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US Army Corps of Engineers
Hydrologic Engineering Center

Phase I Sediment Engineering Investigation of the Caliente Creek Drainage Basin

Prepared for

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Executive Summary

This report presents the results of the second of two elements of a Phase I Sediment Engineering Investigation (SEI) conducted for the Sacramento District Corps of Engineers. Results from the first element of the SEI are reported by Harvey (1989). He presents the results of a Geomorphic Analysis of the Caliente Creek drainage basin. The present report presents the results from the Sedimentation Analysis conducted by the Hydrologic Engineering Center (HEC) which is intended to expand on previous work done by the Corps (USACE, 1988-b) in order to better estimate the average annual sediment yield at the proposed damsite and to also estimate potential single event sediment volumes for various frequency based storms.

The Hydrologic Engineering Center reviewed available scientific and engineering literature pertaining to methods for estimating sediment yield and evaluating sediment transport processes on alluvial fans. HEC conducted a three-day field reconnaissance and sediment data collection investigation, interviewed persons familiar with the Caliente Creek Project and watershed, and conducted a series of sediment engineering analyses to determine the possible sedimentation (scour, deposition, transport) characteristics of the drainage basin and alluvial fan near the proposed damsite.

The average annual sediment yield at the proposed damsite was estimated using results from eight different sources of data and/or methods for estimating sediment yield. Sediment engineering methods presented in the Sediment Engineering Manual, EM 1110-2-4000 (USACE, 1989) were used throughout this investigation. Other methods prescribed by the Soil Conservation Service (USDA, SCS, 1975, 1977, 1980) were also applied. The following procedures were used: (1) Previous reports and publications were thoroughly reviewed for information and data pertaining to the study, (2) USDA (1977) published reservoir sedimentation rates were examined, (3) recent USACE reservoir sedimentation survey data were analyzed, (4) sediment yield maps for the Western United States (USDA, SCS, 1975) were examined, (5) the average annual sediment yield was estimated from computations of the total event sediment volumes for single events ranging from the 2-year event up to the PMF based on channel transport capacity rather than annual watershed sediment production and delivery, (6) a similar flow duration and sediment load curve integration method (see EM 1110-2-4000, USACE, 1989) was used to estimate the average annual sediment yield to the reservoir site, (7) the Pacific Southwest Inter-Agency Committee (PSIAC, 1968) method was used to estimate basin-wide sediment yield from the entire watershed, and (8) the Dendy and Bolton (1976) Regional Analysis Method for sediment yield was applied.

The estimated annual sediment yield compiled by this study ranged from 0.2 AF/sq mi/yr to 2.2 AF/sq mi/yr. Based on results from past studies, recent reservoir surveys and computations performed during the present study, including the consideration for the geomorphic characteristics of the watershed, the average annual sediment yield at the proposed Sivert damsite is estimated to be approximately 0.75 AF/sq mi/yr. This represents approximately 353 acre feet of dry sediment per year in the form of annual removal

requirements. Extrapolated out linearly for the life of the project, this represents approximately 35,300 acre feet of removal requirements. Because of the episodic nature of the basin the annual sediment yield may be significantly higher than .75 AF during high runoff years. For instance, one 100 year event may deliver approximately twenty times the average annual amount of sediment within a one week period. Conversely, the yield can be lower during dry periods.

Sediment transport in the basin is episodic and depends largely on the occurrence of large events. Sediment is stored in the broad valley washes (approximately 3000 to 6600 feet wide) in the lower portions of the Caliente Basin. There is sufficient material located in these expansive washes to supply sediment to the lower fan areas somewhat independently of the production and delivery of sediments from the upper watershed areas. Therefore, sediment yield at the proposed damsite may be more dependent upon the transport capacity of the channels and washes immediately upstream from the damsite than the basinwide (watershed) production of sediment materials during a flood event. Single event floods can produce significantly more sediment per event than the estimated annual sediment yield per year. As much as 43 percent of the total gross pool storage volume (16,000 AF) could be lost due to sediment deposition during a one percent chance (100 year) flood event. This would necessitate the removal of approximately 6,900 AF (11,320,000 yd^3) of sediment material from the reservoir prior to the next flood season. Removal of this amount of mud and debris during one summer season by using traditional removal methods (rubber tire loaders and trucks) may be difficult without dewatering the material first or by applying other special removal methods.

Examination of the sedimentation characteristics of the Caliente Creek basin has raised additional concerns with respect to the presently proposed (i.e., feasibility) J-shaped plan for the dam and reservoir. The proposed reservoir design requires concentration of the flows along the toe of the high Sand Hills (along the western margin of the lower Caliente Creek incised fan). Past floods (1983) have caused erosion of portions of the toe resulting in mass failure of at least two sections of the Sand Hills onto the floodplain. Concentration of future flood flows along the toe of the Sand Hills may lead to the failure of large sections of the high bank materials and significantly increase the sediment volume entering the reservoir during an event, thus decreasing the water storage capacity. Soils stabilization and grouting along the Sand Hills abutment section may be necessary. Stabilization and special treatment of the spillway apron and thorough protection of the east side of the J-shape dam embankment section adjacent to the spillway chute is necessary to prevent spillway and embankment erosion problems.

Active faults (White Wolf and Breckenridge faults) traverse the basin and have caused significant mass wasting in the upper watershed in the past (e.g., the 1952 earthquake). The Caliente Creek drainage basin and proposed damsite are located within seismic zone 4 where the possibility for large earthquakes is great (USACE, 1988-a). Possible mass wasting of the high Sand Hills into a full or partially full reservoir may displace (via overtopping) a large amount of stored water out of the reservoir and onto downstream portions of the fan. Within this scenario, failure of the dam embankment due to overtopping is possible. Dam safety analyses may be required during future (Phase II) studies.

The proposed reservoir design requires water to back up in the pool and into the spillway approach channel for the spillway to function. Closure of the eastern highway opening (under Highway 58) and the installation of a setback levee on the floodplain upstream from the spillway apron is necessary to preclude flow short circuiting directly into the excavated spillway outlet. Installation of these measures places more hydraulic pressure and shearing stresses on the remaining western opening under Highway 58 and onto its earthen embankment as well. Additional detailed hydraulic and scour computations should be conducted during the phase II SEI studies.

Field methods exist that allow circumstantiation of the estimated annual yield values. Time and cost estimates are being prepared for conducting such a circumstantiation investigation as part of the Phase II SEI.

Phase I
Sediment Engineering Investigation
of the
Caliente Creek Drainage Basin

1. Study Purpose

The proposed Caliente Creek Flood Control Project is in the feasibility (planning) phase, and consists of a flood detention reservoir to be built on the Caliente Creek alluvial fan approximately two miles downstream from Highway 58 (USACE, 1988-a). Figure 1 shows the location map of the basin and proposed dam site. The project also includes two seventeen-mile long flood control channels downstream from the damsite. This report summarizes the findings from two elements of the Phase I Sediment Engineering Investigation (SEI) addressing concerns raised by higher authority regarding the estimated sediment yield at the reservoir site presented in the draft Project Feasibility Report (USACE, 1988-b). The two elements of the Phase I SEI are: (a) Geomorphic Analyses - conducted by Water Engineering & Technology, Inc. (WET), Fort Collins, CO, under a work order from CESPK-ED-D, and (b) Sedimentation Analyses - conducted concurrently with the Geomorphic Investigation by the Hydrologic Engineering Center (HEC) in Davis, California. HEC's sedimentation analysis is intended to expand on previous work done by the Corps (USACE, 1988-b) to better estimate the average annual sediment yield at the proposed damsite and to also estimate single event sediment volumes for various probability storms. It does not address sediment issues associated with the flood control channels downstream from the damsite.

Therefore, the purpose of this Phase I SEI is to evaluate the geomorphic characteristics of the Caliente Creek drainage basin and to determine the potential sediment yield from the watershed and channels upstream from the proposed damsite.

2. Authorization and Study Participants

Authorization for this investigation comes from House Document No. 367, 81st Congress and Intra-Army Order No. CESPK-ED-D 89-68, dated 20 September, 1989. Mr. Ed Sing is the CESPK coordinator for the study, Mr. James Nightingale is the Project Engineer and Ms. Lauren Renning is the Individual Project Manager for the Caliente Creek Project. Dr. Michael Harvey was the project geomorphologist and geologist conducting the geomorphic analyses by Water Engineering & Technology and Dr. Robert MacArthur was the hydraulic engineer who conducted the sediment investigation and wrote this report for the Hydrologic Engineering Center.

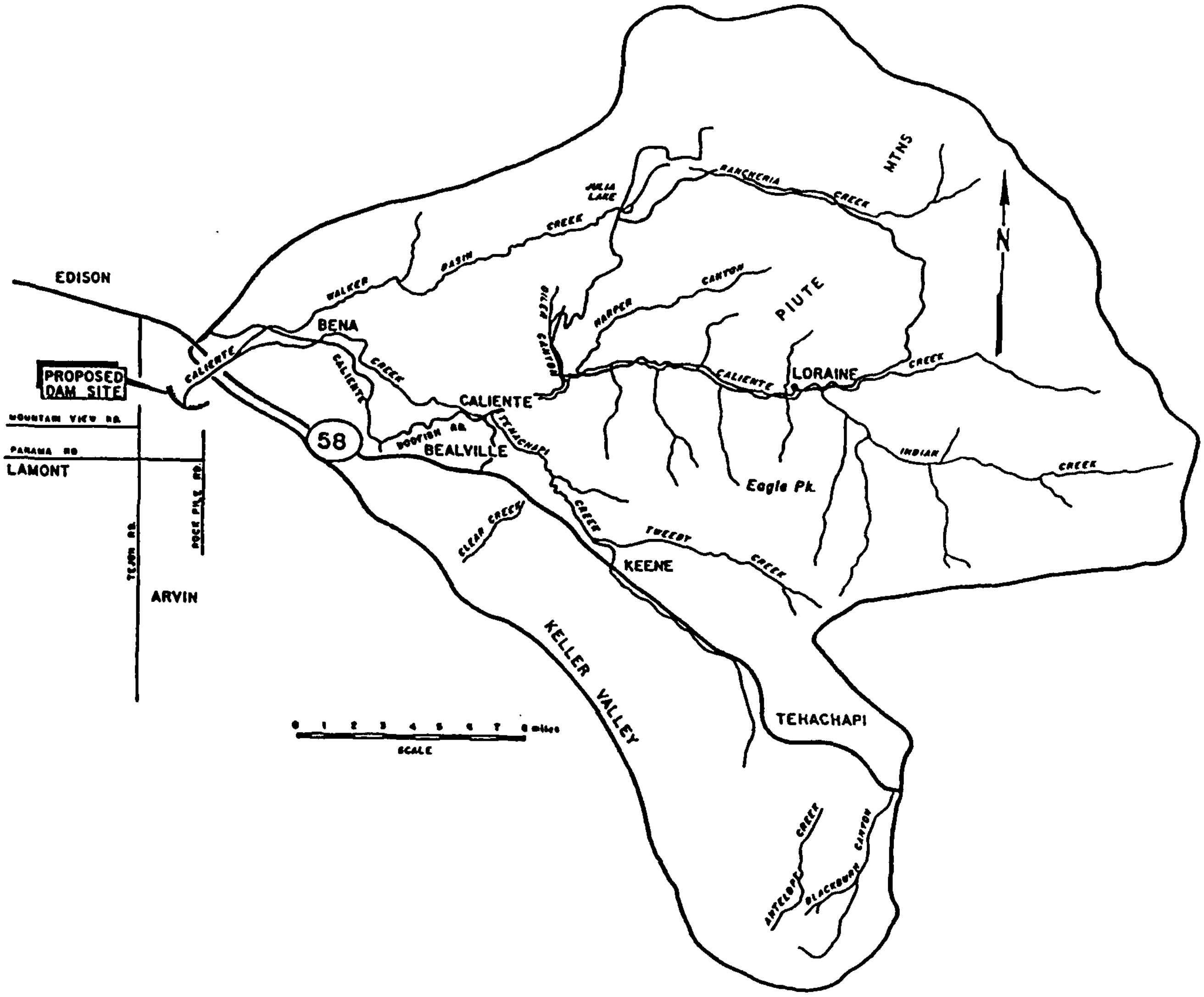

Figure 1
Location Map for Caliente Creek Basin

3. Approach

The Hydrologic Engineering Center reviewed available scientific and engineering literature pertaining to methods for estimating sediment yield and evaluating sediment transport processes on alluvial fans. HEC conducted a three-day field reconnaissance and sediment data collection investigation, interviewed persons familiar with the Caliente Creek Project and watershed, and conducted a series of sediment engineering analyses to determine the possible sedimentation characteristics of the drainage basin at the damsite. Morphometric data for the alluvial fan in the vicinity of the proposed reservoir site were obtained from 2-foot contour mapping provided by the Sacramento District (CESPK). The field reconnaissance and sediment data collection investigation was conducted during October 3 through October 5, 1989. Messrs. E.F. Sing and T. Marx (CESPK-ED-D), Dr. R.C. MacArthur (CEWRC-HEC-T) and Dr. M.D. Harvey (WET) conducted the field investigations and sediment sampling. They inspected the entire Caliente Creek watershed, including Tehachapi Creek and its tributaries Blackburn Canyon and Antelope Creek, Caliente Creek and its tributary Indian Creek, and the upper reaches of Walker Basin Creek. A detailed inspection of Caliente Creek between Bena and the proposed reservoir site was conducted. Portions of the Caliente Creek fan downstream from the proposed damsite were inspected on Panama Rd. and at Tejon Rd. Sixteen sediment samples (bed material and a few bank material samples) and two Wolman Counts (Wolman, 1954) were collected at representative locations throughout the drainage basin from the 1983 flood deposits and in active alluvial channel sections. During the field reconnaissance information was obtained from Mr. Scott Frazer, District Conservationist for the USDA Soil Conservation Service in Tehachapi and from the Kern County Water Agency (Messrs. D.K. Sorenson and R. Iger) in Bakersfield, CA. Mr. Iger accompanied the field inspection team during their visit to the proposed reservoir site and to the lower reaches of Caliente Creek. In early November 1989, Mr. Tom Marx (from CESPK) spent one day examining the Kern County Water Agency's (KCWA) files and data records pertaining to the Caliente Creek drainage basin and project area. Materials obtained during his visit to KCWA were used extensively throughout this study. Personnel from the KCWA provided additional help and cooperation throughout the conduct of both studies (the geomorphic and sediment investigations). CESPK and HEC are very grateful for their courteous and timely assistance.

Additional data and information used by the study team to conduct the investigation are listed in the References section of this report.

Harvey (1989) reports the detailed Regional Geology (including Stratigraphy, Basement Complexity, Sedimentary Formations, Structure, and Faulting). He also discusses the complex Watershed and Channel Morphology, Sedimentology and Geomorphology of the Caliente Creek Basin and Alluvial Fan Complex. Appendix A presents the Executive Summary from Harvey's (1989) report, entitled: "Caliente Creek, California Project - Geomorphic Analysis." Detailed field observations are also reported by Harvey (1989) along with photographs of the area and field mapping that was prepared during the field inspection. Harvey's (1989) primary conclusions include: (1) the potential for sediment delivery to the reservoir site is controlled by the transport capacity of the alluvial channel system (valley width and channel slope), (2) episodic debris flows, mass failure of colluvial slope deposits and incision into old fan deposits accounts for major portions of the active bed material transported to the lower basin during flood events, (3) basin geomorphology supports the possibility that peak discharges may be underestimated, (4) floodflows may bypass the detention basin under its present configuration if floodflows become concentrated on the eastern side of the lower fan, and (5) floodflows can (and have recently) undercut the Sand Hills along the western margin of the fan, resulting in the delivery of significant volumes of sediment directly to the proposed reservoir site.

4. Estimation of Basin Sediment Delivery and Yield to the Proposed Reservoir

In order to determine the amount of sediment that may possibly enter the proposed reservoir during its design life (100 years), both the average annual sediment yield and single event sediment yields are estimated using a variety of sediment engineering procedures as reported in EM 1110-2-4000, "Sediment Investigations of Rivers and Reservoirs," (USACE, 1988) and recommended by others.

4.1 Average Annual Sediment Yield

The average annual sediment yield at the proposed reservoir site was estimated using results from eight different sources of data and/or methods for estimating sediment yield. The following procedures were used: (1) Previous reports and publications were thoroughly reviewed for available data, (2) USDA (1977) published reservoir sedimentation rates were examined, (3) recent USACE reservoir sedimentation survey data were analyzed, (4) sediment yield maps for the Western United States (USDA, SCS, 1975) were examined, (5) the average annual sediment yield was estimated from computations of the total event sediment volumes for single events ranging from the 2-year event up to the PMF based on channel transport capacity rather than watershed sediment production and delivery, (6) a flow duration and sediment load curve integration method (see EM 1110-2-4000, USACE, 1989) was used to estimate the average annual sediment production and yield to the reservoir site, (7) the Pacific Southwest Inter-Agency Committee (PSIAC) method was used to estimate basin-wide sediment yield from the entire watershed, and (8) the Dendy and Bolton (1976) Regional Analysis Method for sediment yield was applied. Results from these analyses are discussed next. Detailed procedures for conducting such investigations are presented in the references cited in the text, in Engineering Manual 1110-2-4000 (USACE, 1989) and listed in the References Section of this report. **Table 1** summarizes the results.

The Caliente Creek, CA project Hydrology Office Report (USACE, 1980) and the Feasibility Study Documentation Report (USACE, 1988) present an estimated average annual sediment deposition rate at the proposed Sivert Dam site of 0.38 AF/sq mi/yr (approximately 180 acre-feet per year). This estimate was based on measured average annual reservoir sedimentation rates reported for the Kern River Basin and on SCS (Stearns, 1978) sediment yield estimates prepared for two proposed flood detention basins located in the Tehachapi Mountains above Tehachapi. Since 1978, when Stearns first estimated an average annual sediment yield of approximately 0.65 AF/sq mi/yr for Blackburn Canyon and Antelope Creek (tributaries to the Tehachapi Creek), the SCS has revised (increased) the annual sediment production rate estimates to 1.5 AF/sq mi/yr and 2.2 AF/sq mi/yr for the Antelope and Blackburn drainages, respectively (USDA, SCS, 1980). The revised values are listed in **Table 1**. These drainage basins are relatively small (less than 10 sq mi each) and are very steep and will, therefore, have a high sediment delivery ratio. Larger drainage basins deliver smaller amounts of the total sediment they produce to the lower reaches of the watershed because of interception (capture) and deposition that occurs along the way. Blackburn and Antelope basins are also comprised of weathered granitic parent materials and, therefore, the sediment yields of the magnitude reported for those basins may not be representative of the sediment production and delivery characteristics at the reservoir site.

