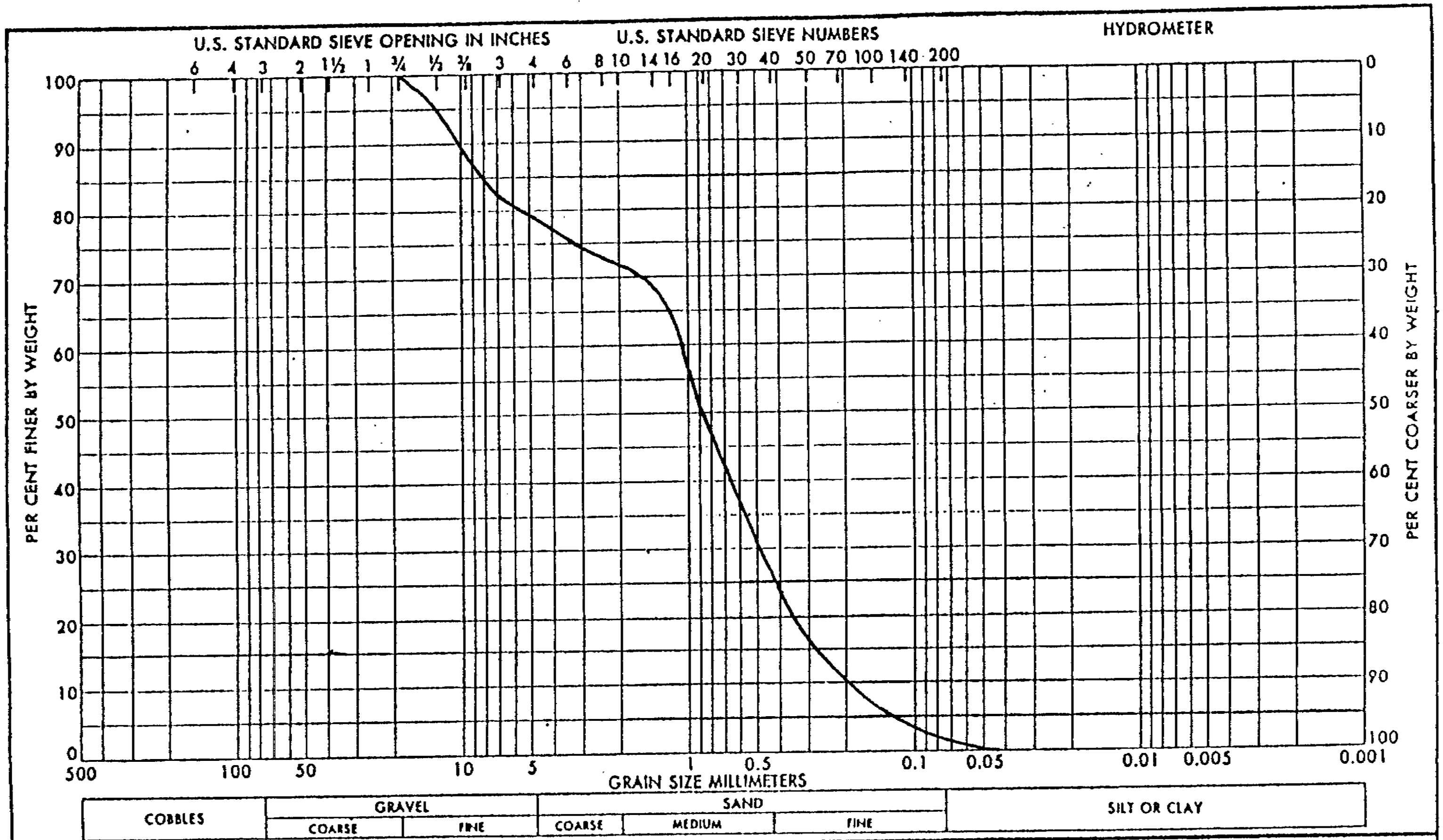
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ________ Computed by ________ Checked by ________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
8		SP				
D_{10}	0.2					
D_{30}	0.49	C_u= 5.3				
D_{60}	1.05	C_c= 1.1				

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Project ____________

Boring No. ____________ Sample No. 9

Total wt in grams of sample, W_s = 1649 g	Wt in grams of material > No. 4 sieve = 24.2 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	15.4	9.3		90.7
0.375	9.52	3/8-in.	4.1	2.5		88.2
0.250	6.35	No. 3	2.5	1.5		86.7
0.187	4.76	No. 4	2.2	1.3		85.4
		Pan				
0.132	3.36	No. 6	7.6	4.6		80.8
0.094	2.38	No. 8				
0.079	2.00	No. 14	20.9	12.7		68.1
0.047	1.19	No. 16				
0.033	0.84	No. 20	22.7	13.8		54.3
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	52.0	31.5		22.8
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	19.1	11.6		11.2
0.0041	0.105	No. 140	6.7	4.1		7.1
0.0029	0.074	No. 200	4.6	2.8		4.3
		Pan	7.1	4.3		
Total weight in grams			164.9			

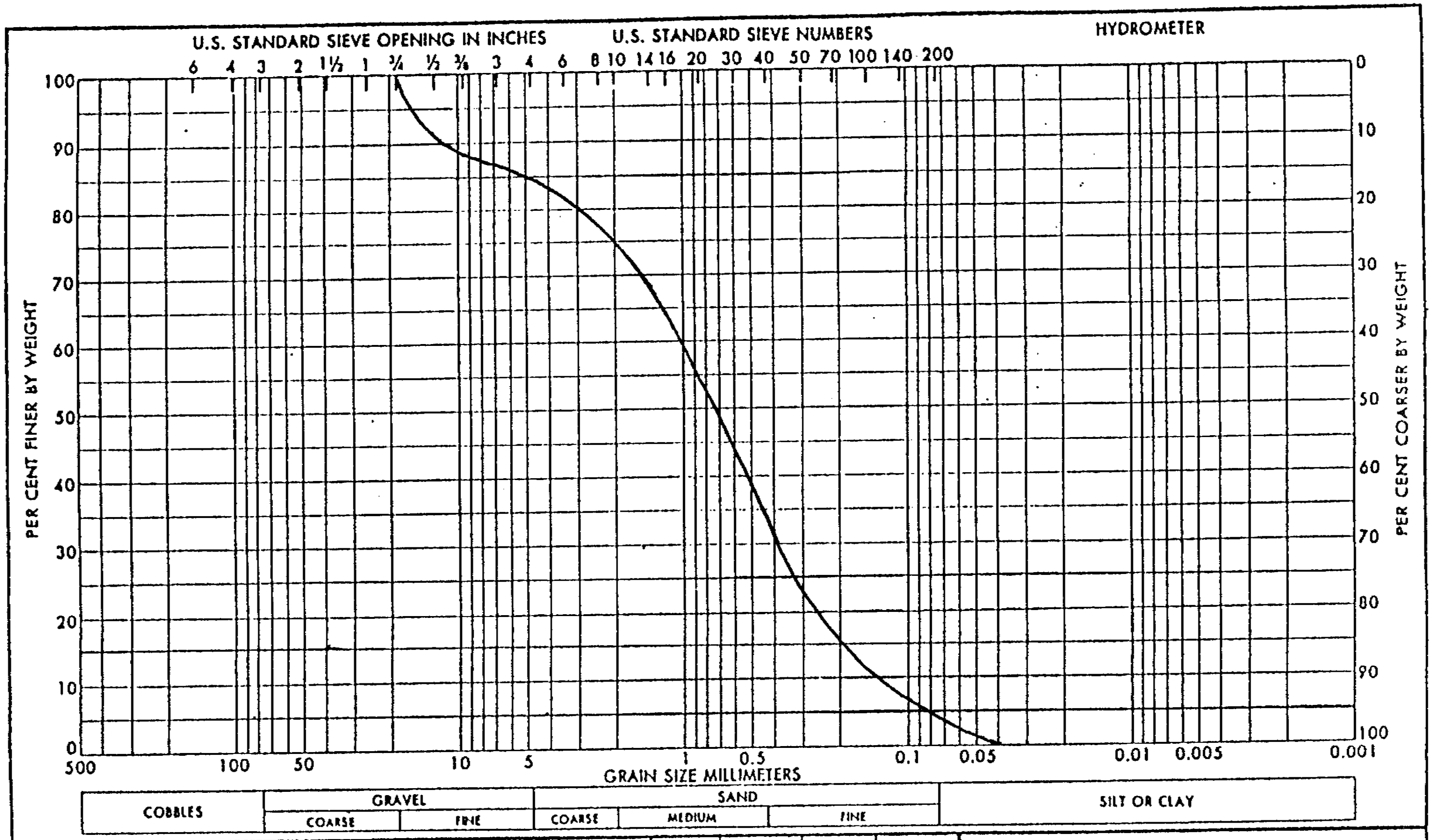
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
9		SW				
D_{10}	0.14					
D_{30}	0.39	C_u = 7.5				
D_{60}	1.05	C_c = 1.0				