TABLE 1

Sediment Surveys for Reservoirs in the Vicinity of Caliente Creek, California, and Estimated Average Annual Sediment Yields Based on Various Computational Methods

Data Source	References[1]	Drainage Basin, Reservoir or Computational Method Used	Drainage Area (sq mi)	Average Annual Yield (AF/sq mi/yr)
SCS	34	Blackburn	7.1	2.20
SCS	34	Antelope Canyon	4.4	1.50
CESPK[2]		Isabella	2,074	0.37
CESPK	33	Pine Flat	1,542	0.20
CESPK	33	Success	393	0.76
CESPK	33	Terminus	560	0.75
SCS	32	SCS Yield Map of Wester US (HEC)[3]	470	0.47
Computed	29	Integration of the Event Volume vs. Frequency Curve (HEC)	470	0.55
Computed	29	Flow Duration Method (HEC)	470	0.90
Computed	29	Dendy & Bolton Method (HEC)	470	0.71
Computed	14	PSIAC Method (HEC)	470	0.75
Computed	17	Kern County Water Agency Study (SLA)	470	0.97

[1] The numbers listed correspond to the references cited in the reference section starting on page 25.

[2] Personal communication with CESPK-ED-H/Herb Hereth (11/21/89).

[3] Letters in parenthesis indicate whether the Hydrologic Engineering Center (HEC) or Simons, Li & Associates (SLA) performed the calculations.

Because of their close proximity to Caliente Creek and similar hydrologic characteristics and geology, the SCS reported values for the Blackburn and Antelope basins do provide an approximate upper bound for the estimated sediment yield near the proposed reservoir site.

Table 1 presents measured reservoir survey data reported by the USDA (1977) from catchments located relatively near to the study area. It also lists sediment yields estimated from SCS Yield Maps and other values computed using various sediment yield methods. **Figure 2** presents the location of the six different drainage areas that were used to compare basin wide sediment yields. Lake Isabella, Kern Co. and Pine Flat Dam, Kings Co. have different geologic characteristics than those found in the Caliente Creek Basin. Their

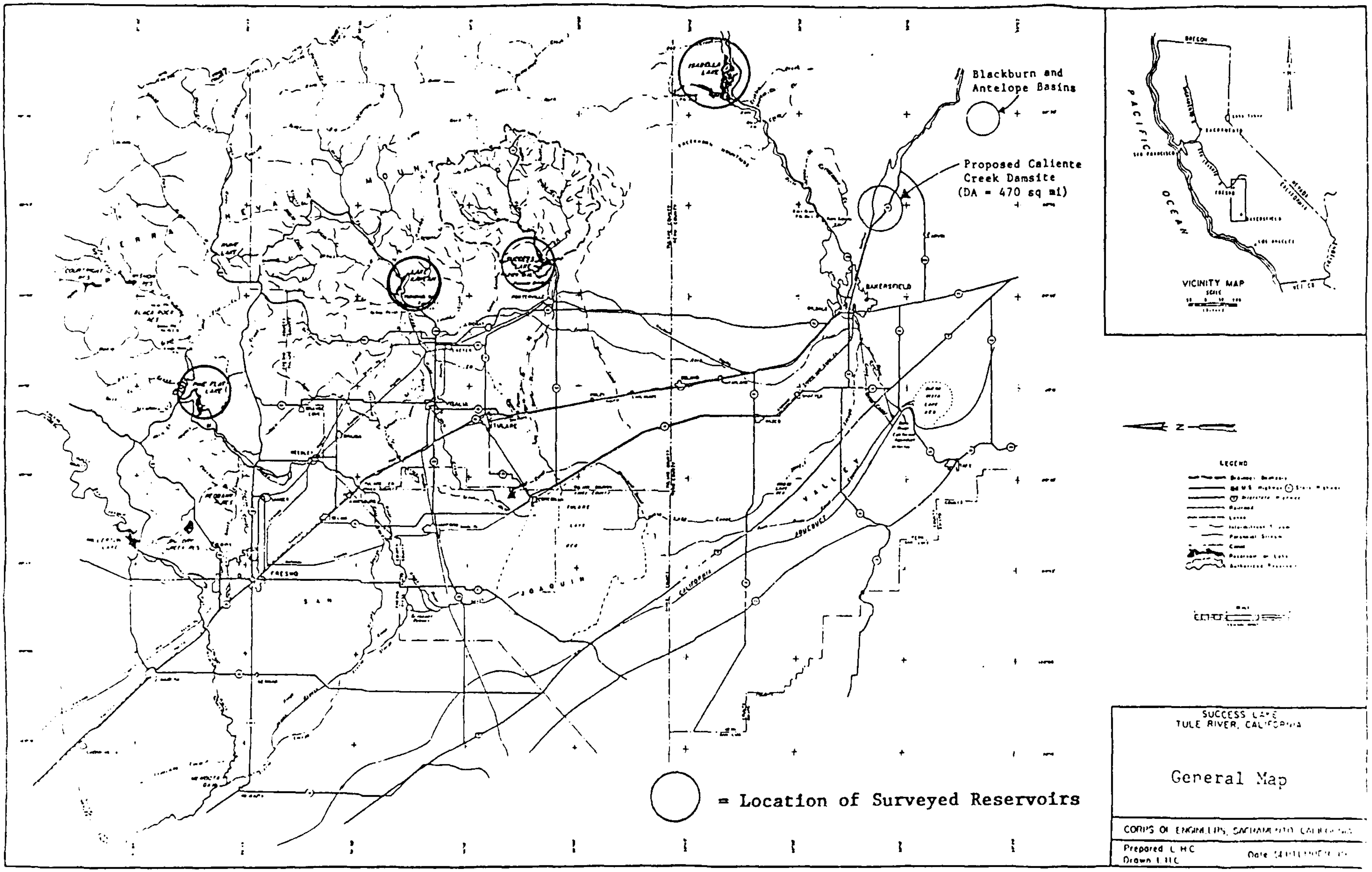

Figure 2
Location of Six Drainage Areas
Used to Estimate Yield

effective drainage areas are much larger (by 77 %) than the Caliente Creek Basin and the maximum watershed elevations are also higher. The measured yields at Lake Isabella and Pine Flat are approximately 0.37 and 0.20 AF/sq mi/yr, respectively.

Success Lake, in Tulare Co. and Kaweah Lake (Terminus Dam), in Tulare Co. are more representative of the kinds of geology and basin watershed conditions found in the Caliente Basin. The Sacramento District Corps of Engineers is presently conducting survey studies to re-evaluate several of their reservoirs in the vicinity of Caliente Creek. At the time of this reporting, most of the new data were not available. However, the sediment yield for Lake Isabella has been revised and is reported in **Table 1** along with the revised yields for Blackburn and Antelope reported by the SCS (1980). Therefore, based on measured sediment accumulation rates recorded in the Tulare, Kings, and Kern County reservoirs (as of 11/20/89), having effective drainage basin areas larger than 390 square miles, the approximate range of observed sediment yields is from 0.2 AF/sq mi/yr to 0.76 AF/sq mi/yr., or approximately 94 to 357 acre-feet per year based on the Caliente Creek Basin drainage area of 470 sq mi.

Sediment yield rates for the Western United States are reported by the USDA, SCS (1975). From the mapping of yield rates, it appears that the upper Caliente watershed area has sediment yield rates from 0.2 to 0.5 AF/sq mi/yr, with pockets as high as 0.5 to 1.0 AF/sq mi/yr. In the lower portions of the basin, on the valley floor and on portions of the broad alluvial fan, the estimated yields are reported to be in the range of 0.1 to 0.2 AF/sq mi/yr. Using area weighting methods to sum the yields from contributing subbasins, the approximate annual yield appears to range from 0.2 to about 0.75 AF/sq mi/yr, with an average of about 0.47 AF/sq mi/yr for the entire watershed (approximately 221 acre feet per year at the dam site).

Another approach used to check these annual yield estimates was based on the transport capacity of the channels in the supply reach. The supply reach is a 4-mile section of the channel considered to be representative of the channel hydraulic conditions and sediment transport characteristics upstream from the dam site. Single event total sediment volumes were computed for each of the 20%, 10%, 5%, 2%, 1%, SPF, and PMF events. The total sediment production for each event was based on the sediment transport capacity of the alluvial channel (supply reach) upstream from the reservoir and the flow hydrographs used for each of the flood events evaluated. The flow hydrographs for the Sivert Dam site were prepared by ratioing the coordinates of the 5-day SPF general rain hydrograph (Chart 63, USACE, 1980) developed for the Pampa dam site (see **Tables 2** and **3** in this report for the developed hydrographs). A total sediment load versus percent exceedance curve was developed from these data and the area under the total load frequency curve was computed to give an estimate for the expected average annual sediment delivery to the reservoir based on channel transport capacity upstream from the reservoir. Two different transport relationships were used to develop the total load curves (the New Laursen and Copeland Laursen methods). Vanoni (1975), Williams and Julien (1989) and Nakato (1990) discuss the differences between many of the often-used transport functions. The resulting average annual sediment delivery ranged from 0.1 AF/sq mi/yr to 1.0 AF/sq mi/yr due to the difference in transport capacity computed with the transport functions. Using these results as a representative range in expected yields based on channel capacity, an average of the two yields seems reasonable. Therefore, based on the channel transport capacity above the reservoir site and the estimated total sediment production from a range of single events, an approximate sediment yield at the reservoir is 0.55 AF/sq mi/yr. The average yield (0.55 AF/sq mi/yr) produces approximately 260 acre feet of sediment each year, while the higher estimated yield (1.0 AF/sq mi/yr) produces 470 acre feet of sediment each year.

This method does not account for the additional contribution of sediment from dry ravel erosion, wind-blown sand transport into the channel or reservoir, channel bank caving, local scour, or toe failure that may occur along the Sand Hills. Therefore, the sediment yield to the reservoir may be as high as the higher of the two transport functions predicts, especially during periods of exceptionally wet years.

The "flow duration sediment discharge rating curve method," (USACE, 1989) is a simple method where the flow duration curve is integrated with the sediment discharge rating curve at the outflow point (at the Sivert Damsite) of the basin. It is very similar to the method just described, however, the average annual sediment yield is based on the channel transport capacity and flow duration relationships rather than the total event volume frequency. The method is the most common method used in the Corps of Engineers for estimating basin sediment yield (USACE, 1989). A mean daily flow, flow duration curve was developed for Caliente Creek at the Sivert damsite by the Hydrology Section of the Sacramento District Corps of Engineers. That relationship along with the total sediment load curve for the channel reach located upstream from the damsite are used to compute the average annual sediment yield to the reservoir. (Methods used to develop the load curve are discussed in the following section.) HEC utilized an unpublished utility computer code called SEDYLD89 (recently developed by the Waterways Experiment Station) to integrate the load relationship and the flow duration curves to compute the average annual sediment yield. The resulting annual sediment yield is approximately 438 AF/year, or 0.9 AF/sq mi/yr.

Further examination of the USDA, SCS (1975) "Sediment Yield Rates for the Western United States" shows areas in the vicinity of the proposed dam site with estimated yields from 0.5 to 1.0 AF/sq mi/yr. These areas may correspond to the broad floodplain channels (4000 to 6500 feet wide) immediately upstream from the proposed reservoir site. If that is the case, then the higher yield values estimated with the channel transport capacity method (1.0 AF/sq mi/yr) and the flow duration method (0.9 AF/sq mi/yr) are supported by SCS yield mapping estimates.

The Dendy and Bolton (1976) method is a widely applicable regional method recommended by Engineering Manual 1110-2-4000 (USACE, 1989). Dendy and Bolton's regression relationships for sediment yield are based on measured sedimentation rates in over 800 reservoirs throughout the continental United States. The relationships associate basin drainage area and mean annual runoff to average annual sediment yield. The Dendy and Bolton (1976) method produces an average annual sediment yield of approximately 0.71 AF/sq mi/yr (334 acre feet /yr) for the Caliente Basin at the Sivert damsite.

The Pacific Southwest Inter-Agency Committee (PSIAC) sediment yield method (PSIAC, 1968) was also used. The PSIAC method was developed specifically for use in the Pacific Southwest and has been considered by many to be one of the most reliable total sediment yield methods for use in the western states. Application of PSIAC procedures to the Caliente Creek watershed produces an estimated average annual sediment yield of 0.75 AF/sq mi/yr at the dam site. This value is right in line with the range of values predicted from the channel capacity approach and the measured reservoir accumulation results from Tulare County.

Summing all of the sediment yields reported above and dividing by the number of entries gives an arithmetic average of 0.76 AF/sq mi/yr. Examining these results in light of the geomorphic characteristics of Caliente Creek Basin (see Harvey, 1989), the most reliable value for the annual basin averaged sediment yield at the proposed reservoir site is 0.76 AF/sq mi/yr, or approximately 357 acre feet of sediment per year.

During the fall of 1989, the Kern County Water Agency (KCWA) hired their own private consultant to conduct an independent assessment of the proposed Caliente Creek Project. The consultant was tasked with estimating the average annual sediment yield and the 1% chances (100-year) flood sediment yield at the proposed damsite. KCWA hired Simons, Li and Associates, Inc. (SLA) from Newport Beach, California, to perform the sediment investigation. They met with KCWA staff to discuss past flooding events, data needs for their analyses and the overall features of the project. SLA (1989) estimated that the average annual sediment yield is approximately 0.51 AF/sq mi/yr (241 AF/yr). They also reported that the annual sediment yield can be as high as 1.42 AF/sq mi/yr or 672 acre feet per year. The arithmetic average of these two yield estimates **(0.97 AF/sq mi/yr)** developed by SLA for the Kern County Water Agency is reported in **Table 1**.

If the KCWA average annual sediment yield (0.97 AF/sq mi/yr) is averaged with the *eleven other* (HEC) yield values presented in **Table 1**, the new arithmetic average yield becomes 0.84 AF/sq mi/yr. If the maximum annual yield reported by SLA is averaged with the previous eleven values the average yield is 0.88 AF/sq mi/yr. **Figure 3** shows all thirteen yield values and the drainage basin area associated with each yield. A best fit line through these data points gives an average annual sediment yield of **0.75 AF/sq mi/yr**.

It is important to note that arid and semi-arid basins, such as Caliente Creek, are very episodic in nature. During dry years (perhaps even normal years) the sediment production and delivery (and, therefore, annual yield) is small. During large runoff events the sediment production and delivery can produce tremendous loads of sediment in the channels. The annual yield during an excessively wet year can be quite high. Therefore, the presentation of a single average annual yield value may be misleading. For planning purposes, the consideration of the range of possible annual yields is more meaningful.

4.2 Single Event Analyses

In addition to the average annual sediment yield developed above, it is important to estimate the sediment production and delivery from possible single events ranging from small 20% chance (5-year) flows to the 1% chance design event (100 year flood) and the SPF and PMF. One or more single events during the design life (100 years) of the project can significantly affect the operation and maintenance of the reservoir much more than average annual events.

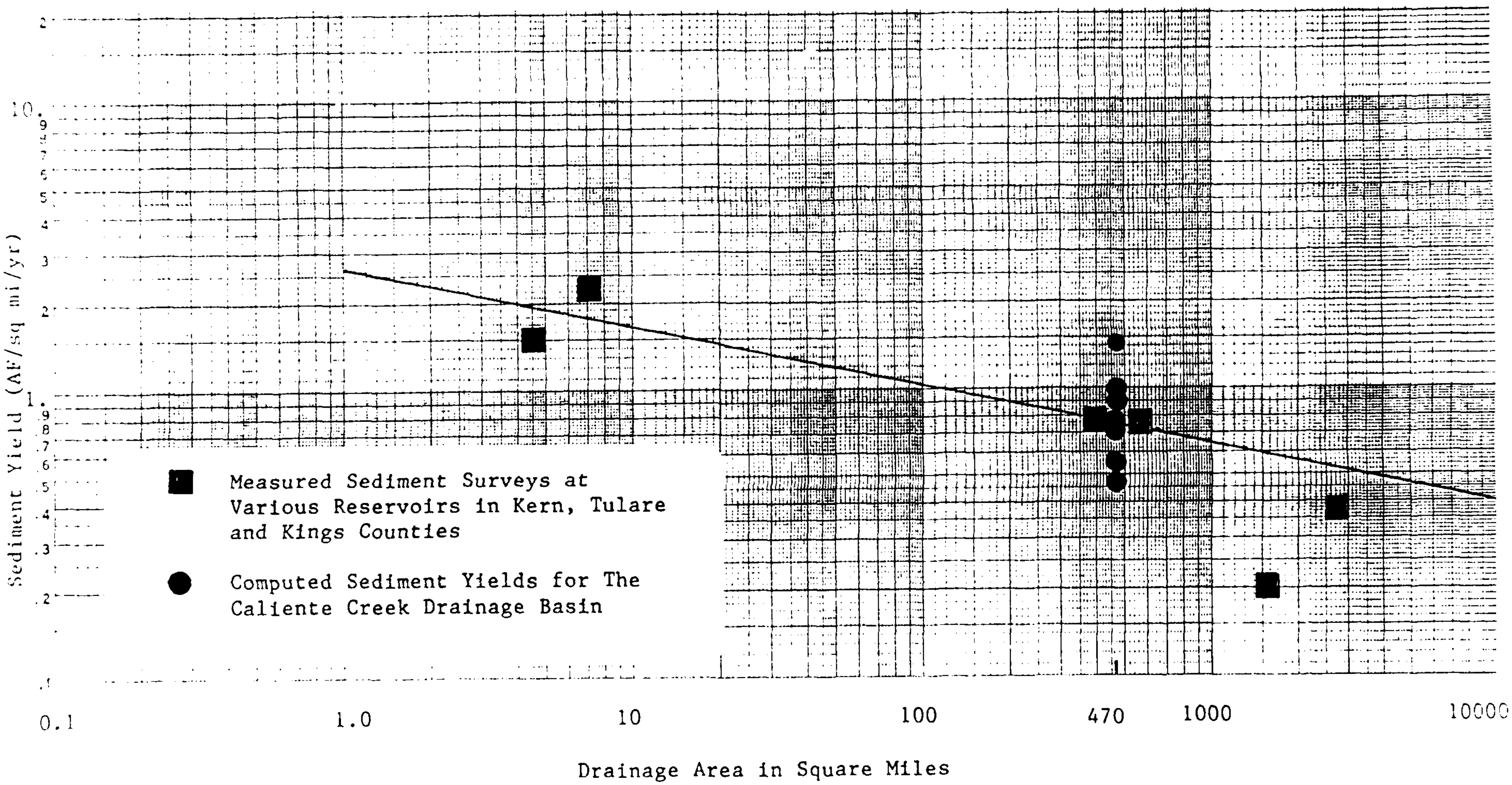

Figure 3
Measured and Computed Values of
Average Annual Sediment Yield Versus Drainage Basin Area

Figure 4 shows a sketch of the study reach that was used to estimate the single event sediment delivery to the reservoir site. The subreach areas shown in the sketch are not to scale. These same subreachs were used to develop the transport capacity-based sediment yields discussed previously in Section 4.1. There are four different subreaches based on distinct hydraulic and geomorphic characteristics (see Harvey, 1989): (1) the upstream sediment supply reach, (2) the reach located just upstream from the highway 58 crossing, (3) the reach just downstream from Highway 58, and (4) the reach located in the reservoir poor area. Four different subreaches are analyzed so that the transport capacity computed for each subreach can be compared to the others with different hydraulic and geomorphic characteristics. These subreaches are evaluated according to their sediment transporting capacity based on the use of seven different transport functions, including: (1) Toffaleti, (2) Yang, (3) Acker-White, (4) Colby, (5) Meyer-Peter Muller, (6) New Laursen, and (7) Copeland Laursen. Vanoni (1975), Williams and Julien (1989) and Nakato (1990) discuss the difference between many of the most widely used sediment transport functions. An undocumented (research version) computer program developed at the Corps' Waterways Experiment Station was used to develop the sediment load curves with each of these methods using a channel-averaged sediment grain size and average channel hydraulic conditions for a given discharge at each of the three channel subreaches, 1 through 3. Subreach 4 (the reach located in the reservoir pool) was not evaluated because the transport capacity in the pool will be very close to zero. Sediment samples collected during the October, 1989 field reconnaissance study were analyzed in the laboratory to develop the grain size data necessary to perform the transport computations. Appendix B presents the detailed results from the laboratory investigations. Data from appendix B are used to develop the sediment grain size distribution curves most representative of the study subreaches identified in **Figure 4**. **Figure 5** presents the reach averaged sediment grain size curve used for the sediment transport calculations. The D_{50}, D_{84}, and D_{16} are approximately 0.75 mm, 2.4 mm, and 0.34 mm, respectively.

Appendix C presents the seven synthesized single event flood hydrographs used for the 20%, 10%, 5%, 2%, 1%, SPF, and PMF flood events. As discussed in Section 4.1, these hydrographs were developed by ratioing the coordinates of the 5-day general rain SPF hydrograph developed for the Pampa damsite to translate it to the Sivert damsite. Sediment load relationship curves were developed for the full range of expected flows for each of the three active transport subreaches (subreaches 1, 2, and 3). Families of load curves (sediment load in tons/day versus water discharge in cfs) were developed using the seven different transport functions listed above. These curves are provided in Appendix D. Because the Caliente Wash in the area of the proposed reservoir is so wide (on the order of 3,000 to 6,000 feet wide) the load curves were developed for two ranges of peak flows: (1) low flows including the 20%, 10%, 5%, and 2% chance flows, and (2) high flows including the 1% (100 year), SPF, and PMF. The low and high flow load curves were then combined to develop one continuous load curve for the full range of possible flows. Using the sediment load curves for each reach and the flow hydrograph for each event, the sediment load hydrographs for each event were computed. Summing the area under the sediment hydrographs gives the total bed material load in tons of sediment per event. These values are then compared to estimate the potential amount of sediment that can be delivered to the Sivert Reservoir for each magnitude of event.

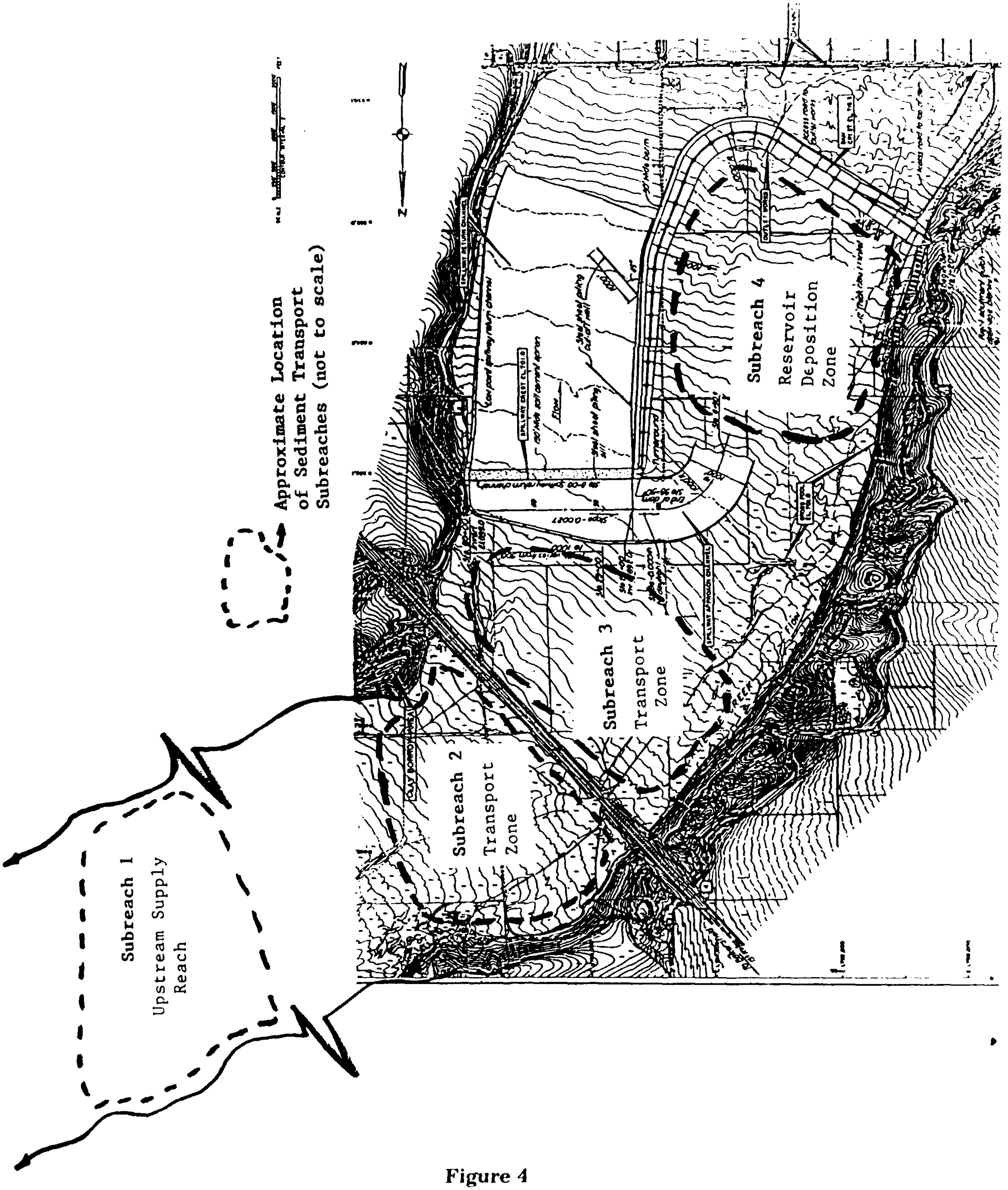

Figure 4
Delineation of the Four Different Sediment Transport Capacity Evaluation Subreaches

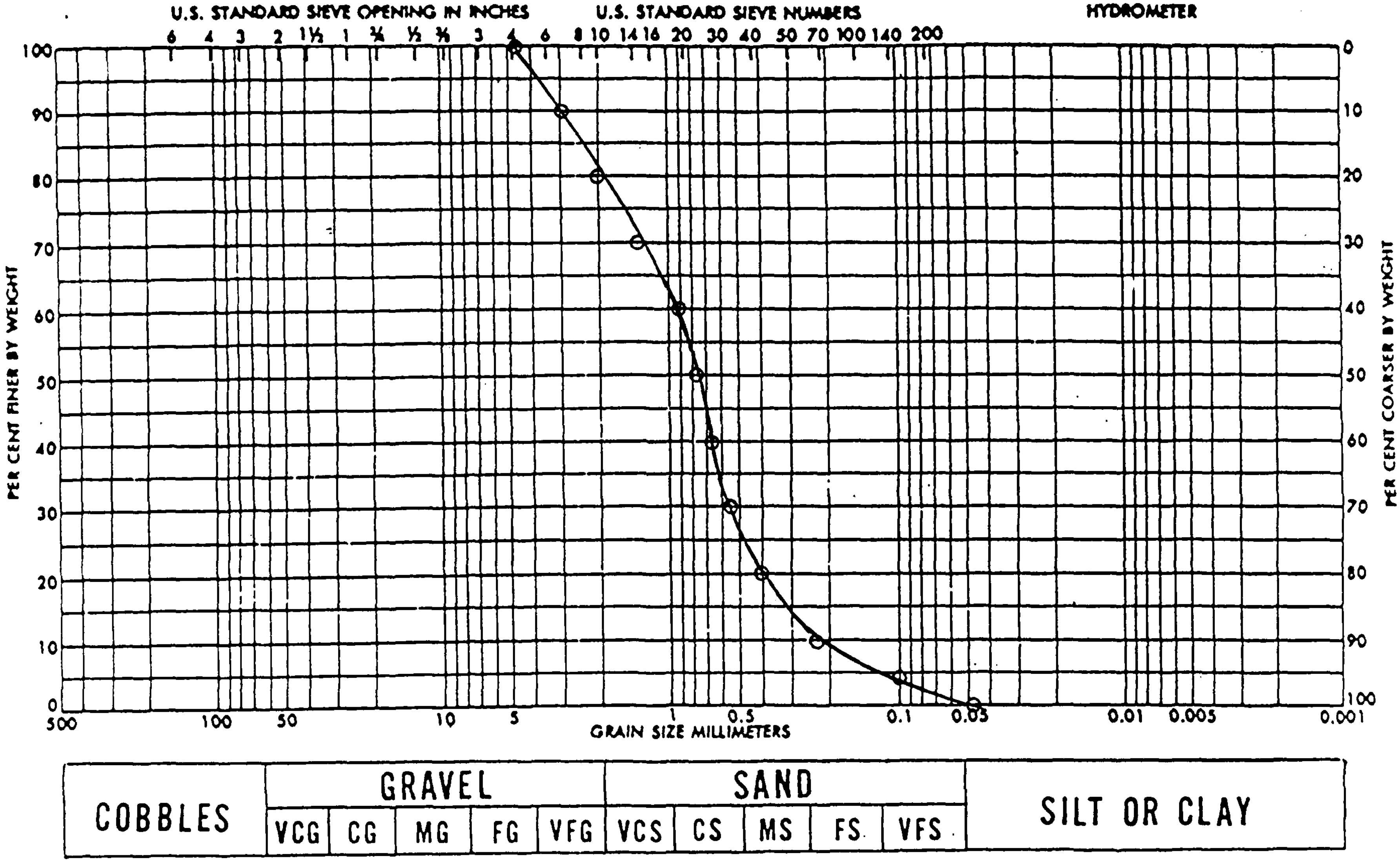

Figure 5
Reach-Averaged Bed Material Grain Size
Distribution Curve Caliente Creek, CA

The following assumptions are made for all of the single event analyses: (1) the eastern bridge opening under Highway 58 is closed, (2) Highway 58 can survive overtopping during high flows (the SPF and PMF events), (3) steady gradually varied flow hydraulic computations (HEC-2) are valid for estimating the channel hydraulic conditions for the full range of flows, (4) hyperconcentrated sediment loads will not affect the hydraulic computations, (5) mobile boundary effects will not affect the hydraulic computations, (6) the New Laursen and Copeland Laursen transport functions provide a good representation of the range of channel transport characteristics for all flows considered.

The Copeland Laursen and New Laursen methods are considered to be the most representative of the sediment transport characteristics found in the Caliente Creek Wash. The New Laursen method provides similar results as the Yang and Toffaleti methods. Colby and Meyer-Peter Muller methods are considered to underestimate the transport capacity. The Acker-White method over estimates the transport and gives unreasonably high concentrations of sediment per unit discharge. Therefore, the New Laursen and Copeland Laursen load curves are used for the remaining analyses to develop a range of possible sediment production rates based on the transport capacity of the Caliente Creek channel upstream from the reservoir site. **Tables 2** and **3** summarize the results from combining the water discharge hydrographs with the two different sediment load curves to compute total bed material load transported during each of the seven different events for each of the three active transport subreaches. The **total bed material load** transported during each event is listed at the bottom of the columns below each event category (eg, 5 year, 10 year, ..., 100 year, SPF, and PMF) in dry tons/event, cubic yards/event and acre feet/event. The **total sediment load** is listed in the bottom row of numbers and is based on the assumption that the **wash load** will contribute another 15 percent to the bed material load computed above. This is a conservative estimate for the wash load. Greater percentages of fines may be produced from the watershed during large runoff events.

Sediment transport rates computed with the Copeland Laursen method are approximately one order of magnitude larger than those computed by the New Laursen method. Estimates of the sediment concentrations for various flows as computed by the two different transport methods indicate the Copeland Laursen method yields larger concentrations of sediment for the same magnitude of water flow. As previously mentioned, the curves in Appendix D show that the results from the New Laursen method are similar to those computed with Yang and Toffaleti and fall approximately midway between the large spread found in the seven different curves. It is the author's opinion that the New Laursen method probably under estimates the actual sediment transport characteristics found in the broad Caliente Creek Wash upstream from the damsite. The Copeland Laursen method provides a more likely value of the bed material transport per unit discharge in Caliente Creek because it uses the hydraulic radius due to grain roughness to compute bed shear for different flow intensities and flow depths. The Copeland Laursen method accounts for the effects of grain size and bed roughness more explicitly than the other transport functions and, therefore, better accounts for the transport of bed materials found along the Caliente fan. These effects are important during large flow events. The Copeland Laursen method has been successfully used in the design of several Corps of Engineers flood control channels in California.

DURATION (days)	HOURS	QBASE	Q5	Q10	Q20	Q50	Q100	Qspf	Qpmf
			R5 0.046	R10 0.130	R20 0.288	R50 0.683	R100 1.196	RSPF 2.460	RPMF 7.740
					(cfs)				
	0	50	2	7	14	34	60	123	387
0.5	12	100	5	13	29	66	120	246	774
0.25	18	4270	196	555	1230	2916	5107	10504	33050
0.25	24	1350	62	176	389	922	1615	3321	10449
0.5	36	400	18	52	115	273	478	984	3096
0.333333	44	670	31	87	193	458	801	1648	5186
0.166666	48	3200	147	416	922	2186	3827	7872	24768
0.166666	52	2400	110	312	691	1639	2870	5904	18576
0.333333	60	6200	285	806	1786	4235	7415	15252	47988
0.166666	64	9350	430	1216	2693	6386	11183	23001	72369
0.083333	66	15000	690	1950	4320	10245	17940	36900	116100
0.083333	68	23000	1058	2990	6624	15709	27508	56580	178020
0.166666	72	16000	736	2080	4608	10928	19136	39360	123840
0.166666	76	8000	368	1040	2304	5464	9568	19680	61920
0.083333	78	4800	221	624	1382	3278	5741	11808	37152
0.083333	80	2950	136	384	850	2015	3528	7257	22833
0.166666	84	1350	62	176	389	922	1615	3321	10449
0.166666	88	550	25	72	158	376	658	1353	4257
0.333333	96	500	23	65	144	342	598	1230	3870
0.333333	104	275	13	36	79	188	329	677	2129
0.333333	112	100	5	13	29	68	120	246	774
0.333333	120	5	0	1	1	3	6	12	39

SINGLE EVENT HYDROGRAPH COORDINATES
(hours vs cfs)

TABLE 2

Summary of Single Event Sediment Transport Capacity Analyses Based on the New Laursen Bed Material Transport Capacity Procedures

NEW LAURSEN
BED MATERIAL LOAD BELOW HIGHWAY 58

QS5	QS10	QS20	QS50	QS100	QSspf	QSpmf
			(tons/day)			
1.22E+02	4.27E+02	8.54E+02	2.07E+03	3.66E+03	7.50E+03	2.36E+04
3.05E+02	7.93E+02	1.77E+03	4.15E+03	7.32E+03	1.50E+04	4.72E+04
1.20E+04	3.38E+04	7.50E+04	1.82E+05	3.34E+05	7.54E+05	1.56E+06
3.78E+03	1.07E+04	2.37E+04	5.62E+04	9.92E+04	2.08E+05	7.50E+05
1.10E+03	3.17E+03	7.01E+03	1.66E+04	2.91E+04	6.00E+04	1.93E+05
1.89E+03	5.31E+03	1.18E+04	2.79E+04	4.88E+04	1.01E+05	3.40E+05
8.96E+03	2.54E+04	5.62E+04	1.35E+05	2.44E+05	5.40E+05	1.33E+06
6.71E+03	1.90E+04	4.21E+04	1.01E+05	1.79E+05	3.91E+05	1.26E+06
1.74E+04	4.91E+04	1.10E+05	2.73E+05	5.02E+05	1.14E+06	2.42E+06
2.62E+04	7.41E+04	1.68E+05	4.25E+05	8.09E+05	1.31E+06	3.99E+06
4.21E+04	1.20E+05	2.79E+05	7.33E+05	1.25E+06	1.78E+06	7.01E+06
6.45E+04	1.86E+05	4.42E+05	1.18E+06	1.36E+06	2.91E+06	1.24E+07
4.49E+04	1.29E+05	2.99E+05	7.89E+05	1.26E+06	1.92E+06	7.54E+06
2.24E+04	6.34E+04	1.43E+05	3.60E+05	6.78E+05	1.27E+06	3.27E+06
1.35E+04	3.81E+04	8.45E+04	2.05E+05	3.79E+05	8.60E+05	1.80E+06
8.29E+03	2.34E+04	5.18E+04	1.25E+05	2.23E+05	4.89E+05	1.31E+06
3.78E+03	1.07E+04	2.37E+04	5.62E+04	9.92E+04	2.08E+05	7.50E+05
1.52E+03	4.39E+03	9.63E+03	2.29E+04	4.01E+04	8.26E+04	2.74E+05
1.40E+03	3.96E+03	8.78E+03	2.09E+04	3.65E+04	7.50E+04	2.47E+05
7.93E+02	2.20E+03	4.82E+03	1.15E+04	2.01E+04	4.13E+04	1.32E+05
3.05E+02	7.93E+02	1.77E+03	4.15E+03	7.32E+03	1.50E+04	4.72E+04
0.00E+00	6.10E+01	6.10E+01	1.83E+02	3.66E+02	7.32E+02	2.38E+03

107	305	656	1555	2744	5625	17699
1532	4329	9596	23228	42725	96128	201111
1967	5572	12340	29737	54212	120243	288904
1220	3476	7683	18217	32092	66981	235656
498	1413	3130	7429	12998	26885	88860
905	2556	5666	13611	24385	53402	139145
1306	3699	8196	19679	35211	77539	215669
4014	11362	25365	62238	113504	255325	612724
3633	10275	23133	58150	109302	204192	533891
2846	8108	18594	48251	85850	128821	458247
4441	12784	30029	79631	108844	195537	806677
9116	26255	61758	163901	218836	402826	1657905
5610	16009	36834	95696	161878	266206	900902
1496	4228	9472	23527	44048	88807	210992
907	2561	5678	13727	25083	56237	129342
1006	2846	6296	15066	26817	58109	171410
442	1260	2780	6596	11612	24211	85316
488	1392	3069	7297	12765	26269	86845
366	1026	2266	5386	9421	19381	63103
183	498	1098	2602	4563	9380	29832
51	142	305	722	1281	2622	8262

BED MATERIAL LOAD (in tons) TRANSPORTED DURING 5 DAY EVENT
4.21E+04 1.20E+05 2.74E+05 6.96E+05 1.14E+06 2.18E+06 6.94E+06

BED MATERIAL LOAD (in cubic yards) TRANSPORTED DURING 5 DAY EVENT
3.29E+04 9.37E+04 2.14E+05 5.43E+05 8.88E+05 1.70E+06 5.42E+06

BED MATERIAL LOAD (in acre-feet) TRANSPORTED DURING 5 DAY EVENT
2.11E+01 6.00E+01 1.37E+02 3.48E+02 5.69E+02 1.09E+03 3.47E+03

TOTAL LOAD[1](AF)/EVENT
24.3 69 158 400 654 1253 3990

[1]TOTAL LOAD = BED MATERIAL LOAD + 15% for WASH LOAD (in acre-feet (AF))

TABLE 2
(continued)