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Project ____________

Boring No. ____________ Sample No. 10

Total wt in grams of sample, W_s = 149.9 g	Wt in grams of material > No. 4 sieve = 31.1 g.

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				100.0
0.375	9.52	3/8-in.	9.0	6.0		94.1
0.250	6.35	No. 3	10.9	7.3		86.8
0.187	4.76	No. 4	11.2	7.5		79.3
		Pan				
0.132	3.36	No. 6	5.7	3.8		75.5
0.094	2.38	No. 8				
0.079	2.00	No. 14	24.0	16.0		59.5
0.047	1.19	No. 16				
0.033	0.84	No. 20	23.1	15.4		44.1
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	42.4	28.3		15.8
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	13.5	9.0		6.8
0.0041	0.105	No. 140	4.0	2.7		4.1
0.0029	0.074	No. 200	2.7	1.8		2.3
		Pan	3.4	2.3		
Total weight in grams			149.9			

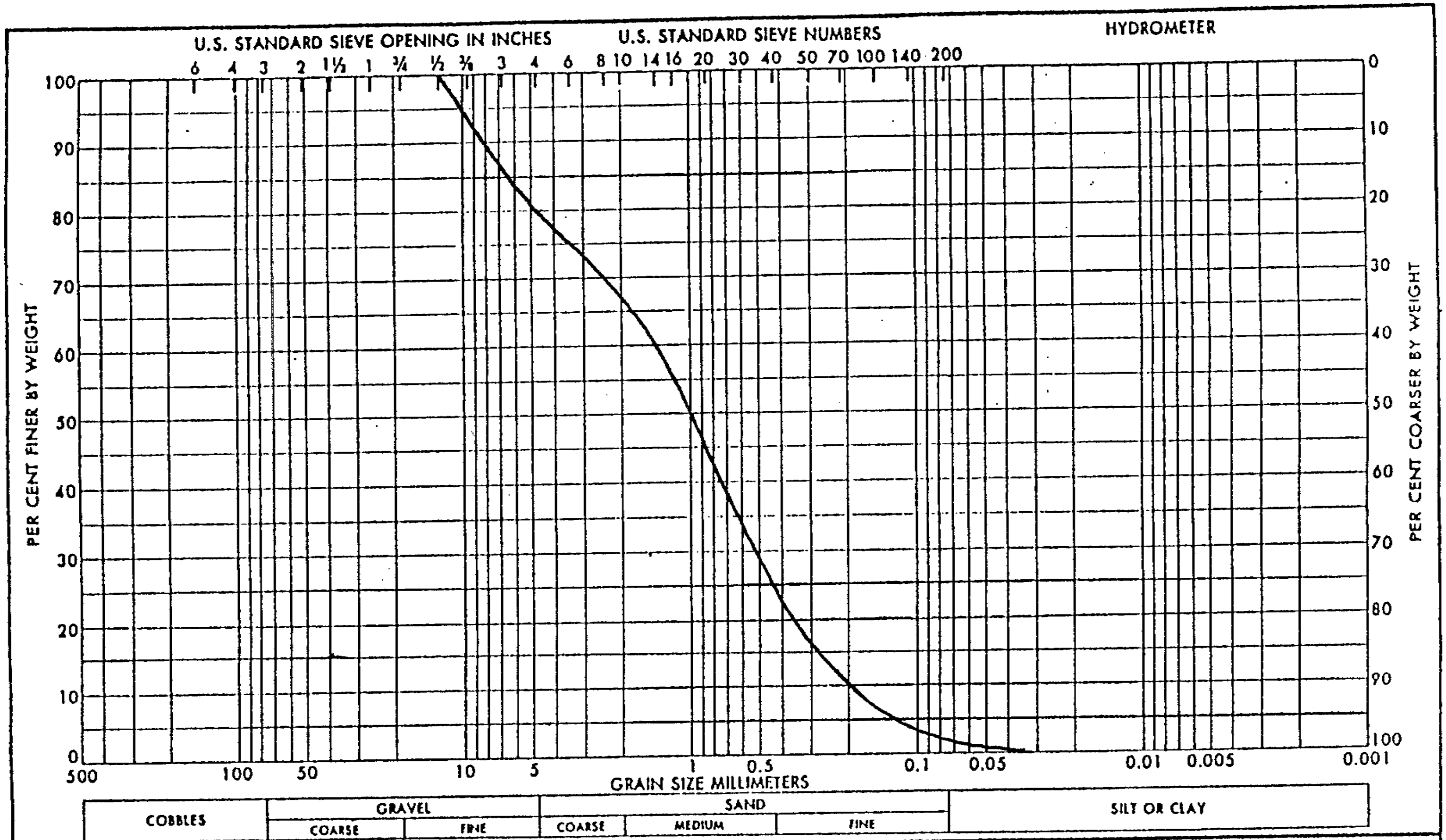
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
10		SW				
D_{10}	0.2					
D_{30}	0.52	C_u = 7.0				
D_{60}	1.4	C_c = 1.0				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 11

Total wt in grams of sample, W_s = 173.0 g | Wt in grams of material > No. 4 sieve = 49.0 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	27.6	16.0		84.1
0.375	9.52	3/8-in.	10.3	6.0		78.1
0.250	6.35	No. 3	5.5	3.2		74.9
0.187	4.76	No. 4	5.6	3.2		71.7
		Pan				
0.132	3.36	No. 6	3.1	1.8		69.9
0.094	2.38	No. 8				
0.079	2.00	No. 14	26.7	15.4		54.5
0.047	1.19	No. 16				
0.033	0.84	No. 20	22.6	13.1		41.4
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	43.4	25.1		16.3
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	14.3	8.3		8.0
0.0041	0.105	No. 140	4.9	2.8		5.2
0.0029	0.074	No. 200	3.8	2.2		3.0
		Pan	5.2	3.0		
Total weight in grams			173.0			