NEW LAURSEN
BED MATERIAL LOAD JUST ABOVE HIGHWAY 58

QS5	QS10	QS20	QS50 (tons/day)	QS100	QSspf	QSpmf
1.00E+02	3.50E+02	7.00E+02	1.70E+03	3.00E+03	6.15E+03	1.94E+04
2.50E+02	6.50E+02	1.45E+03	3.40E+03	6.00E+03	1.23E+04	3.87E+04
9.80E+03	2.78E+04	6.15E+04	1.49E+05	2.68E+05	5.85E+05	1.32E+06
3.10E+03	8.80E+03	1.95E+04	4.61E+04	8.10E+04	1.70E+05	5.81E+05
9.00E+02	2.60E+03	5.75E+03	1.37E+04	2.39E+04	4.92E+04	1.58E+05
1.55E+03	4.35E+03	9.65E+03	2.29E+04	4.01E+04	8.27E+04	2.72E+05
7.35E+03	2.08E+04	4.61E+04	1.11E+05	1.97E+05	4.26E+05	1.21E+06
5.50E+03	1.56E+04	3.46E+04	8.22E+04	1.47E+05	3.11E+05	9.95E+05
1.43E+04	4.03E+04	8.99E+04	2.20E+05	3.98E+05	8.71E+05	1.36E+06
2.15E+04	6.08E+04	1.37E+05	3.38E+05	6.26E+05	1.15E+06	1.44E+06
3.45E+04	9.85E+04	2.25E+05	5.69E+05	9.73E+05	1.33E+06	1.91E+06
5.29E+04	1.53E+05	3.51E+05	8.97E+05	1.30E+06	1.39E+06	2.57E+06
3.68E+04	1.05E+05	2.40E+05	6.10E+05	1.01E+06	1.34E+06	1.99E+06
1.84E+04	5.20E+04	1.17E+05	2.87E+05	5.28E+05	1.03E+06	1.41E+06
1.11E+04	3.12E+04	6.91E+04	1.68E+05	3.03E+05	6.63E+05	1.33E+06
6.80E+03	1.92E+04	4.25E+04	1.02E+05	1.81E+05	3.89E+05	1.14E+06
3.10E+03	8.80E+03	1.95E+04	4.61E+04	8.10E+04	1.70E+05	5.81E+05
1.25E+03	3.60E+03	7.90E+03	1.88E+04	3.29E+04	6.77E+04	2.21E+05
1.15E+03	3.25E+03	7.20E+03	1.71E+04	2.99E+04	6.15E+04	2.00E+05
6.50E+02	1.80E+03	3.95E+03	9.40E+03	1.65E+04	3.39E+04	1.08E+05
2.50E+02	6.50E+02	1.45E+03	3.40E+03	6.00E+03	1.23E+04	3.87E+04
0.00E+00	5.00E+01	5.00E+01	1.50E+02	3.00E+02	6.00E+02	1.95E+03

88	250	538	1276	2251	4614	14518
1257	3551	7872	19041	34216	74611	169508
1613	4571	10123	24380	43588	94333	237328
1000	2851	6302	14943	26222	54824	184899
408	1159	2568	6094	10663	21987	71732
742	2097	4648	11142	19793	42390	123214
1071	3035	6723	16086	28665	61455	183456
3293	9320	20745	50347	90827	197032	393326
2980	8428	18932	46483	85328	168071	233977
2334	6637	15075	37788	66614	103157	139526
3643	10469	23980	61083	94705	113417	186335
7478	21504	49279	125597	192815	227488	379547
4602	13107	29774	74789	128523	197513	283153
1228	3468	7754	18965	34613	70660	114160
744	2101	4652	11237	20149	43837	102951
825	2334	5165	12332	21835	46583	143473
363	1034	2280	5410	9491	19813	66861
400	1142	2518	5986	10471	21533	70146
300	842	1859	4418	7728	15898	51273
150	408	900	2134	3743	7695	24423
42	117	250	592	1050	2151	6778

Quantity	QS5	QS10	QS20	QS50	QS100	QSspf	QSpmf
BED MATERIAL LOAD (in tons) TRANSPORTED DURING 5 DAY EVENT	3.46E+04	9.84E+04	2.22E+05	5.50E+05	9.33E+05	1.59E+06	3.18E+06
BED MATERIAL LOAD (in cubic yards) TRANSPORTED DURING 5 DAY EVENT	2.70E+04	7.68E+04	1.73E+05	4.29E+05	7.28E+05	1.24E+06	2.48E+06
BED MATERIAL LOAD (in acre-feet) TRANSPORTED DURING 5 DAY EVENT	1.73E+01	4.92E+01	1.11E+02	2.75E+02	4.67E+02	7.95E+02	1.59E+03
TOTAL LOAD(AF)/EVENT	20	57	128	316	537	914	1829

NEW LAURSEN
BED MATERIAL LOAD FROM UPSTREAM SUPPLY REACH

QS5	QS10	QS20	QS50 (tons/day)	QS100	QSspf	QSpmf
1.18E+02	4.14E+02	8.27E+02	2.01E+03	3.54E+03	7.27E+03	2.29E+04
2.95E+02	7.68E+02	1.71E+03	4.02E+03	7.09E+03	1.45E+04	4.57E+04
1.16E+04	3.28E+04	7.27E+04	1.83E+05	3.20E+05	6.12E+05	2.18E+06
3.66E+03	1.04E+04	2.30E+04	5.45E+04	9.77E+04	2.10E+05	6.10E+05
1.06E+03	3.07E+03	6.79E+03	1.61E+04	2.82E+04	5.81E+04	1.95E+05
1.83E+03	5.14E+03	1.14E+04	2.71E+04	4.73E+04	9.99E+04	3.24E+05
8.68E+03	2.46E+04	5.45E+04	1.35E+05	2.44E+05	4.78E+05	1.49E+06
6.50E+03	1.84E+04	4.08E+04	9.93E+04	1.80E+05	3.65E+05	1.00E+06
1.68E+04	4.76E+04	1.09E+05	2.70E+05	4.52E+05	8.41E+05	3.32E+06
2.54E+04	7.18E+04	1.69E+05	3.93E+05	6.45E+05	1.33E+06	5.33E+06
4.08E+04	1.20E+05	2.75E+05	6.00E+05	9.71E+05	2.47E+06	9.13E+06
6.25E+04	1.88E+05	4.06E+05	8.63E+05	1.73E+06	3.98E+06	1.45E+07
4.35E+04	1.28E+05	2.91E+05	6.33E+05	1.03E+06	2.66E+06	9.80E+06
2.17E+04	6.14E+04	1.43E+05	3.40E+05	5.67E+05	1.05E+06	4.42E+06
1.31E+04	3.69E+04	8.23E+04	2.07E+05	3.56E+05	6.75E+05	2.49E+06
8.03E+03	2.27E+04	5.02E+04	1.24E+05	2.24E+05	4.43E+05	1.32E+06
3.66E+03	1.04E+04	2.30E+04	5.45E+04	9.77E+04	2.10E+05	6.10E+05
1.48E+03	4.25E+03	9.33E+03	2.22E+04	3.89E+04	8.04E+04	2.71E+05
1.36E+03	3.84E+03	8.51E+03	2.02E+04	3.53E+04	7.27E+04	2.46E+05
7.68E+02	2.13E+03	4.67E+03	1.11E+04	1.94E+04	4.00E+04	1.32E+05
2.95E+02	7.68E+02	1.71E+03	4.02E+03	7.09E+03	1.45E+04	4.57E+04
0.00E+00	5.91E+01	5.91E+01	1.77E+02	3.54E+02	7.09E+02	2.30E+03

103	295	635	1506	2659	5450	17147
1484	4195	9297	23439	40843	78359	277975
1905	5398	11956	29745	52170	102816	348470
1182	3367	7444	17650	31486	67082	201261
482	1369	3033	7198	12593	26335	86589
876	2476	5489	13534	24240	48135	151045
1265	3584	7941	19553	35335	70247	207484
3889	11008	24967	61514	105345	201072	720861
3520	9955	23147	55215	91390	181159	720905
2757	7985	18477	41360	67327	158586	602232
4303	12840	28377	60962	112523	269001	984686
8832	26395	58126	124668	229850	553725	2025410
5435	15817	36188	81070	132971	309722	1184851
1450	4096	9395	22809	38463	72077	288000
879	2481	5523	13810	24156	46574	158774
975	2757	6100	14879	26796	54398	160632
428	1221	2693	6390	11381	24219	73395
473	1349	2974	7070	12367	25515	86242
354	994	2196	5219	9128	18777	62999
177	482	1063	2521	4421	9088	29554
49	138	295	699	1241	2540	8005

Quantity	QS5	QS10	QS20	QS50	QS100	QSspf	QSpmf
BED MATERIAL LOAD (in tons) TRANSPORTED DURING 5 DAY EVENT	4.08E+04	1.18E+05	2.65E+05	6.11E+05	1.07E+06	2.32E+06	8.40E+06
BED MATERIAL LOAD (in cubic yards) TRANSPORTED DURING 5 DAY EVENT	3.18E+04	9.22E+04	2.07E+05	4.76E+05	8.32E+05	1.81E+06	6.55E+06
BED MATERIAL LOAD (in acre-feet) TRANSPORTED DURING 5 DAY EVENT	2.04E+01	5.91E+01	1.33E+02	3.05E+02	5.33E+02	1.16E+03	4.20E+03
TOTAL LOAD(AF)/EVENT	23.5	68	153	351	613	1334	4830

			R5	R10	R20	R50	R100	RSPF	RPMF
			0.046	0.130	0.288	0.683	1.196	2.460	7.740
DURATION (days)	HOURS	QBASE	Q5	Q10	Q20 (cfs)	Q50	Q100	Qspf	Qpmf
	0	50	2	7	14	34	60	123	387
0.5	12	100	5	13	29	68	120	246	774
0.25	18	4270	196	555	1230	2916	5107	10504	33050
0.25	24	1350	62	176	389	922	1615	3321	10449
0.5	36	400	18	52	115	273	478	984	3096
0.333333	44	670	31	87	193	458	801	1648	5186
0.166666	48	3200	147	416	922	2186	3827	7872	24768
0.166666	52	2400	110	312	691	1639	2870	5904	18576
0.333333	60	6200	285	806	1786	4235	7415	15252	47988
0.166666	64	9350	430	1216	2693	6386	11183	23001	72369
0.083333	66	15000	690	1950	4320	10245	17940	36900	116100
0.083333	68	23000	1058	2990	6624	15709	27508	56580	178020
0.166666	72	16000	736	2080	4608	10928	19136	39360	123840
0.166666	76	8000	368	1040	2304	5464	9568	19680	61920
0.083333	78	4800	221	624	1382	3278	5741	11808	37152
0.083333	80	2950	136	384	850	2015	3528	7257	22833
0.166666	84	1350	62	176	389	922	1615	3321	10449
0.166666	88	550	25	72	158	376	658	1353	4257
0.333333	96	500	23	65	144	342	598	1230	3870
0.333333	104	275	13	36	79	188	329	677	2129
0.333333	112	100	5	13	29	68	120	246	774
0.333333	120	5	0	1	1	3	6	12	39

SINGLE EVENT HYDROGRAPH COORDINATES
(hours vs cfs)

COPELAND LAURSEN
BED MATERIAL LOAD BELOW HIGHWAY 58

QS5	QS10	QS20	QS50 (tons/day)	QS100	QSspf	QSpmf
1.23E+03	4.32E+03	8.64E+03	2.10E+04	3.70E+04	7.59E+04	2.39E+05
3.09E+03	8.03E+03	1.79E+04	4.20E+04	7.41E+04	1.52E+05	4.78E+05
1.21E+05	3.43E+05	7.59E+05	2.28E+06	4.00E+06	8.89E+06	9.05E+06
3.83E+04	1.09E+05	2.40E+05	5.69E+05	1.09E+06	2.63E+06	8.83E+06
1.11E+04	3.21E+04	7.10E+04	1.69E+05	2.95E+05	6.08E+05	2.44E+06
1.91E+04	5.37E+04	1.19E+05	2.83E+05	4.95E+05	1.12E+06	4.06E+06
9.08E+04	2.57E+05	5.69E+05	1.61E+06	3.02E+06	6.30E+06	1.05E+07
6.79E+04	1.93E+05	4.27E+05	1.11E+06	2.23E+06	4.61E+06	1.36E+07
1.76E+05	4.98E+05	1.24E+06	3.33E+06	5.85E+06	1.36E+07	1.46E+07
2.65E+05	7.51E+05	2.07E+06	4.98E+06	9.55E+06	1.14E+07	2.54E+07
4.26E+05	1.39E+06	3.40E+06	8.63E+06	1.39E+07	1.05E+07	4.69E+07
6.53E+05	2.34E+06	5.16E+06	1.40E+07	9.20E+06	1.78E+07	8.09E+07
4.54E+05	1.51E+06	3.62E+06	9.30E+06	1.33E+07	1.14E+07	5.07E+07
2.27E+05	6.42E+05	1.72E+06	4.27E+06	7.97E+06	1.30E+07	2.03E+07
1.36E+05	3.85E+05	8.75E+05	2.60E+06	4.48E+06	1.02E+07	1.06E+07
8.40E+04	2.37E+05	5.25E+05	1.45E+06	2.79E+06	5.70E+06	1.15E+07
3.83E+04	1.09E+05	2.40E+05	5.69E+05	1.09E+06	2.63E+06	8.83E+06
1.54E+04	4.45E+04	9.75E+04	2.32E+05	4.06E+05	8.49E+05	3.35E+06
1.42E+04	4.01E+04	8.89E+04	2.11E+05	3.69E+05	7.59E+05	3.05E+06
8.03E+03	2.22E+04	4.88E+04	1.16E+05	2.03E+05	4.18E+05	1.56E+06
3.09E+03	8.03E+03	1.79E+04	4.20E+04	7.41E+04	1.52E+05	4.78E+05
0.00E+00	6.17E+02	6.17E+02	1.85E+03	3.70E+03	7.41E+03	2.41E+04

1080	3087	6637	15743	27782	56953	179194
15512	43834	97160	289764	509255	1129904	1190579
19910	56413	124942	355669	636014	1440232	2235010
12348	35191	77790	184442	345816	810501	2818448
5042	14303	31692	75217	131605	287632	1083475
9158	25878	57365	157692	292990	618235	1217110
13222	37454	82986	226635	437957	909152	2010970
40644	115038	278485	740560	1347585	3027190	4694398
36785	104028	276400	692590	1283840	2080568	3331680
28811	89366	227949	567108	977242	911907	3012968
44966	155740	356584	943158	962420	1176455	5323465
92298	321372	731517	1942256	1875880	2428840	10964191
56799	179569	444646	1131414	1773251	2035693	5914894
15152	42805	108029	286439	518837	967222	1284456
9184	25930	58340	168960	303226	661044	919234
10187	28611	63744	168552	323410	694216	1694066
4476	12759	28142	66780	124533	290285	1015284
4939	14097	31075	73880	129238	268049	1067390
3704	10393	22946	54535	95385	196224	768622
1852	5042	11113	26341	46201	94973	339226
514	1441	3087	7306	12965	26547	83655

BED MATERIAL LOAD (in TONS) TRANSPORTED DURING 5 DAY EVENT

4.27E+05 1.32E+06 3.12E+06 8.18E+06 1.22E+07 2.01E+07 5.11E+07

BED MATERIAL LOAD (in cubic yards) TRANSPORTED DURING 5 DAY EVENT

3.33E+05 1.03E+06 2.43E+06 6.38E+06 9.48E+06 1.57E+07 3.99E+07

BED MATERIAL LOAD (in acre-feet) TRANSPORTED DURING 5 DAY EVENT

2.13E+02 6.61E+02 1.56E+03 4.09E+03 6.08E+03 1.01E+04 2.56E+04

TOTAL LOAD[1](AF)/EVENT

245 760 1794 4704 6992 11,615 29,440

TABLE 3

Summary of Single Event Sediment Transport Capacity Analyses Based on the Copeland Laursen Bed Material Transport Capacity Procedure

[1]TOTAL LOAD = BED MATERIAL LOAD + 15% for WASH LOAD (in acre-feet (AF))

TABLE 3
(continued)

COPELAND LAURSEN
BED MATERIAL LOAD JUST ABOVE HIGHWAY 58

QS5	QS10	QS20	QS50 (tons/day)	QS100	QSspf	QSpmf
8.45E+02	2.96E+03	5.91E+03	1.44E+04	2.53E+04	5.20E+04	1.63E+05
2.11E+03	5.49E+03	1.22E+04	2.87E+04	5.07E+04	1.04E+05	3.27E+05
8.28E+04	2.34E+05	5.20E+05	1.67E+06	2.96E+06	5.49E+06	1.01E+07
2.62E+04	7.43E+04	1.64E+05	3.89E+05	7.10E+05	1.97E+06	5.47E+06
7.60E+03	2.20E+04	4.86E+04	1.15E+05	2.02E+05	4.16E+05	1.81E+06
1.31E+04	3.67E+04	8.15E+04	1.93E+05	3.38E+05	7.35E+05	3.00E+06
6.21E+04	1.76E+05	3.89E+05	1.13E+06	2.28E+06	4.33E+06	1.01E+07
4.65E+04	1.32E+05	2.92E+05	7.28E+05	1.64E+06	3.39E+06	8.50E+06
1.20E+05	3.40E+05	8.37E+05	2.49E+06	4.13E+06	7.58E+06	8.31E+06
1.82E+05	5.14E+05	1.51E+06	3.65E+06	5.79E+06	9.61E+06	5.42E+06
2 91E+05	9.58E+05	2.54E+06	5.38E+06	8.34E+06	9.63E+06	6.05E+06
4.47E+05	1.73E+06	3.78E+06	7.78E+06	1.07E+07	7.29E+06	7.02E+06
3.11E+05	1.05E+06	2.69E+06	5.68E+06	8.64E+06	9.34E+06	6.17E+06
1.55E+05	4.39E+05	1.22E+06	3.15E+06	5.08E+06	8.78E+06	6.66E+06
9.33E+04	2.64E+05	5.84E+05	1.94E+06	3.30E+06	6.07E+06	9.60E+06
5.74E+04	1.62E+05	3.59E+05	1.01E+06	2.11E+06	4.06E+06	9.57E+06
2.62E+04	7.43E+04	1.64E+05	3.89E+05	7.10E+05	1.97E+06	5.47E+06
1.06E+04	3.04E+04	6.67E+04	1.59E+05	2.78E+05	5.71E+05	2.51E+06
9.71E+03	2.75E+04	6.08E+04	1.44E+05	2.53E+05	5.20E+05	2.30E+06
5.49E+03	1.52E+04	3.34E+04	7.94E+04	1.39E+05	2.86E+05	1.09E+06
2.11E+03	5.49E+03	1.22E+04	2.87E+04	5.07E+04	1.04E+05	3.27E+05
0.00E+00	4.22E+02	4.22E+02	1.27E+03	2.53E+03	5.07E+03	1.65E+04
739	2112	4541	10771	19007	38964	122596
10612	29989	66472	212730	376619	699403	1301731
13622	38595	85479	257819	459084	933016	1944250
8448	24076	53220	126186	228077	597108	1818347
3449	9785	21682	51460	90037	191742	801832
6265	17705	39246	110532	217787	422160	1088699
9046	25624	56775	155092	326184	643434	1546589
27807	78703	188135	537053	961454	1829070	2802087
25167	71171	195421	511918	826689	1433228	1144276
19711	61330	168662	376084	588738	801842	477675
30763	111924	263184	548084	795170	705113	544214
63146	231865	539252	1121259	1615455	1385884	1098523
38859	124481	326220	736011	1143265	1509602	1068838
10366	29285	75166	212288	349222	618487	677446
6283	17740	39281	122808	225718	421922	798831
6969	19711	43611	116319	235418	502734	1253264
3062	8729	19253	45687	82361	212024	664419
3379	9644	21260	50545	88418	181834	800695
2534	7110	15698	37310	65258	134246	564828
1267	3449	7603	18022	31608	64976	236280
352	986	2112	4998	8870	18162	57232

BED MATERIAL LOAD (in TONS) TRANSPORTED DURING 5 DAY EVENT
2.92E+05 9.24E+05 2.23E+06 5.36E+06 8.73E+06 1.33E+07 2.08E+07

BED MATERIAL LOAD (in cubic yards) TRANSPORTED DURING 5 DAY EVENT
2.28E+05 7.21E+05 1.74E+06 4.18E+06 6.81E+06 1.04E+07 1.62E+07

BED MATERIAL LOAD (in acre-feet) TRANSPORTED DURING 5 DAY EVENT
1.46E+02 4.62E+02 1.12E+03 2.68E+03 4.37E+03 6.67E+03 1.04E+04

TOTAL LOAD(AF)/EVENT
168 531 1288 3082 5026 7670 11,960

COPELAND LAURSEN
BED MATERIAL LOAD IN UPSTREAM SUPPLY REACH

QS5	QS10	QS20	QS50 (tons/day)	QS100	QSspf	QSpmf
1.19E+03	4.16E+03	8.31E+03	2.02E+04	3.56E+04	7.30E+04	2.30E+05
2.97E+03	7.72E+03	1.72E+04	4.04E+04	7.13E+04	1.46E+05	4.60E+05
1.16E+05	3.30E+05	7.30E+05	1.93E+06	3.39E+06	6.39E+06	2.12E+07
3.68E+04	1.05E+05	2.31E+05	5.48E+05	1.00E+06	2.22E+06	6.36E+06
1.07E+04	3.09E+04	6.83E+04	1.62E+05	2.84E+05	5.84E+05	2.06E+06
1.84E+04	5.17E+04	1.15E+05	2.72E+05	4.76E+05	1.02E+06	3.43E+06
8.73E+04	2.47E+05	5.48E+05	1.41E+06	2.59E+06	5.02E+06	1.46E+07
6.53E+04	1.85E+05	4.10E+05	1.02E+06	1.90E+06	3.86E+06	1.03E+07
1.69E+05	4.79E+05	1.12E+06	2.87E+06	4.75E+06	8.68E+06	3.36E+07
2.55E+05	7.22E+05	1.77E+06	4.14E+06	6.72E+06	1.33E+07	5.67E+07
4.10E+05	1.24E+06	2.92E+06	6.26E+06	9.98E+06	2.44E+07	1.02E+08
6.28E+05	1.99E+06	4.29E+06	8.90E+06	1.68E+07	4.07E+07	1.67E+08
4.37E+05	1.33E+06	3.09E+06	6.59E+06	1.06E+07	2.65E+07	1.11E+08
2.19E+05	6.18E+05	1.49E+06	3.60E+06	5.94E+06	1.08E+07	4.57E+07
1.31E+05	3.71E+05	8.33E+05	2.19E+06	3.76E+06	7.02E+06	2.46E+07
8.08E+04	2.28E+05	5.05E+05	1.29E+06	2.37E+06	4.66E+06	1.31E+07
3.68E+04	1.05E+05	2.31E+05	5.48E+05	1.00E+06	2.22E+06	6.36E+06
1.48E+04	4.28E+04	9.38E+04	2.23E+05	3.91E+05	8.12E+05	2.88E+06
1.37E+04	3.86E+04	8.55E+04	2.03E+05	3.55E+05	7.30E+05	2.62E+06
7.72E+03	2.14E+04	4.69E+04	1.12E+05	1.95E+05	4.02E+05	1.37E+06
2.97E+03	7.72E+03	1.72E+04	4.04E+04	7.13E+04	1.46E+05	4.60E+05
0.00E+00	5.94E+02	5.94E+02	1.78E+03	3.56E+03	7.13E+03	2.32E+04
1039	2969	6384	15143	26722	54781	172359
14920	42162	93454	246786	432313	816943	2710864
19151	54261	120176	310178	548451	1076748	3448775
11877	33848	74822	177406	321052	702213	2106496
4850	13757	30483	72348	126584	268061	916183
8808	24891	55177	140172	255272	504059	1506030
12718	36026	79820	202306	374043	740324	2077033
39094	110650	255567	648072	1109156	2090115	7315495
35382	100060	241413	584626	955939	1829742	7523430
27712	81785	195628	433712	695679	1570556	6630723
43250	134490	300283	631938	1113780	2714387	11240000
88777	276753	614779	1291351	2275673	5598665	23155358
54632	162634	382208	849400	1374502	3106300	13025079
14574	41172	96997	241347	404180	743248	2931679
8833	24941	55747	145044	255657	486642	1573859
9798	27712	61313	152908	281118	573749	1625731
4305	12272	27069	64232	115925	253074	770566
4751	13559	29889	71061	124308	257128	917057
3563	9996	22071	52455	91746	188738	664609
1781	4850	10689	25337	44438	91351	304802
495	1386	2969	7027	12470	25535	80464

BED MATERIAL LOAD (in TONS) TRANSPORTED DURING 5 DAY EVENT
4.10E+05 1.21E+06 2.76E+06 6.36E+06 1.09E+07 2.37E+07 9.07E+07

BED MATERIAL LOAD (in cubic yards) TRANSPORTED DURING 5 DAY EVENT
3.20E+05 9.44E+05 2.15E+06 4.96E+06 8.53E+06 1.85E+07 7.07E+07

BED MATERIAL LOAD (in acre-feet) TRANSPORTED DURING 5 DAY EVENT
2.05E+02 6.05E+02 1.38E+03 3.18E+03 5.47E+03 1.18E+04 4.53E+04

TOTAL LOAD(AF)/EVENT
236 696 1587 3657 6291 13,570 52,095

Harvey (1989) estimates that there may have been approximately 9 inches of sediment deposited in the reach upstream from the Highway 58 crossing during the 1983 flood event. That event is estimated to be approximately a 2% chance (50 year) event according to the Kern County Water Agency. Comparing the total sediment loads computed in the supply reach with the total load just above the Highway 58 Bridge from the Copeland Laursen method (presented in **Table 3**), it is seen that there is approximately 575 acre feet more sediment transported into subreach 2 from the supply reach (subreach 1) than leaves the reach through the bridge opening. The approximate surface area of reach 2 above the bridge is one square mile (640 acres). Assuming that the 575 acre feet of sediment deposits uniformly over subreach 2, that would give an approximate sediment deposition thickness of 10.8 inches. This matches the observed deposition depth for a 2% chance (50 year) event reasonably well.

During the 1983 flood event, Mr. Malouf, of the Edison Sand Company, Inc. collected grab samples of the suspended load and determined that approximately 30 to 40 percent by volume was sediment (personal communication with Mr. Gerald Malouf, November, 1989). Sediment concentrations computed with the Copeland Laursen method are on the order of 20 to 30 percent for most flows evaluated, indicating good correlation with the observed concentrations measured by Malouf (1989) during the 1983 event.

News video footage taken during the 1983 flood event from the Highway 58 Bridge indicates the likely presence of hyperconcentrated flows in the Caliente Wash during the flood. Hydraulic bores and standing waves indicated that the bed forms were changing rapidly from dunes to antidunes, to a flat bed and back to dunes again. This type of bed form change, transports tremendous amounts of bed material. Traditional bed material transport functions often underestimate the total load being transported for the kinds of hydraulic conditions observed during the 1983 event.

Neither of the two transport function methods accounts for the wash load portion of the total load (which can be significant during high flows), or the contributions from channel bank sloughing, local scour or toe failures that may occur along the Sand Hills deposits near the reservoir site, especially during high flows. Therefore, the higher transport rate per unit discharge computed using the Copeland Laursen method is thought to be more appropriate for the Caliente Wash if we consider all of the other sediment sources that are not directly accounted for by traditional bed material load transport functions.

4.3 Discussion of Single Event Results

Table 4 presents the computed sediment inflow to the reservoir from subreach 3 for the various flood events for both transport methods. The 1% chance (100 year) flood event can possibly produce enough sediment during the single design event to remove 43.7 percent of the gross pool storage capacity (6992 AF according to the Copeland Laursen method) or as little as approximately 4.1 percent of the gross pool storage (654 AF according to the New Laursen method). An independent consulting report prepared for the Kern County Water Agency (SLA, 1989) estimates approximately 8,700 acre feet of sediment delivery for a 1% chance (100-year) event. This represents approximately 54 percent of the planned detention storage volume (16,000 acre feet) for the reservoir. The data presented in **Table 4** also suggests that events greater than about the 7.5% chance

TABLE 4

Computed Single Event Sediment Inflow to the Proposed Reservoir and Comparison to Planned Detention Storage Volume of 16,000 Feet

	New Laursen Method[1]		**Copeland Laursen Method[1]**	
% Change of Exceedance Event	**Total Load/Event (Ac-ft, dry volume)**	**Percent of the Planned Detention Storage Volume Associated with Single Event Sediment Delivery**	**Total Load/Event (Ac-ft, dry volume)**	**Percent of the Planned Detention Storage Volume Associated with Single Event Sediment Delivery**
20 (5-yr)	24.3	<1%	245	1.5%
10 (10-yr)	69	<1%	760	4.8%
5 (20-yr)	158	1%	1794	11.2%
2 (50-yr)	400	2.5%	4709	29.4%
1 (100-yr)	654	4.1%	6992	43.7%
SPF	1253	7.8%	11,615	72.3%
PMF	3990	25%	29,440	184%

[1]Total Bed Material Load Transport Function Used

Results from the Kern County Water Agency Report (SLA, 1989)

Event: 1% chance flood event

Methodology Used: SLA used a combination of the Meyer-Peter Muller and Einstein Transport Functions with an adjustment for high concentrations of suspended material

Computed Total Sediment Load Per Event (acre-feet): **8,700 AF** [dry volume]

Percent of the Planned Detention
Storage Volume Associated with the
1% Chance Flood Event Sediment Delivery: **54%**

(15 year) event can possibly remove 10 percent or more of the gross pool storage in one 5 day period. The HEC computed total sediment loads account for the total bed material load with an additional 15 percent added for the wash load.

Typical wash loads can account for as much as 90 to 95 percent of the total load in most sand bed rivers (Vanoni, 1975). However, in the Caliente River Basin the availability of fines (silts and clays) may be limited due to the nature of the granitic parent materials throughout the basin (see Harvey, 1989). HEC postulates that the wash load near the damsite will have an inverted bed load/wash load relationship, and may only account for approximately 15 percent of the total sediment load being transported by each event. This is based on the stratigraphic information from the Corps of Engineers boring data near the damsite, the bed material samples collected in field and the field observations showing the lack of thick soil horizons or mud drapes. It is possible, however, that for the less frequent, large discharge events (greater than 2% chance events), considerably more wash load than 15 percent of the total load is possible. If the actual wash load accounted for 50 to 75 percent of the total load, then the actual volume of sediment transported into the reservoir during a 1% chance (100-year) storm could be as high as 9,120 to 10,640 AF/event, respectively. These volumes represent 57 and 66.5 percent of the planned detention storage volume of the reservoir. Measured suspended sediment concentrations as high as 30 to 40 percent by volume have been observed during large flood events in Caliente Creek near Highway 58. This is another good reason to utilize the larger total bed material load values computed with the Copeland Laursen method. Vanoni (1975) shows that with high fine sediment concentrations in the flow, the transport capacity of coarser sized materials (sand and gravel) increases.

Large events such as a 2% chance (50 year) flood or greater may produce large amounts of sediment material that enter the water course due to mass wasting, channel bank failure and erosion of prograded alluvial fans that often extend into the channel in the upper basin. It may be that single event sediment production can contribute sufficient quantities of sediment materials to the reservoir in a short period of time (a few days) and affect the operation and storage characteristics of the project.

5. Discussion of Other Concerns

Consideration is being given for the closure of the eastern bridge opening under Highway 58 in order to avoid flow short circuiting directly into the emergency spillway. Consideration is also being given to the installation of a setback levee along the left overbank in the floodplain area upstream from the spillway to further ensure that flood flows will enter the reservoir and not the spillway directly. Focussing the flow energies along the toe of the high Sand Hills may lead to sloughing of the high bank into the channel upstream from the reservoir (some problems presently exist as a result of flows that nicked the toe during the 1983 flood event). Depending on the magnitude of the bank failure, large blocks of sandy and gravelly material could enter the reservoir almost instantaneously. Field observations during the October 1989 field inspection show the existence of two large slide areas that probably occurred during the 1983 event as a result of toe scour at the base of the Sand Hills. The estimated volume of material associated with each of these slips is approximately 75 to 100 AF. Much larger soil slips are possible and could potentially occur along the entire length of the Sand Hills if the toe is not protected from high flows. This could introduce approximately 500,000 cubic yards (265 acre feet) of loose sediment materials into the channel to be carried directly into the reservoir during a large event. Soils stabilization and grouting along the Sand Hills abutment section may be necessary.

Preliminary hydraulic analyses indicate that the Highway 58 crossing will be overtopped by large events greater than the 1% chance (100 year) event. The potential for this increases if future plans call for the closure of the eastern bridge opening. The highway embankment is not designed to be overtopped and would most likely fail. Failure of the highway embankment could possibly fail the Sivert Dam two miles downstream.

The basin wide sediment yields presented in this report do not account for possible increases in sediment yield from increasing urbanization, the possibility of forest fires, future road building, future dust storms (aeolian transport) such as occurred in the late 1970's or continued overgrazing of the watershed. The occurrence of a major forest fire or a large dust storm could easily produce sufficient sediment in the basin to increase the annual sediment yield by 2 to 5 times for a period of approximately 10 to 15 years until the basin "heals."

The Highway 58 embankment presently acts like a sediment retention dam by reducing the local sediment transport capacity just upstream from the highway embankment. Field evidence shows that sediment is depositing slowly upstream from the embankment, however, at the lowest point along the highway embankment (at elevation 755), the Caliente Wash elevation is only 2 feet lower than the road elevation (elevation 753). High velocity (approximately 6 to 8 fps) flows during a flood aimed at the low point in the highway could ramp up the 2 to 3 feet and flow over the highway, possibly damaging the embankment or even leading to its failure. Flows impinging on the embankment must turn abruptly and flow parallel to the embankment toward the western bridge opening to get to the reservoir. Unless sufficient bank protection is provided, toe scour along the embankment may also cause damage to the highway and contribute to the overall increase in sediment delivered to the reservoir.

With the reservoir pool full or partially full, an earthquake could induce a mass wasting failure of the high Sand Hills embankment into the reservoir, thus possibly displacing a large volume of water over the top of the reservoir embankment. Such an overtopping occurrence might lead to the failure of the earthen dam itself. Dam safety analyses may be required during future studies.

Locating the dredged sediment drying and spoiling operation (reservoir maintenance dredging) just upstream from the reservoir needs to be reevaluated. Placement of loose dredged materials in the active channel area may lead to dredging of the same materials over again along with those fresh materials that flow in during an event. The conditions inside the reservoir following a large storm event will be extremely wet and muddy. Traditional rubber tire excavators will be unable to operate in the reservoir area. More costly excavation and dredging methods may be necessary in order to remove accumulated sediment from the reservoir prior to the next rainy season.

Present estimates indicate a possible 250 cfs of infiltration losses through the reservoir bottom. Sizing of the gross pool capacity should not depend on infiltration losses to decrease the storage volume requirements in the reservoir or the outlet capacity necessary to safely release stored water. Sufficient fines may enter the reservoir during an event and seal up the bottom, thus reducing or eliminating infiltration losses.

Design of the low level outlet needs to be reevaluated. The present (feasibility) design calls for a single grated outlet pipe at the bottom of the reservoir near the toe of the dam. Sediment and debris entering the reservoir can clog the outlet, thus rendering it inoperative.

Local scour depths at the Highway 58 Bridge need to be computed for the increased flows that will occur due to the closure of the eastern opening. Harvey (1989) points out that the present natural slope of the Caliente wash is slightly west to east above the bridge. Therefore, high flows may concentrate along the eastern side of the floodplain, thus reducing the hydraulic efficiency of the single bridge opening on the west side of the valley.

Ponding of flood waters upstream from the bridge embankment due to the closure of the eastern opening may cause additional flooding problems for the present landowner located upstream from the Highway. Easements, or other precautionary agreements may be necessary to avoid law suits stemming from modification to the present drainage.

Capture of fluvial sediments in the reservoir and release of relatively clear water from the reservoir into downstream channels must be considered with respect to the stability of the downstream channels. Evaluation of downstream channel stability should be part of the Phase II SEI investigations.

6. Conclusions

The following conclusions are drawn from the results of this investigation:

1) The morphology of the Caliente Creek drainage basin and the nature of the sediments delivered to the channels and the potential for sediment storage within the drainage basin are controlled by basin geology (Harvey, 1989).

2) Sediment transport in the basin is episodic and depends on the occurrence of large runoff events. Sediment is stored in the broad valley washes (3,000 to 6,600 feet wide) in the lower portions of the Caliente Basin. There is sufficient material located in these expansive washes to provide sediment supply to the lower fan areas somewhat independently of the production and delivery of sediments from the upper watershed areas. Therefore, sediment yield at the proposed damsite may be more dependent upon the transport capacity of the channels and washes upstream from the damsite, than the watershed production of sediment materials during a flood event.

3) Examination of the results from eight different sources of yield data and methods for estimating yield at the damsite concludes that the approximate average annual sediment yield at the Sivert Reservoir is 0.75 AF/sq mi/yr. This

represents approximately 353 acre feet of sediment each year. Computed and measured annual sediment yields (dry volume) ranged from 0.2 AF/sq mi/yr to approximately 0.97 AF/sq mi/yr for basins larger than 390 square miles.

4) Simons, Li and Associates, Inc. conducted an independent analysis for Kern County Water Agency to develop the average annual and 1% chance (100-year) flood sediment yields. They concluded that the average annual sediment yield may range from 0.51 AF/sq mi/yr to 1.42 Af/sq mi/yr. For the 1% chance flood, the estimated sediment delivery to the reservoir was approximately 8,700 acre feet (dry volume). This represents approximately 54 percent of the planned detention storage volume (16,000 acre feet) and 37 percent of the proposed spillway design flood pool (23,500 acre feet).

5) Single event floods may produce significantly more sediment per event than the annual sediment yield indicates. As much as 43 percent (Corps of Engineers estimates) of the total gross pool storage volume (16,000 AF) may be lost due to sediment deposition during a 1% chance (100 year) event. This would necessitate the removal of approximately 6,990 AF of sediment material (dry volume) from the reservoir prior to the next flood season.