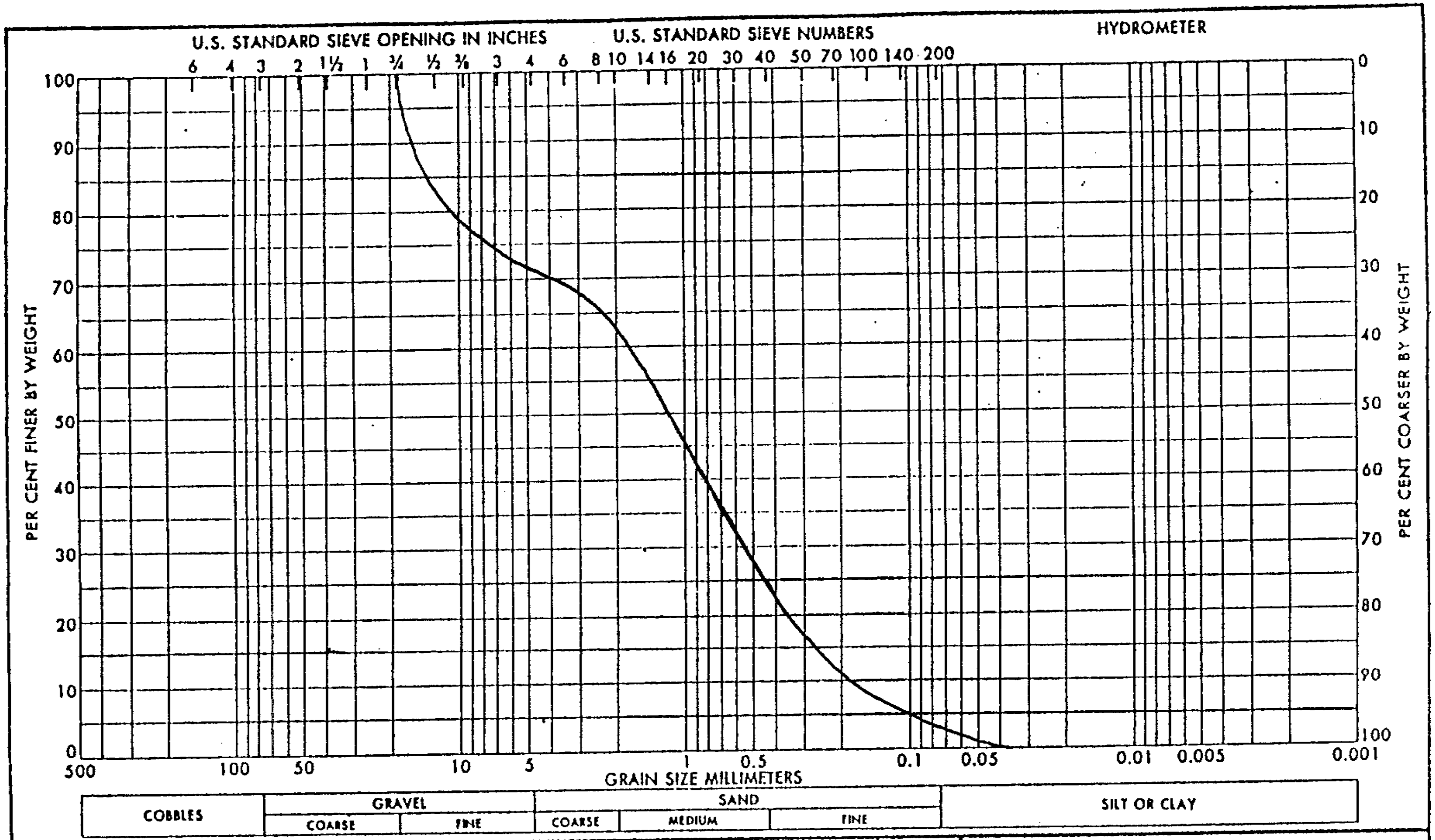
Partial percent retained = $\frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$

Total percent retained = $\frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
11		SW				
D_{10}	0.185					
D_{30}	0.54	C_u= 9.7				
D_{60}	1.8	C_c= 0.9				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 12

Total wt in grams of sample, W_s = 198.3 g	Wt in grams of material > No. 4 sieve = 16.7 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	5.7	2.9		97.0
0.375	9.52	3/8-in.	3.8	1.9		95.1
0.250	6.35	No. 3	3.0	1.5		93.6
0.187	4.76	No. 4	4.2	2.1		91.5
		Pan				
0.132	3.36	No. 6	7.5	3.8		89.7
0.094	2.38	No. 8				
0.079	2.00	No. 14	10.7	5.4		82.3
0.047	1.19	No. 16				
0.033	0.84	No. 20	14.3	7.2		75.1
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	77.6	39.1		36.0
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	41.5	20.9		15.1
0.0041	0.105	No. 140	10.0	5.0		10.1
0.0029	0.074	No. 200	6.9	3.5		66
		Pan	13.1	6.6		
Total weight in grams			198.3			

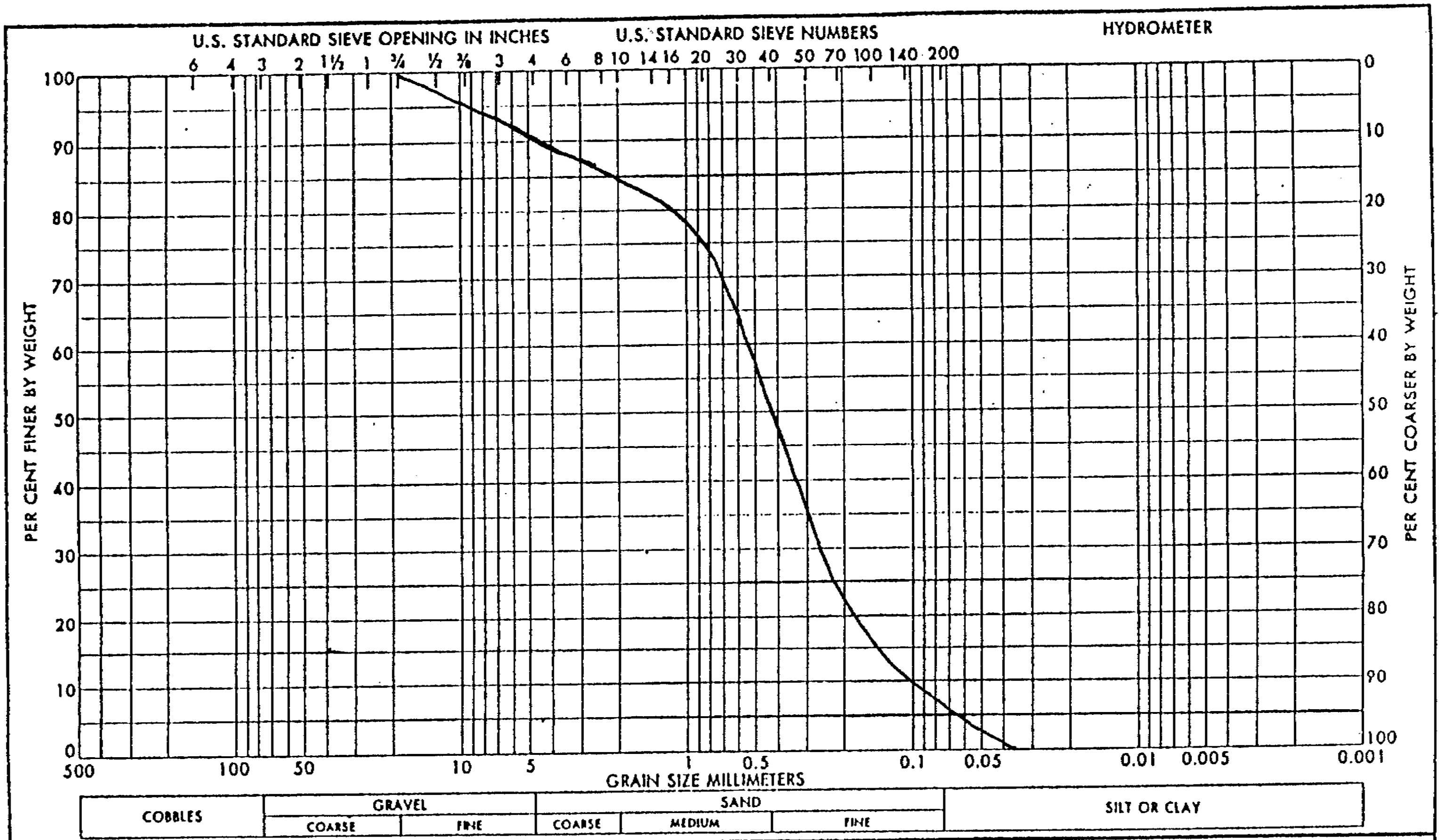
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve − percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
12		SP-SM		463	27.7	18.6
D_{10}	0.105					
D_{30}	0.26	C_u= 5.0				
D_{60}	0.53	C_c= 1.2				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 13