6) The present (feasibility) reservoir design requires the concentration of flow along the toe of high Sand Hills (along the western margin of the lower Caliente Creek incised fan). Flood flows in 1983 barely nicked the toe of the Sand Hills in two places causing mass failure of the banks onto the floodplain. Concentrating future flood flows along the toe may lead to the failure of large sections of embankment along the Sand Hills and significantly increase the volume of sediment entering the reservoir during an event. This could further reduce the water storage capacity of the reservoir.

7) A detailed hydraulic evaluation of the Highway 58 bridge opening located at the western side of the valley needs to be conducted. Present plans require the closure of the east side opening, thus flood flows are concentrated through one opening instead of two. Pier scouring, embankment erosion and possible overtopping of the highway are of concern.

8) Design of the low-level outlet, along with the spillway apron and chute channel need reevaluation. The stability of channels downstream from the reservoir must also be considered.

9) Forest fires, urbanization, future road building and the possibility of aeolian sand storms may increase the annual sediment yield to the reservoir site for many years following any one of these kinds of occurrences. Cumulative effects from several such occurrences are difficult to estimate.

10) Field circumstantiation of the estimated annual sediment yield is possible via field logging in a network of deep trenches.

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APPENDICES

APPENDIX A

Executive Summary from Harvey (1989)

EXECUTIVE SUMMARY [1]

This report presents the results of a Geomorphic Analysis of the Caliente Creek drainage basin in Kern County, California (Fig. 1.1). The investigation was one of two elements of the first phase of a two-phase Sediment Engineering Investigation (SEI) of which the primary objective was to determine the watershed sediment yield upstream of a proposed flood detention reservoir. Significant flood damage has occurred historically on the Caliente fan downstream of the proposed damsite (COE, 1988).

The geomorphic analysis was conducted concurrently with a Sedimentation Analysis performed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and is based on: 1) a field reconnaissance of the watershed, 2) analysis of topographic maps, 3) sediment samples collected in the field and 4) a review of the pertinent scientific and engineering literature. The objectives of the investigation were: 1) to identify specific geomorphic characteristics of the stream channels and watersheds upstream of the proposed detention basin that would affect sediment yield to the detention basin and 2) to relate channel and basin processes to sediment yield for various frequency precipitation and flood flow events.

The morphology of the basin is controlled primarily by the basin geology and structural setting. The lower elevation portions of the basin are composed of Pleistocene and Recent age alluvial fans. Tertiary age non-marine rocks separate the alluvial fans from the majority of the basin that is underlain primarily by quartz diorites. Two active faults, the White Wolf Fault and the Breckenridge Fault, traverse the basin and recent (1952) earthquakes related to these faults have caused significant mass wasting of the slopes in the basin. Weathering of the diorite in a semi-arid climate produces primarily sand size sediment that has a low fines content. The potential for sediment delivery to the proposed reservoir site is controlled by the valley width and channel slopes (Table 3.1). Canyon sections are narrow and have steep slopes that limit the potential for sediment storage; therefore, they act as conveyance sections. Wider valley sections have flatter slopes and substantially increased sediment storage potential. Reaches C1 and C2 (Fig. 3.1) on Caliente Creek and possibly Reach WB1 on Walker Basin Creek (Fig. 3.3) have sufficient sediment stored in them

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(1) from Harvey, Michael (1989)

to be considered as sediment supply reaches for the proposed reservoir regardless of the amount of sediment that is delivered to them by future flood flows.

Channel morphology within the basin is indeterminate. In the canyon sections, channel morphology is controlled by flood flows and in the alluvial sections, the flows are ephemeral. Therefore, the channel morphology reflects the last flow that was experienced. The very high permeabilities of the alluvial sediments (K ranges from 85 to 350 ft./day) cause high infiltration losses (1 cfs per acre inundated) that reinforce sediment deposition in the alluvial reaches.

Dry ravel is an important sediment delivery process in the basin on steep slopes underlain by diorite that have limited ground cover (Plate 1). Debris flows episodically transport valley floor stored sediments in the lower order drainages. Mass failure of colluvial slope deposits delivers significant volumes of sediment to the channels during flood flows (Plate 5). Terraces along the channels and alluvial fans that are located at the confluences of lower order channels and the major channels within the basin can be significant sources of sediment during flood flows. Sediment transport within the basin is episodic and depends to a large extent on the occurrence of flood flows.

Sediment samples collected in the basin channels indicate that, in general, the silt-clay content of the sediments is low, which reflects the basin lithology and the climate (Table 4.1). Bimodal grain size distributions are found in canyon sections (Sample W2) and where flow expansion and sediment deposition have been (Samples S6 and W1). Samples S7 and S10 represent sediments transported by unconfined flows on the Caliente fan. Samples S8, S9, S12 and S13 represent sediments transported by confined, but relatively shallow, flows on the Caliente fan. Shallow flow depths are indicated by the horizontal bedding of the sediments.

Stratigraphic evidence on the Caliente fan (Fig. 6.8; Plates 13 and 14) suggests that an average value for sediment deposition on the fan upstream of the Highway 58 embankment is about 9 inches per flood event. Significant volumes of sediment are being stored on the fan surface upstream of the highway embankment (Fig. 6.1). The highway embankment is acting as a sediment detention structure and may be causing degradation of the western channel on the fan downstream of the highway crossing (Plate 15). Concentration of flows on the western margin of the fan could result in undercutting of the Pleistocene age fan sediments that form the fan margin (Sand Hills) unless remedial measures are taken. If undercutting occurs, considerable volumes of sediment could be delivered to the proposed reservoir site. Deposition on the western margin of the fan upstream of the highway crossing may cause future flood flows to be concentrated on the eastern side of the fan (Fig. 6.7), in which case there is a possibility that flood flows could bypass the proposed detention structure.

Floods in the Caliente Creek basin have a significant impact on sediment delivery to the proposed reservoir site. Floods are generated both by summer-fall thunderstorms and winter-spring frontal rainstorms. The Standard Project Flood (SPF) for the two types of storms has been computed to be 17,500 cfs and 56,500 cfs, respectively. The presence of different aged and very coarse-grained flood deposits in many of the channels in the basin (Plates 11 and 12) and the fact that the basin characteristics appear to fit the profile for extreme flood discharges (Costa, 1987a, b) suggest that peak discharges in the basin may have been underestimated.

The results of this investigation suggest that there are three areas of concern that have the potential to affect adversely the proposed detention reservoir. First, the possibility exists that peak discharges may have been underestimated. Second, the possibility exists that flood flows may bypass the detention basin if flows become concentrated on the eastern side of the fan. Third, the possibility exists that flood flows could undercut the Sand Hills on the western fan margin, thereby delivering significant volumes of sediment to the proposed detention basin. It is recommended that these areas of concern be investigated further.

APPENDIX B

Sediment Sample Gradation Analyses

Sediment Gradation (Sieve and Hydrometer) Analyses
Were Conducted Using Standard Laboratory Soils Testing Methods
As Prescribed By

Engineering Manual 1110-2-1906

Laboratory Soils Testing

Headquarters, Department of the Army

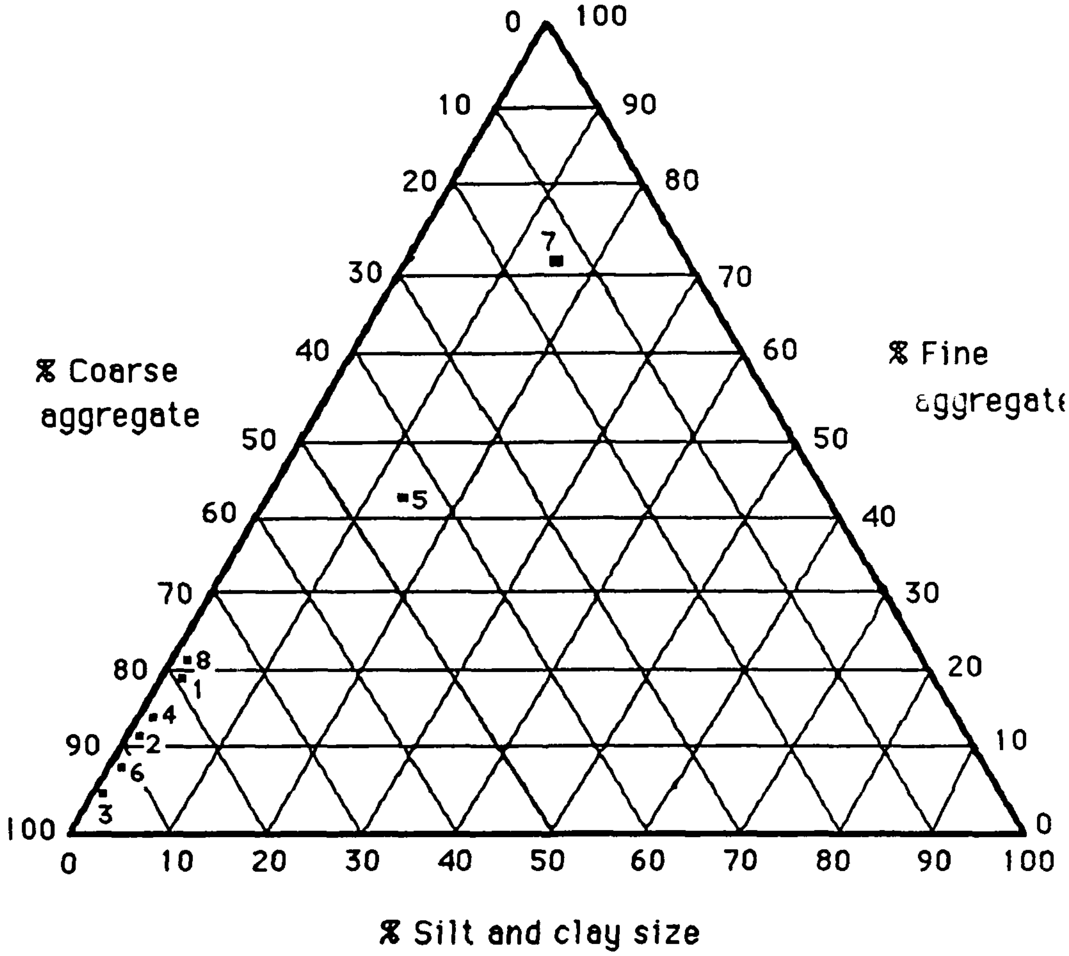
Office of the Chief of Engineers

30 November 1970
(Updated August 1986)

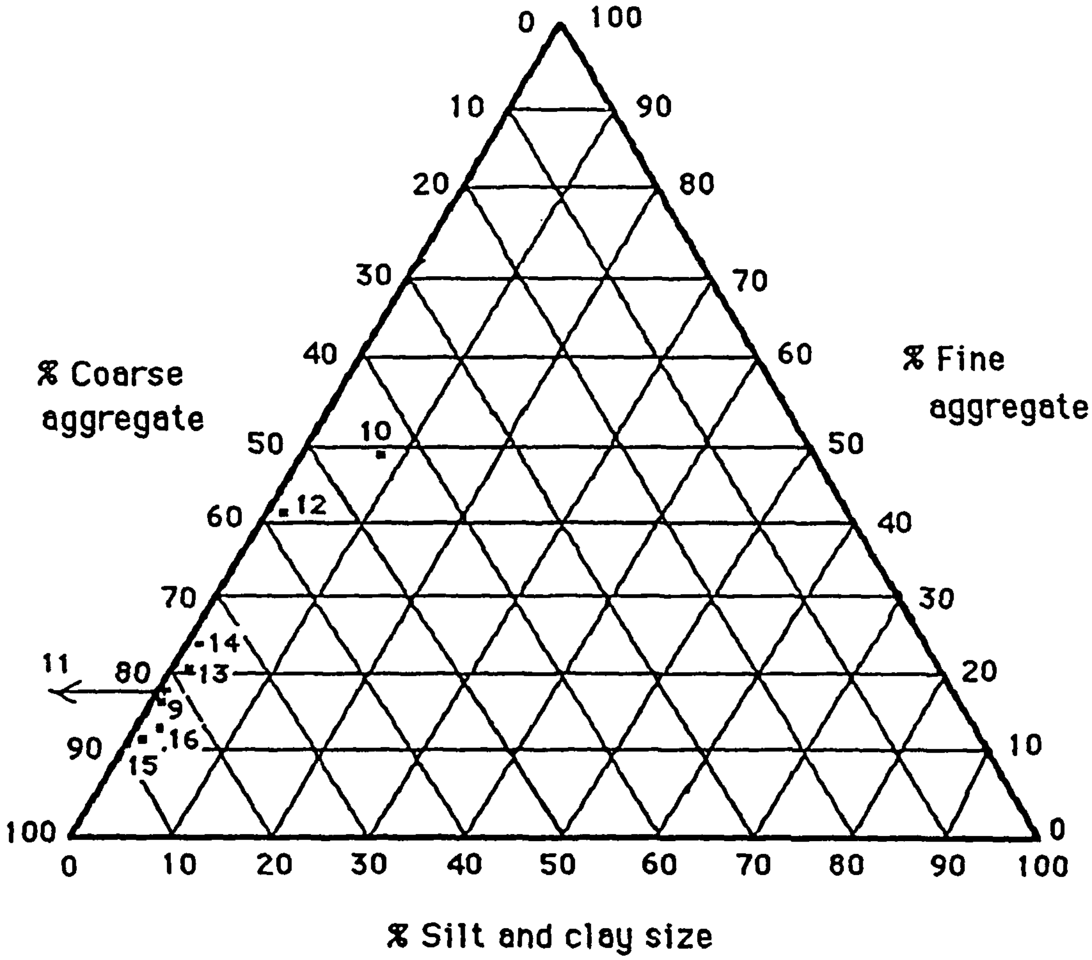
CALENTE CREEK PROJECT

SUMMARY OF THE TEST RESULTS

SAMPLE #	SOIL TYPE	% PASSING #200	GS	% ORGANIC
1	SW	1.89	2.682	0.630
2	GW - SW	2.00	2.760	0.841
3	GW - SW	1.00	2.717	0.652
4	SP	0.50	2.705	0.647
5	SC - SM	13.00	2.702	1.446
6	GW - SW	0.25	2.687	0.421
7	SP	17.00	2.737	1.900
8	SP	0.50	2.690	0.444
9	(SW)-SP	0.70	2.690	0.402
10	SP	9.00	2.737	0.891
11	SW	0.13	2.695	0.436
12	SP	1.50	2.684	0.612
13	(SW)-SP	0.50	2.709	0.598
14	SP	0.25	2.665	0.388
15	SP	1.00	2.806	0.430
16	SW	1.00	2.782	0.630



Soil Sample * 1 to * 8



SAMPLE *9 TO * 16

GRAIN SIZE ANALYSIS-MECHANICAL

Data Sheet 5

Project CALIENTE CREEK   Job No. ______

Location of Project ______   Boring No. ______   Sample No. S1

Description of Soil ______   Depth of Sample ______

Tested By ______   Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,430 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
7	2.83	600.0	41.95	58.05
40	0.42	562.5	39.37	18.68
100	0.149	187.0	13.15	5.53
170	0.088	42.0	2.93	2.594
200	0.075	10.0	0.69	1.89
pan	-	28.0	1.95	0.0--

% passing = 100 − $\sum$ % retained

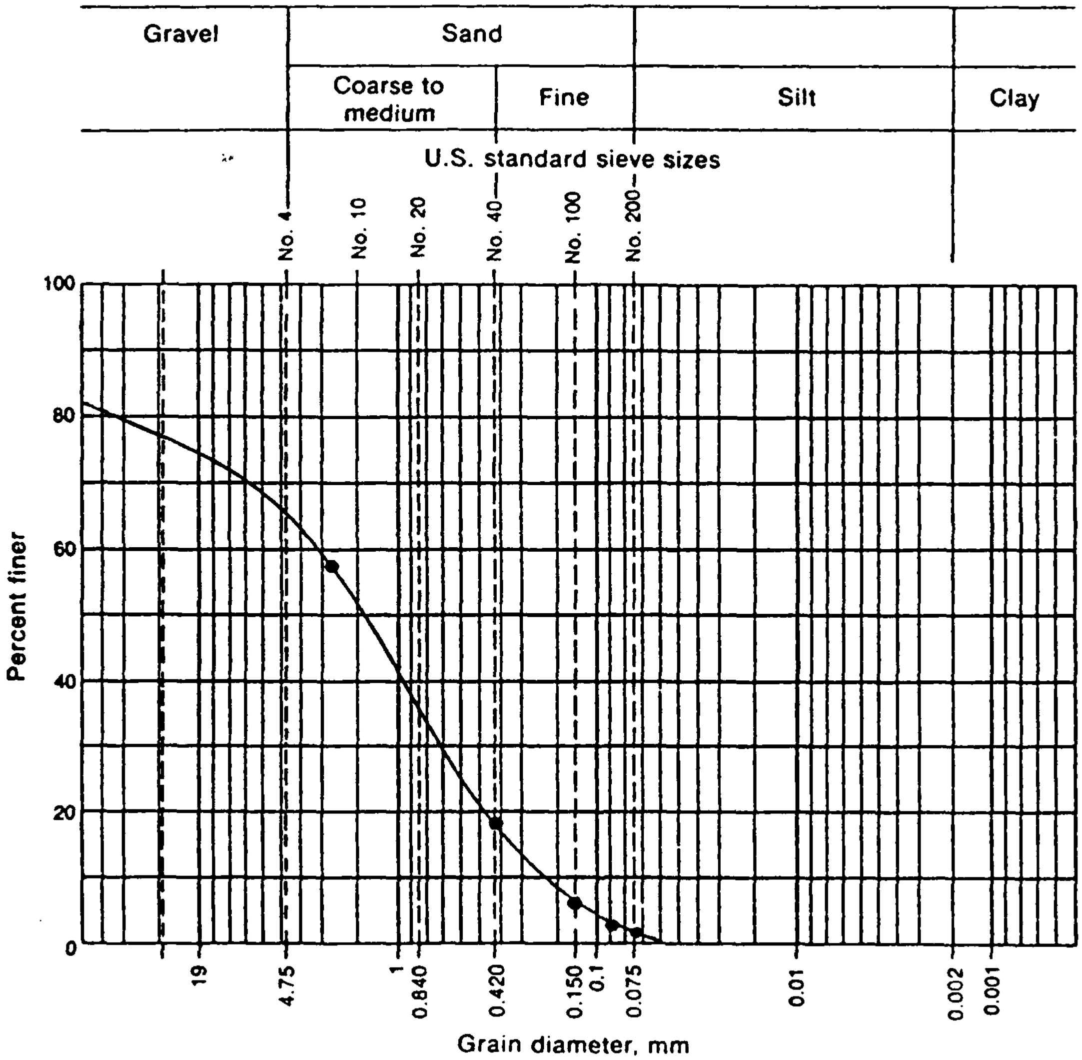
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No.

Location of Project Boring No. Sample No. S1

Description of Soil Depth of Sample

Tested By. Date of Testing



Visual soil description Well graded sand with few gravels

cu = 15.0

Soil classification:

SW System Unified Soil Classification

Gravels = 36.0 % ; Sands = 62.1 % ; Silts + Clays = 1.89 %

GRAIN SIZE ANALYSIS-MECHANICAL

Data Sheet 5

Project CALIENTE CREEK

Job No.

Location of Project

Boring No.

Sample No. S2

Description of Soil

Depth of Sample

Tested By

Date of testing

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,701 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
---	12.50	432.00	25.39	74.61
7	2.83	658.00	38.68	35.93
40	0.42	387.0	22.75	13.18
100	0.149	146.00	8.58	4.60
170	0.088	36.00	2.11	2.49
200	0.075	7.00	0.41	2.07
pan	-	35.00	2.05	0.0--

% passing = 100 − $\sum$ % retained.

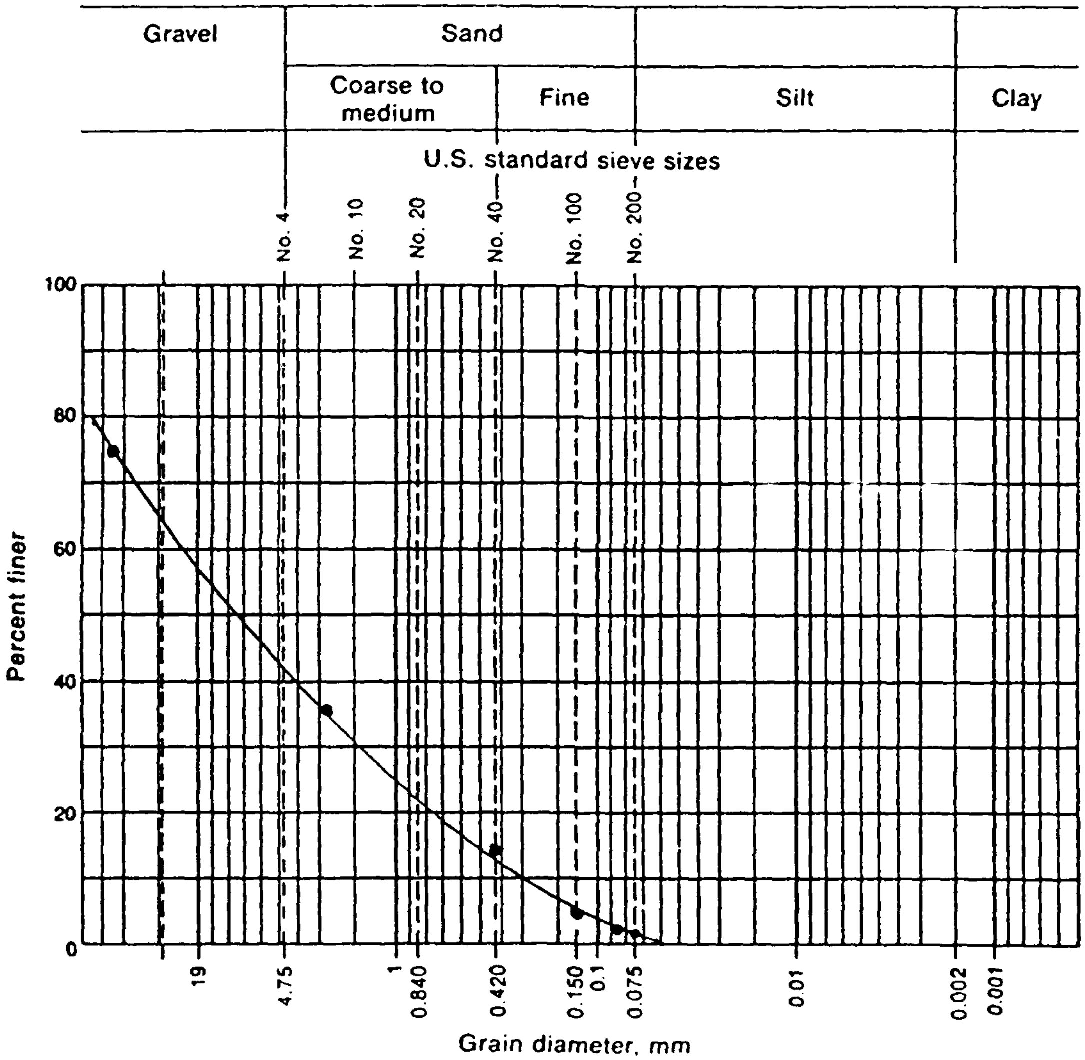
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ____

Location of Project ____ Boring No. ____ Sample No. S2

Description of Soil ____ Depth of Sample ____

Tested By. ____ Date of Testing ____



Visual soil description Well graded gravelly sand

cu = 34.66

Soil classification:

GW-SW System Unified Soil Classification

Gravels = 58 % ; Sands = 40 % ; Silts+clays = 2 %

GRAIN SIZE ANALYSIS-MECHANICAL

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S3

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,519 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
---	12.50	303.00	19.94	80.06
7	2.83	480.00	31.59	48.47
40	0.42	634.00	41.73	6.74
100	0.149	77.00	5.06	1.68
170	0.088	10.00	0.65	1.03
200	0.075	2.00	0.13	0.90
pan	--	13.0	0.85	-0.0

% passing = 100 − $\sum$ % retained

GRAIN SIZE DISTRIBUTION

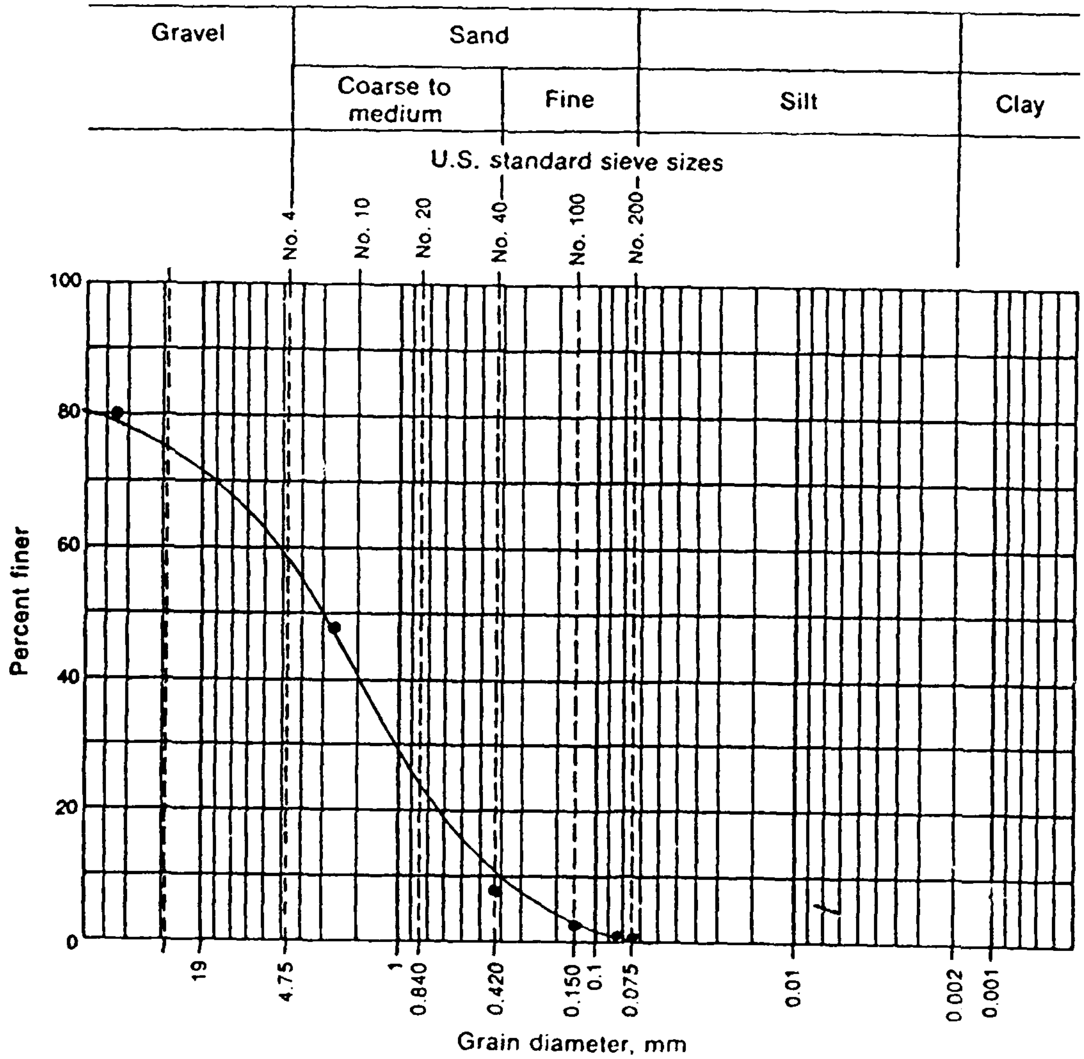
Data Sheet 6

Project CALIENTE CREEK Job. No. ______

Location of Project ______ Boring No. ______ Sample No. S3

Description of Soil ______ Depth of Sample ______

Tested By. ______ Date of Testing ______



Visual soil description Well graded gravelly sand
cu = 12.85

Soil classification:
Gw-SW System Unified soil classification

Gravels = 42 % ; Sand = 57 % ; Silts +Clays = 1 %

GRAIN SIZE ANALYSIS-MECHANICAL

Data Sheet 5

Project CALIENTE CREEK Job No.

Location of Project Boring No. Sample No. S4

Description of Soil Depth of Sample

Tested By Date of testing

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	962.0 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
30	0.594	599.0	62.26	37.74
40	0.425	216.0	22.45	15.29
100	0.149	135.0	14.03	1.26
170	0.088	6.0	0.623	0.637
200	0.075	1.0	0.10	0.537
pan	--	5.0	0.52	0

% passing = $100 - \sum$ % retained.

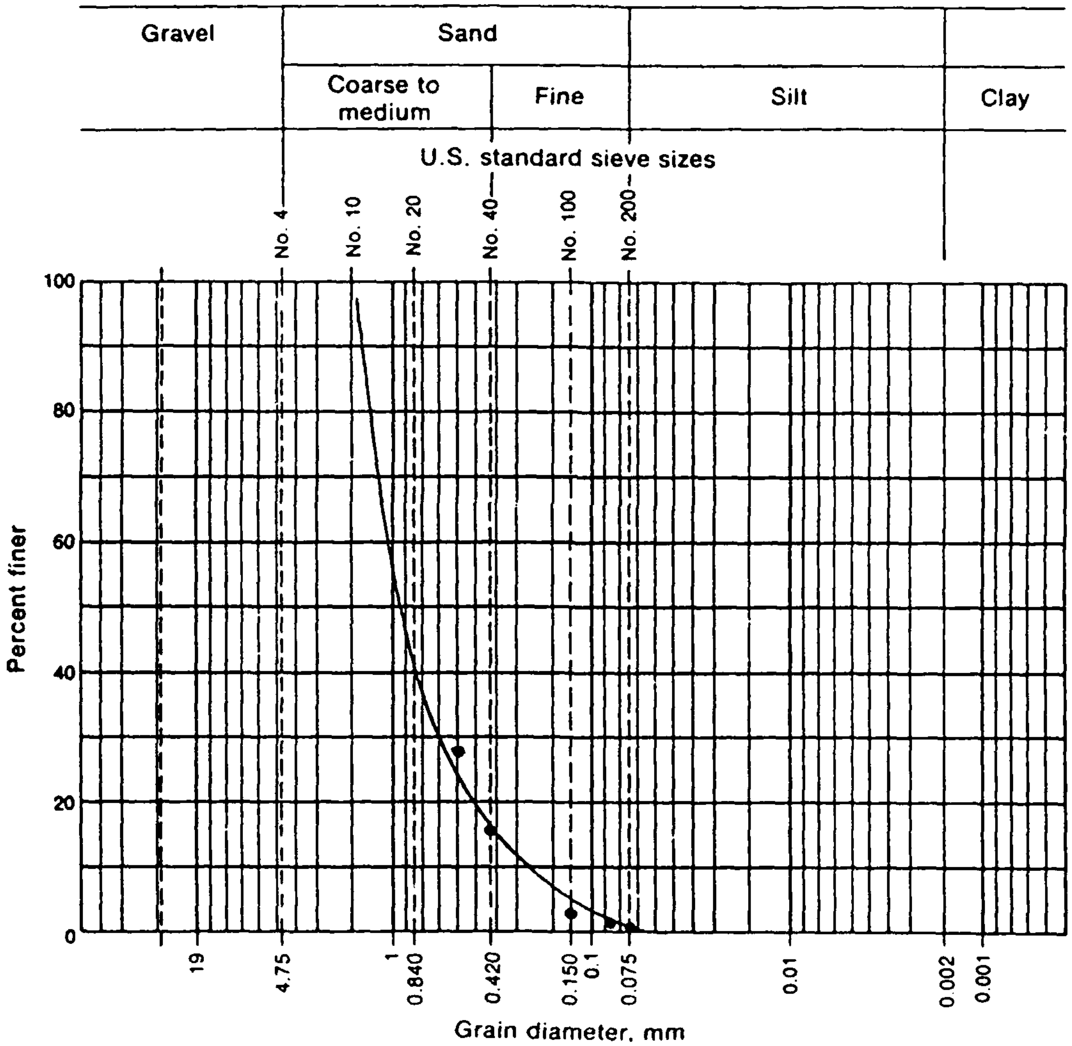
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ______

Location of Project ______ Boring No. ______ Sample No. S4

Description of Soil ______ Depth of Sample ______

Tested By. ______ Date of Testing ______



Visual soil description Poorly graded sans with little fines
~~cu = 3.20~~

Soil classification:

SP System Unified Soil Classification

Gravels = 0 % ; Sands = 99.5 % ; Silts+Clays = 0.5 %

GRAIN SIZE ANALYSIS-MECHANICAL

Data Sheet 5

Project CALIENTE CREEK

Job No.

Location of Project

Boring No.

Sample No. S5

Description of Soil

Depth of Sample

Tested By

Date of testing

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	859 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
-	6.3	80.0	9.31	90.69
7	2.83	70.0	8.14	82.55
18	1.0	90.0	10.47	72.08
40	0.425	118.0	13.73	58.35
80	0.177	207.0	24.09	34.26
100	0.15	56.0	6.51	27.75
140	0.105	66.0	7.68	20.07
200	0.075	60.0	6.98	13.09
pan	--	112.0	13.03	-0

% passing = 100 − $\sum$ % retained.

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S5

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Hydrometer analysis

Hydrometer no. ______ G_s of solids = 2.702 a = 0.99

Dispersing agent $NaPO_3$ Amount 4% of 125ml Wt. of soil, W_s 50.0 g

Zero correction +4 Meniscus correction +1

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_c *	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
		1	18.	40.5	36.5	71.3	41.5	9.5	9.5	.0138	0.0425
		2	18.	35.0	31.0	60.4	36.0	10.4	5.2	.0138	0.0314
		3	18.0	31.5	27.5	53.5	32.5	11.0	3.6	.0138	0.0261
		4	18.0	30.0	26.0	50.5	31.0	11.2	2.8	.0138	0.0230
		8	18.0	24.0	20.0	38.6	25.0	12.2	1.52	.0138	0.0170
		15	18.0	21.0	17.0	32.7	22.0	12.7	0.84	.0138	0.0126
		30	18.0	16.0	12.0	22.8	17.0	13.5	0.45	.0138	0.0093
		60	18.0	14.0	10.0	18.8	15.0	13.8	0.23	.0138	0.0066
		120	18.0	12.0	8.0	14.9	13.0	14.2	.118	.0138	0.00474
		273	18.0	9.0	5.0	8.91	10.0	14.7	.053	.0138	0.00317
		423	18.0	8.0	4.0	6.93	9.0	14.8	.035	.0138	0.00258
		1047	18.0	7.0	3.0	4.95	8.0	15.0	.014	.0138	0.00163
		1603	18.0	7.0	3.0	4.95	8.0	15.0	.001	.0138	0.00044
		========									

$R_c = R_{actual}$ − zero correction + C_T % finer = $R_c(a)/W_s$ $D = K\sqrt{L/t}$

* correction on temperature, CT was applied on % finer calculatio

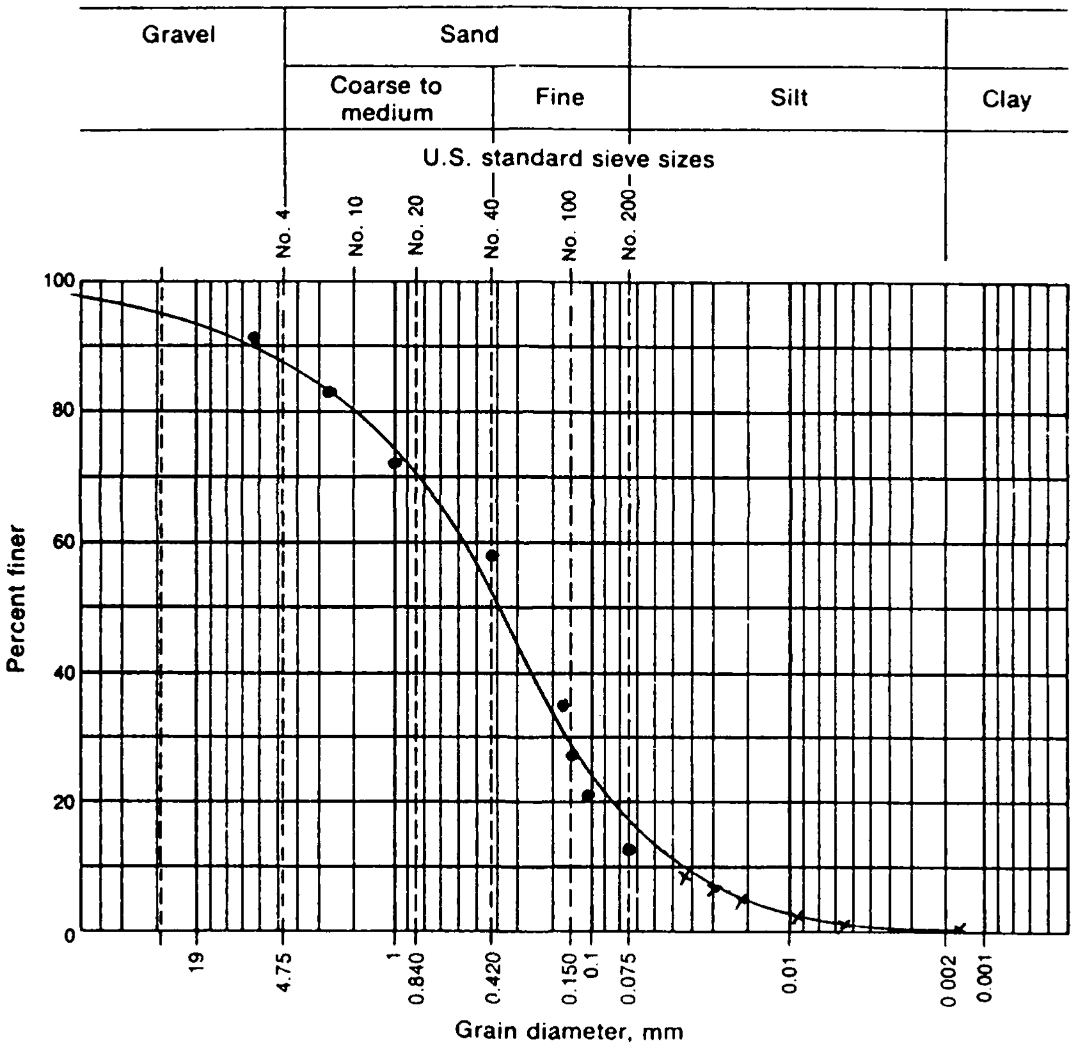
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No.