Total wt in grams of sample, W_s = 153.4 g

Wt in grams of material > No. 4 sieve = 32.4 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	10.6	6.9		93.0
0.500	12.7	1/2-in.	8.0	5.2		87.8
0.375	9.52	3/8-in.	6.7	4.4		83.4
0.250	6.35	No. 3	3.6	2.3		81.1
0.187	4.76	No. 4	3.5	2.3		78.8
		Pan				
0.132	3.36	No. 6	4.6	3.0		75.8
0.094	2.38	No. 8				
0.079	2.00	No. 14	24.1	15.7		60.1
0.047	1.19	No. 16				
0.033	0.84	No. 20	22.6	14.7		45.4
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	41.3	26.9		18.5
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	15.7	10.2		8.3
0.0041	0.105	No. 140	4.8	3.1		5.2
0.0029	0.074	No. 200	3.5	2.3		2.9
		Pan	4.4	2.9		
Total weight in grams			153.4			

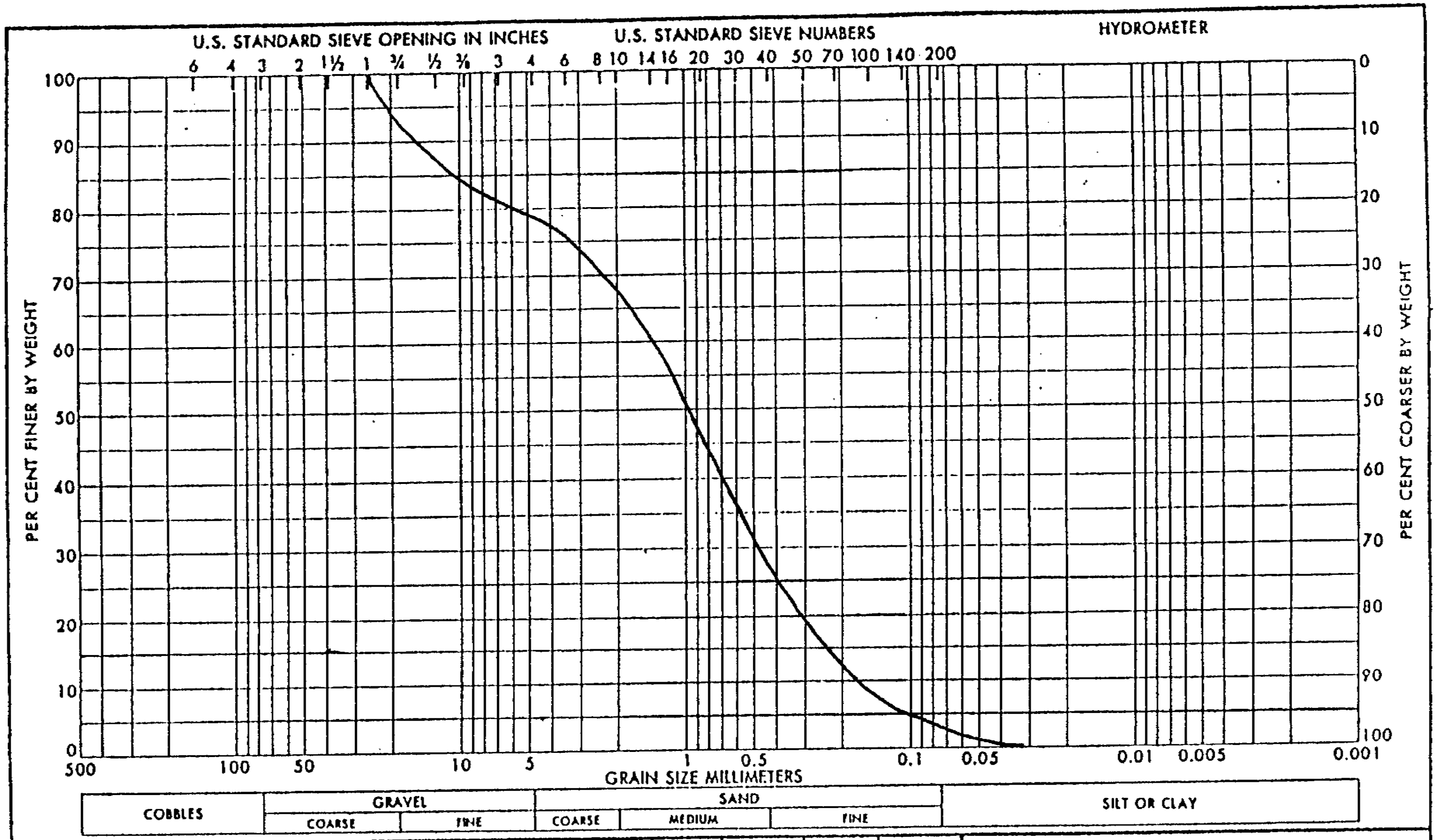
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
13		SW				
D_{10}	0.17					
D_{30}	0.48	C_u= 8.2				
D_{60}	1.4	C_c= 1.0				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date

Project

Boring No.

Sample No. 14

Total wt in grams of sample, W_s = 147.6g

Wt in grams of material > No. 4 sieve = 16.6g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				100.0
0.375	9.52	3/8-in.	5.2	3.5		96.5
0.250	6.35	No. 3	5.9	4.0		92.5
0.187	4.76	No. 4	5.5	3.7		88.8
		Pan				
0.132	3.36	No. 6	4.6	3.1		85.7
0.094	2.38	No. 8				
0.079	2.00	No. 14	20.1	13.6		72.1
0.047	1.19	No. 16				
0.033	0.84	No. 20	20.0	13.6		58.5
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	52.3	35.4		23.1
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	18.4	12.5		10.6
0.0041	0.105	No. 140	5.7	3.9		6.7
0.0029	0.074	No. 200	4.3	2.9		3.8
		Pan	5.6	3.8		
Total weight in grams			147.6			

$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

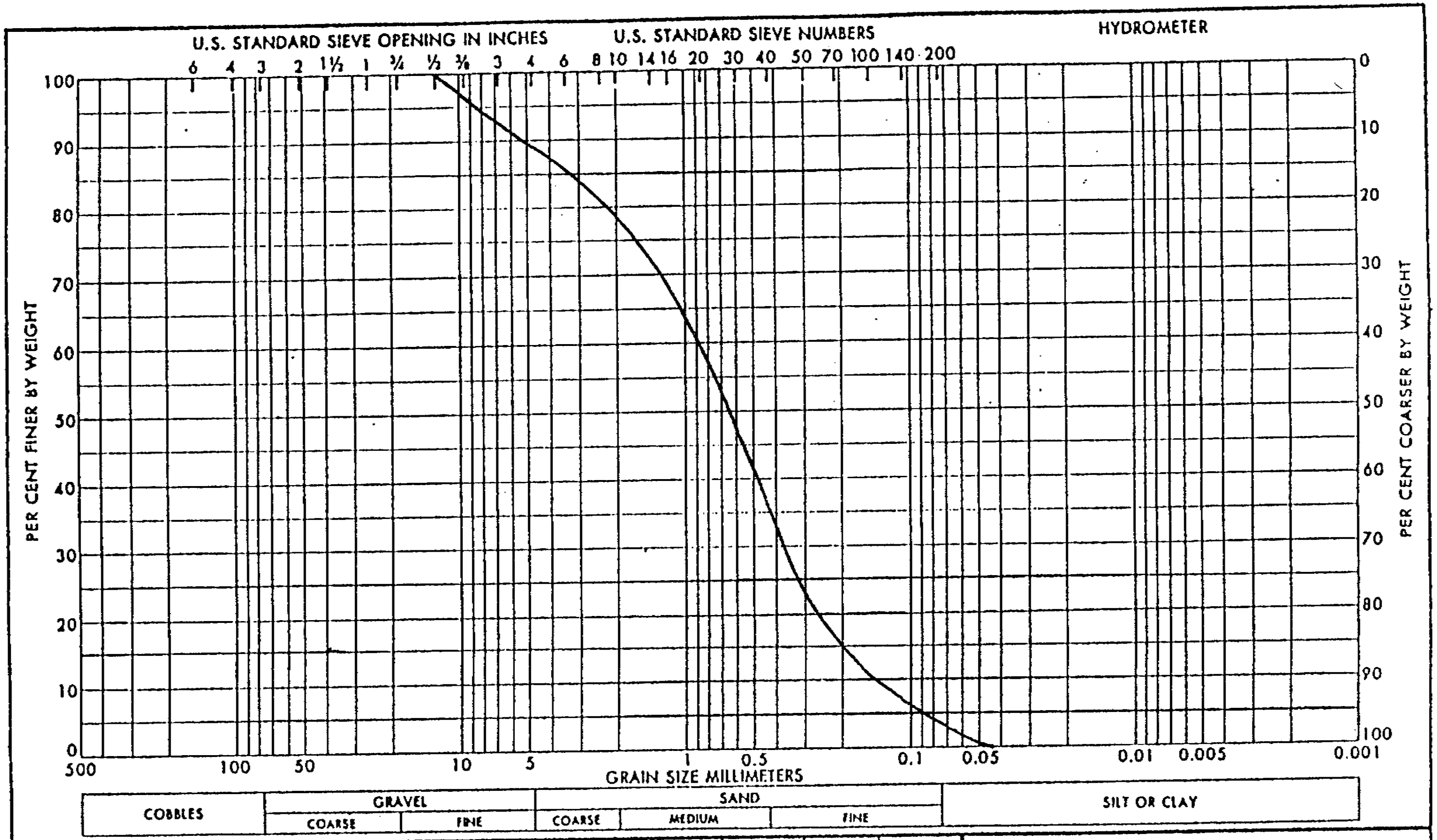
For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician

Computed by

Checked by



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
14		SW				
D_{10}	0.14					
D_{30}	0.37	C_u = 6.4				
D_{60}	0.89	C_c = 1.1				

GRADATION CURVES

PROJECT

AREA

BORING NO.

DATE

SIEVE ANALYSIS

Date

Project

Boring No.

Sample No. 15

Total wt in grams of sample, W_s = 179.7

Wt in grams of material > No. 4 sieve = 12.6g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				
0.375	9.52	3/8-in.				100.0
0.250	6.35	No. 3	7.7	4.3		95.9
0.187	4.76	No. 4	4.9	2.7		93.2
		Pan				
0.132	3.36	No. 6	8.8	4.9		88.3
0.094	2.38	No. 8				
0.079	2.00	No. 14	33.0	18.4		69.9
0.047	1.19	No. 16				
0.033	0.84	No. 20	24.9	13.9		56.0
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	52.1	29.0		27.0
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	23.7	13.2		13.8
0.0041	0.105	No. 140	9.1	5.1		8.7
0.0029	0.074	No. 200	7.3	4.1		4.6
		Pan	8.2	4.6		
Total weight in grams			179.7			

$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

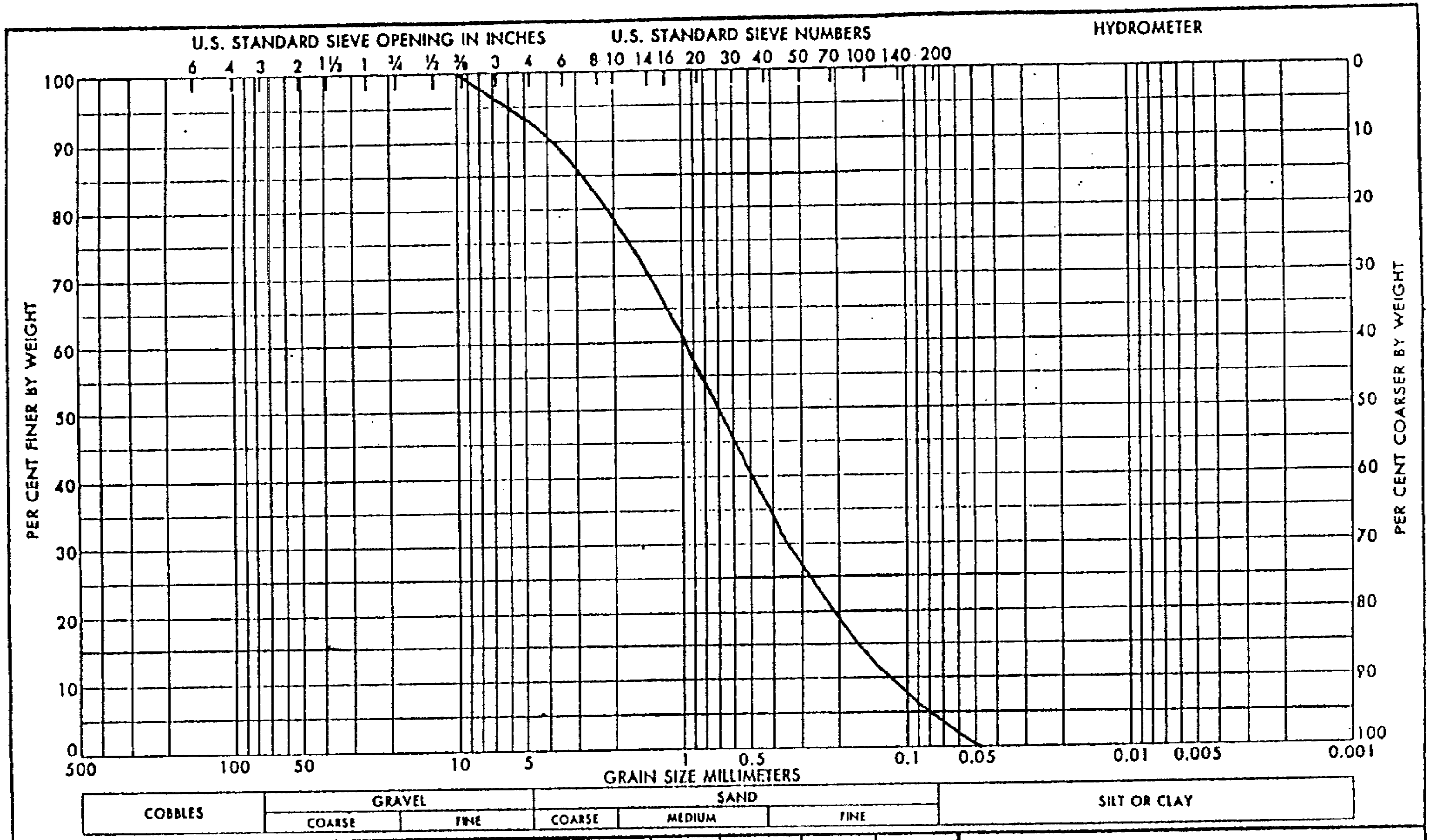
For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician

Computed by

Checked by



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
15		SW				
D_{10}	0.12					
D_{30}	0.34	C_u = 8.2				
D_{60}	0.98	C_c = 1.0				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 16

Total wt in grams of sample, W_s =

Wt in grams of material > No. 4 sieve = 21.7 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	3.9	3.4		96.7
0.375	9.52	3/8-in.	4.7	4.1		92.6
0.250	6.35	No. 3	9.5	8.3		84.3
0.187	4.76	No. 4	3.6	3.1		81.2
		Pan				
0.132	3.36	No. 6	4.0	3.5		77.7
0.094	2.38	No. 8				
0.079	2.00	No. 14	9.9	8.6		69.1
0.047	1.19	No. 16				
0.033	0.84	No. 20	6.4	5.6		63.5
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	26.3	22.9		40.6
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	18.9	16.5		24.1
0.0041	0.105	No. 140	8.8	7.7		16.4
0.0029	0.074	No. 200	8.1	7.1		9.3
		Pan	10.7	9.3		
Total weight in grams			114.8			

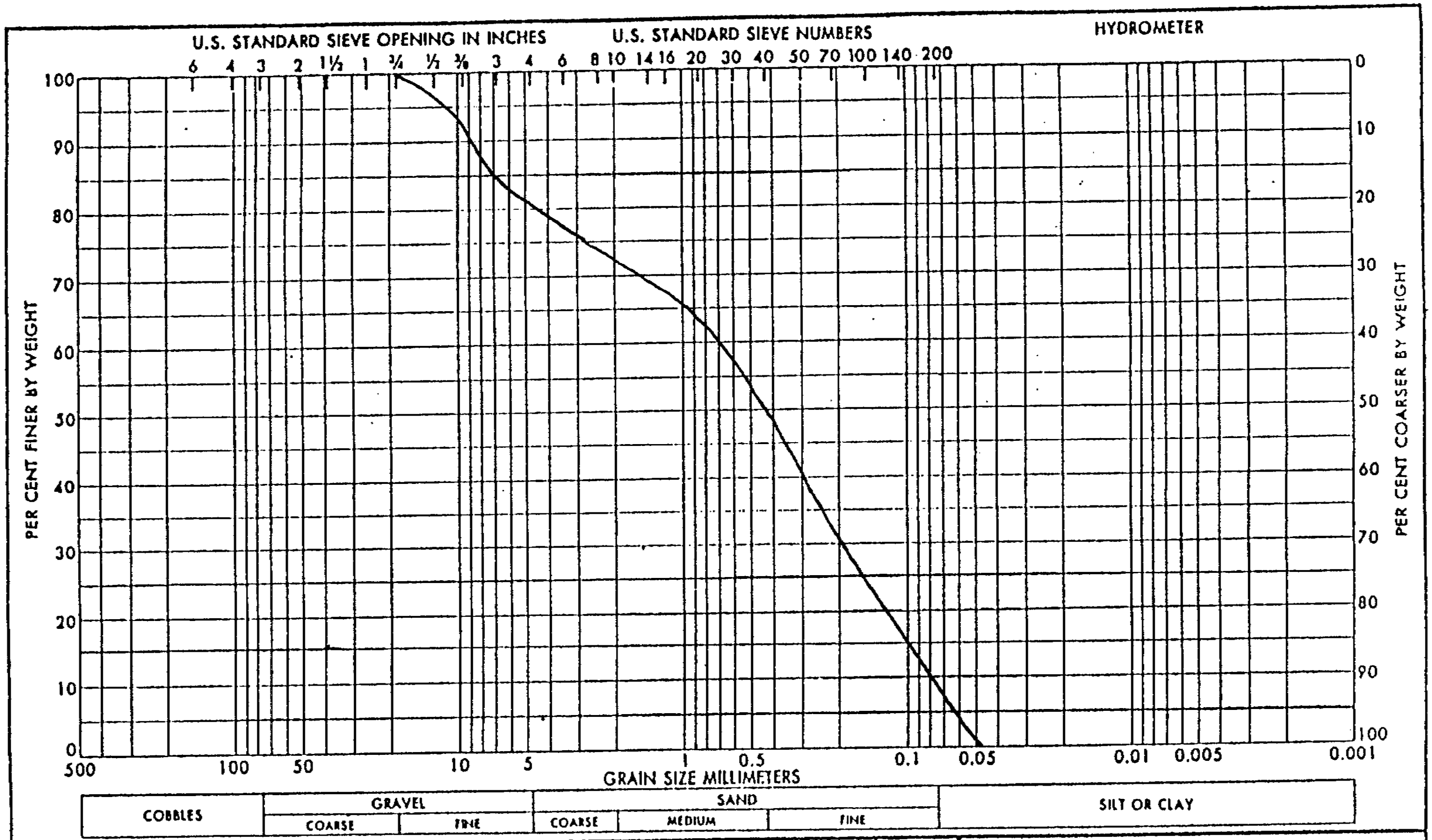
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
16		SP-SM		40.4	29.3	11.1
D_{10}	0.08					
D_{30}	0.19	Cu= 8.8				
D_{60}	0.7	Cc= 0.6				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ______

Project ______

Boring No. ______ Sample No. 17

Total wt in grams of sample, W_s = 162.8 g | Wt in grams of material > No. 4 sieve = 50.2 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				100.0
0.750	19.1	3/4-in.	26.5	16.3		83.7
0.500	12.7	1/2-in.	4.3	2.6		81.1
0.375	9.52	3/8-in.	4.0	2.5		78.6
0.250	6.35	No. 3	10.5	6.4		72.2
0.187	4.76	No. 4	4.9	3.0		69.2
		Pan				
0.132	3.36	No. 6	7.0	4.3		64.9
0.094	2.38	No. 8				
0.079	2.00	No. 14	19.9	12.2		52.7
0.047	1.19	No. 16				
0.033	0.84	No. 20	25.7	15.8		36.9
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	33.8	20.8		16.1
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	11.9	7.3		8.8
0.0041	0.105	No. 140	4.5	2.8		6.0
0.0029	0.074	No. 200	4.1	2.5		3.5
		Pan	5.7	3.5		
Total weight in grams			162.8			

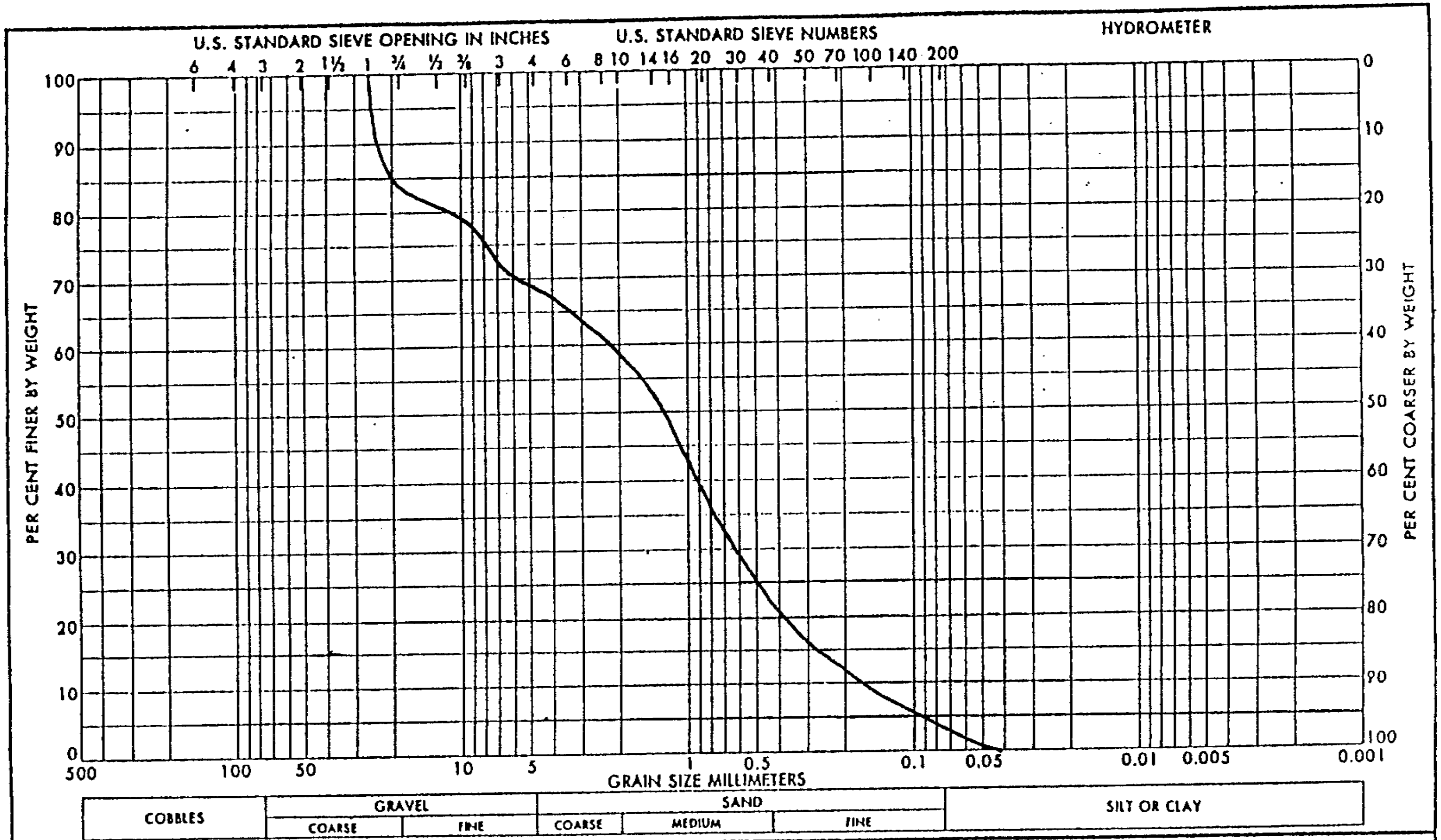
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	
17		SW					PROJECT
D_{10}	0.17						AREA
D_{30}	0,63	C_u = 12.9					BORING NO.
D_{60}	2.2	C_c = 1.1					
GRADATION CURVES							DATE

SIEVE ANALYSIS

Date ____________

Project ____________

Boring No. ____________ Sample No. 18

Total wt in grams of sample, W_s = 137.8 g			Wt in grams of material > No. 4 sieve = 19.4 g			
Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.				100.0
0.375	9.52	3/8-in.	9.7	7.0		92.9
0.250	6.35	No. 3	5.9	4.3		88.6
0.187	4.76	No. 4	3.8	2.8		85.8
		Pan				
0.132	3.36	No. 6	6.8	4.9		80.9
0.094	2.38	No. 8				
0.079	2.00	No. 14	32.7	23.7		57.2
0.047	1.19	No. 16				
0.033	0.84	No. 20	22.0	16.0		41.2
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	37.5	27.2		14.0
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	11.3	8.2		5.8
0.0041	0.105	No. 140	3.1	2.2		3.6
0.0029	0.074	No. 200	2.6	1.9		1.7
		Pan	2.4	1.7		
Total weight in grams			137.8			

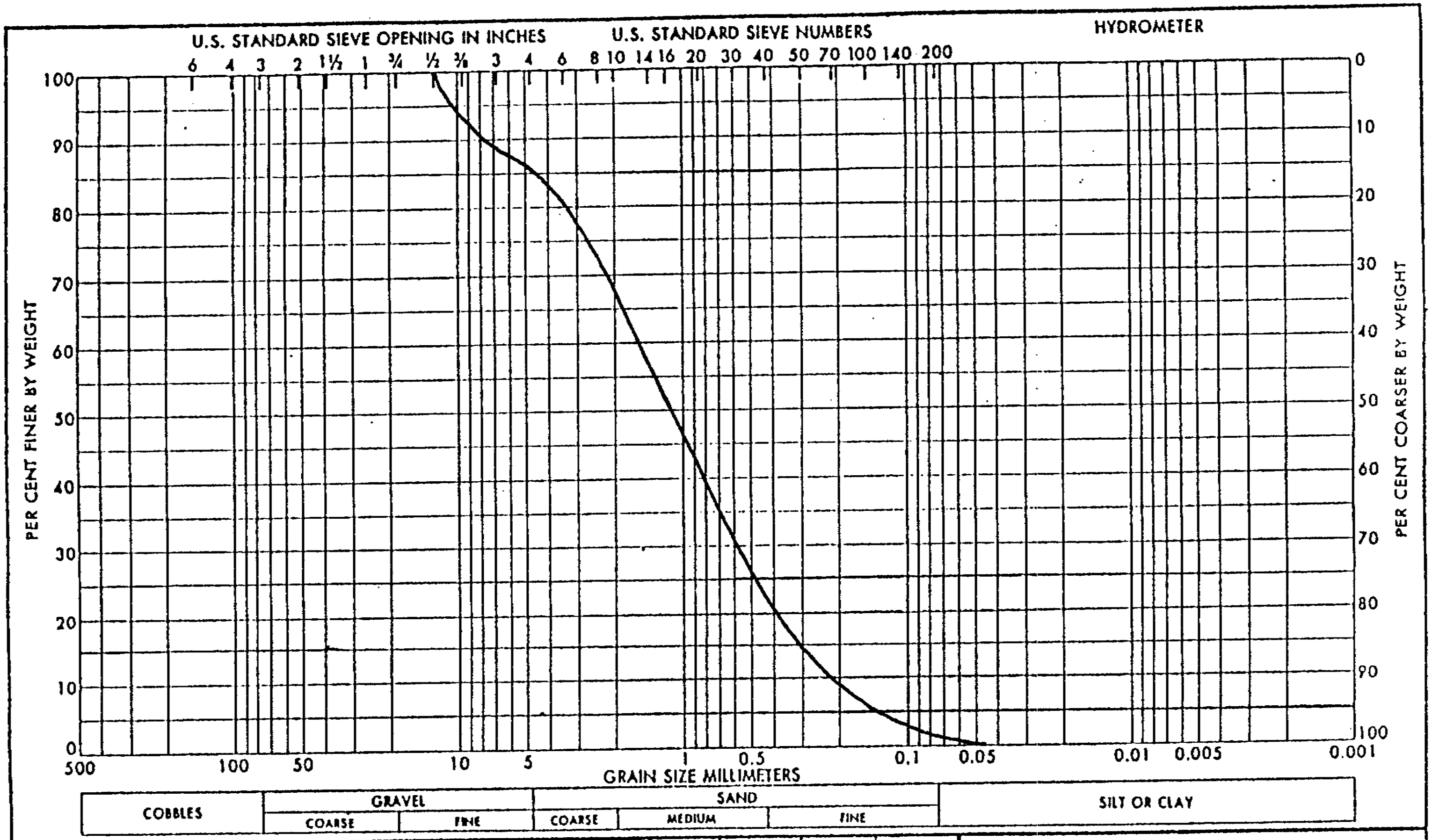
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ____________ Computed by ____________ Checked by ____________



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
18		SW				
D_{10}	0.22					
D_{30}	0.58	C_u = 7.3				
D_{60}	1.6	C_c = 1.0				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES

SIEVE ANALYSIS

Date ______

Project ______

Boring No. ______ Sample No. 19

Total wt in grams of sample, W_s = 154.0 g	Wt in grams of material > No. 4 sieve = 33.0 g

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				100.0
0.500	12.7	1/2-in.	6.8	4.4		95.6
0.375	9.52	3/8-in.	5.5	3.6		92.0
0.250	6.35	No. 3	10.3	6.7		85.3
0.187	4.76	No. 4	10.4	6.8		78.5
		Pan				
0.132	3.36	No. 6	4.5	2.9		75.6
0.094	2.38	No. 8				
0.079	2.00	No. 14	36.7	23.8		51.8
0.047	1.19	No. 16				
0.033	0.84	No. 20	27.6	17.9		33.9
0.023	0.59	No. 30				
0.0165	0.42	No. 40				
0.0117	0.297	No. 50	33.6	21.8		12.1
0.0083	0.210	No. 70				
0.0059	0.149	No. 100	9.7	6.3		5.8
0.0041	0.105	No. 140	3.3	2.1		3.7
0.0029	0.074	No. 200	2.7	1.8		1.9
		Pan	2.9	1.9		
Total weight in grams			154.0			

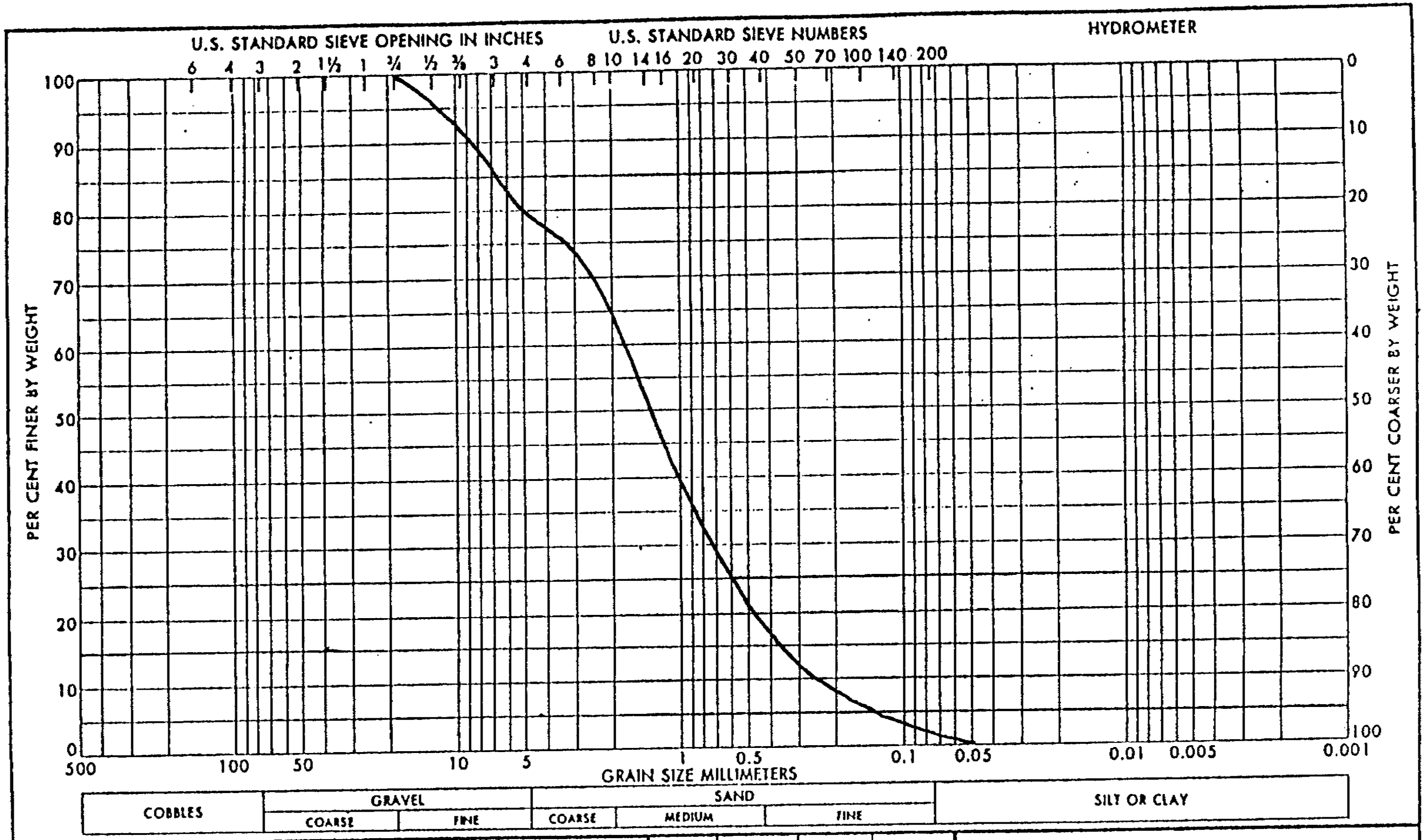
$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
19		SW				
D_{10}	0.26					
D_{30}	0.72	C_u = 7.2				
D_{60}	1.8	C_c = 1.2				

PROJECT

AREA

BORING NO.

DATE

GRADATION CURVES