Location of Project Boring No. Sample No. S5

Description of Soil Depth of Sample

Tested By. Date of Testing



Visual soil description Poorly graded sand with fines, cu = 13.8

Soil classification:

SC-SM System Unified Soil Classification

Gravels = 12 % ; Sands = 75 % ; Silts+clays = 13 %

GRAIN SIZE ANALYSIS-MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S6

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	2,098 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
-	12.50	942.50	44.92	55.08
7	2.83	263.50	12.55	42.53
40	0.425	693.0	33.03	9.50
100	0.149	179.00	8.53	0.97
170	0.088	15.00	0.71	0.26
200	0.075	1.0	0.047	0.21
pan	-	4.0	0.19	-0

% passing = 100 − $\sum$ % retained.

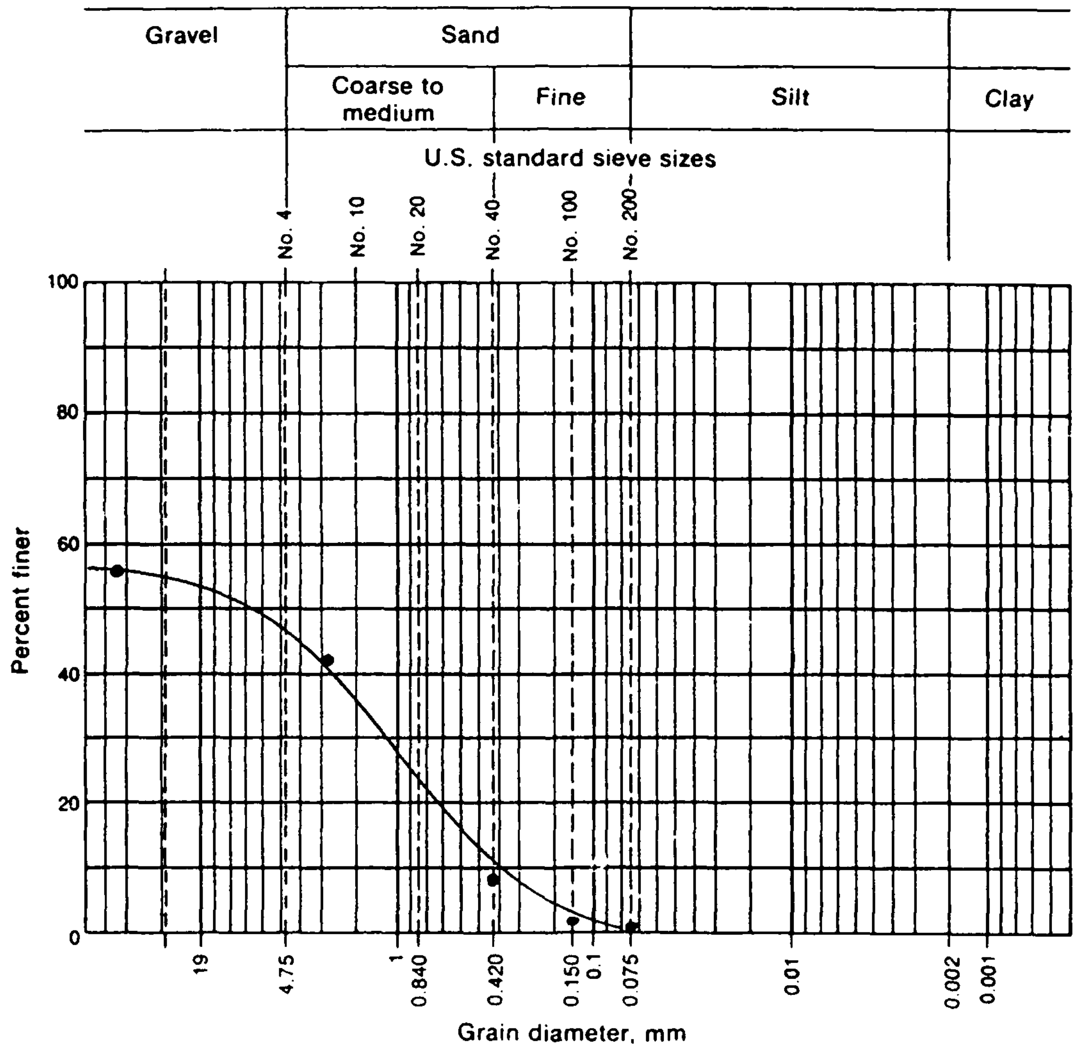
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE Creek Job. No. ______

Location of Project ______ Boring No. ______ Sample No. S6

Description of Soil ______ Depth of Sample ______

Tested By. ______ Date of Testing ______



Visual soil description Well graded sand with gravels, cu = 34.88

Soil classification:
GW-SW System Unified Soil Classification

Gravels = 55 % ; Sands = 44.75 % ; Silts +clays= 0.25 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S7

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	688 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
40	0.425	75.0	10.90	89.10
100	0.149	286.5	41.64	47.46
170	0.088	161.0	23.40	24.06
200	0.075	50.0	7.26	16.80
Pan	-	115.5	16.78	-0-

% passing = 100 − $\sum$ % retained.

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project CALIENTE CREEK Job No. ____

Location of Project ____ Boring No. ____ Sample No. S7

Description of Soil ____ Depth of Sample ____

Tested By ____ Date of Testing ____

Hydrometer analysis

Hydrometer no. ____ G_s of solids = 2.737 a = 0.997

Dispersing agent $NaPO_3$ Amount 4% of 125ml Wt. of soil, W_s 50 g

Zero correction +4 Meniscus correction +1

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_c	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	L/t	K from Table 6-4	D, mm
		1	18.	28.	23.5	46.9	29.	11.5	11.5	.0136	0.0461
		2	18.	20.	15.5	30.9	21.	12.9	6.45	.0136	.0345
		3	18.	17.	12.5	24.9	18.	13.3	4.43	.0136	.0286
		4	18.	15.	10.5	20.9	16.	13.7	3.43	.0136	.0252
		8	18.	11.	6.5	12.9	12.	14.3	1.79	.0136	.0182
		15	18.	9.	4.5	8.97	10.	14.7	0.98	.0136	.0134
		30	18.	7.	2.5	4.99	8.	15.0	0.5	.0136	.0096
		60	18.	5.5	1.0	1.99	6.5	15.2	0.25	.0136	.0068
		120	18.	5.	0.5	0.99	6.	15.3	0.13	.0136	.0048
		====	====	==							

$R_c = R_{actual}$ − zero correction + C_T % finer = $R_c(a)/W_s$ $D = K\sqrt{L/t}$

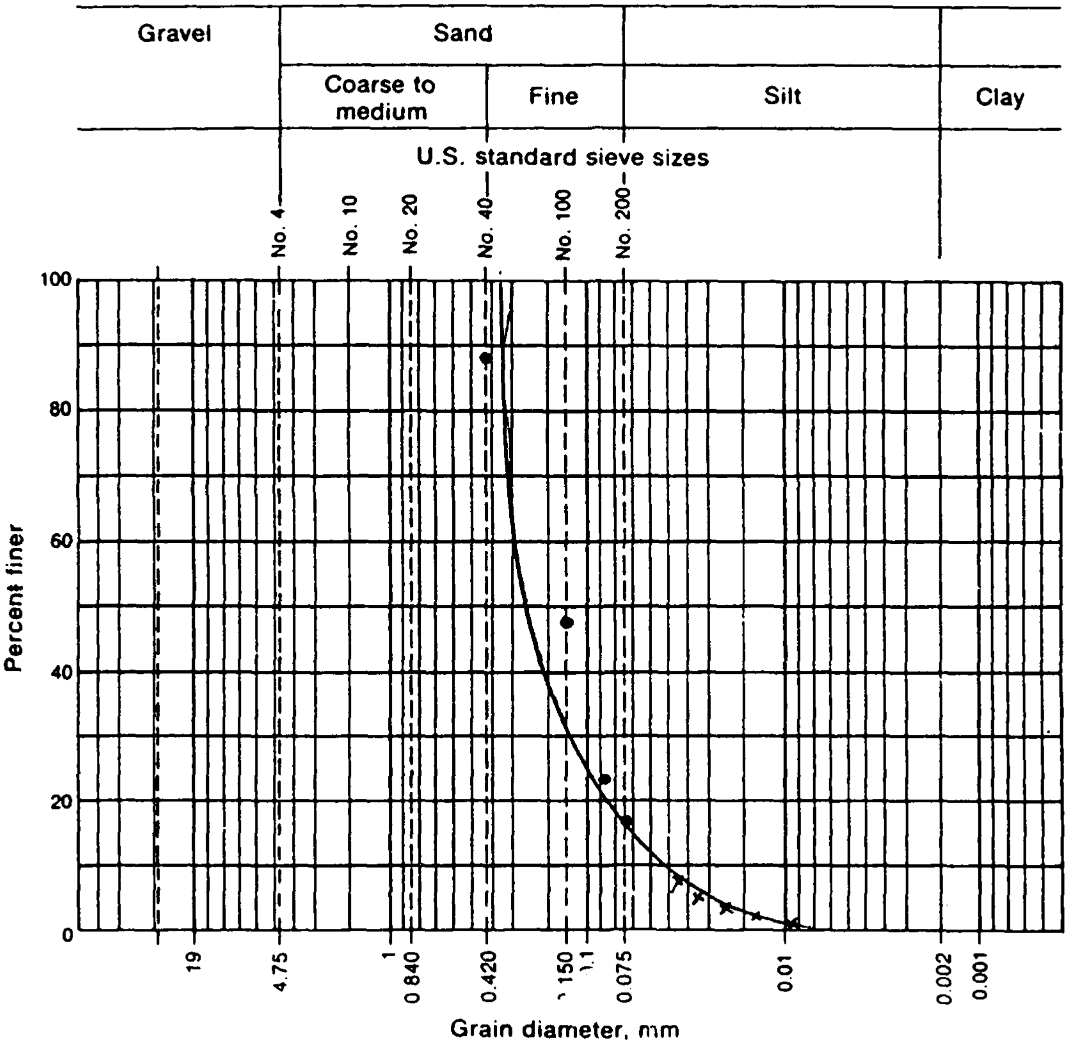
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ______

Location of Project ______ Boring No. ______ Sample No. S7

Description of Soil ______ Depth of Sample ______

Tested By. ______ Date of Testing ______



Visual soil description Poorly graded sand with fines, cu = 6.0

Soil classification:

SP System Unified Soil Classification

Gravels = 0 % ; Sands = 83 % ; Silts+clays = 17 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project Caliente creek Job No. ______

Location of Project ______ Boring No. ______ Sample No. S8

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	924 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
7	2.83	66.0	7.14	92.86
30	0.594	511.0	55.30	37.56
40	0.425	150.0	16.23	21.33
100	0.149	178.5	19.31	2.02
170	0.088	13.5	1.46	0.56
200	0.075	1.0	0.108	0.452
pan	-	4.0	0.432	-0-

% passing = 100 − $\sum$ % retained.

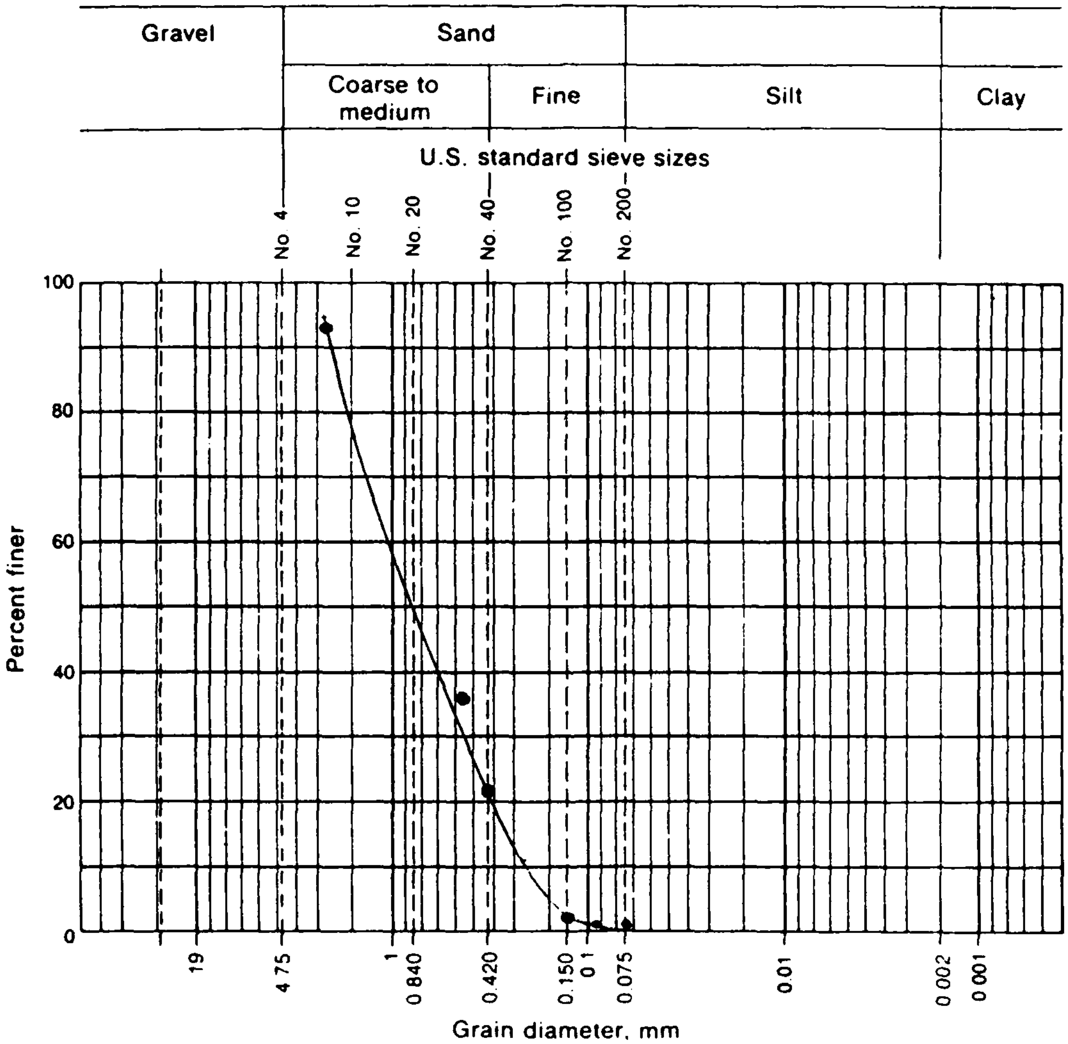
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job No.

Location of Project Boring No. Sample No. S8

Description of Soil Depth of Sample

Tested By. Date of Testing



Visual soil description Poorly graded clean sand, cu =5.09

Soil classification:

SP System Unified Soil Classification

Gravels = 0 % ; Sands = 99.5 % ; Silts+clays = 0.5 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S9

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,074 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
30	0.594	755.0	70.29	29.71
40	0.425	113.0	10.52	19.19
170	0.088	189.0	17.59	1.60
200	0.075	10.0	0.93	0.67
pan	-	7.0	0.65	-0-

% passing = 100 − $\sum$ % retained.

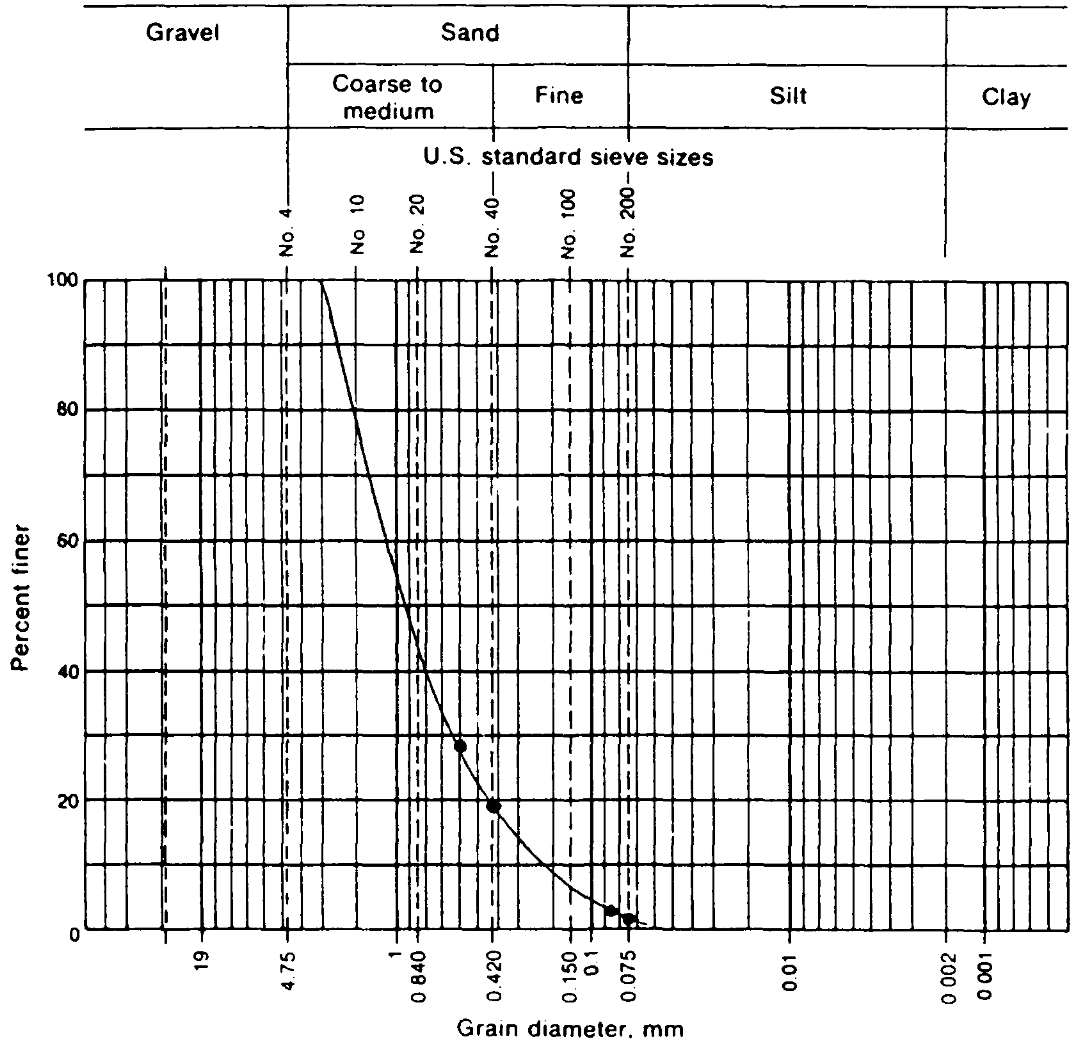
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ______

Location of Project ______ Boring No. ______ Sample No. S9

Description of Soil ______ Depth of Sample ______

Tested By. ______ Date of Testing ______



Visual soil description Poorly graded clean sand, cu = 6.0

Soil classification:
(SW) - SP System Unified Soil Classification

Gravels = 0 % ; Sands = 99.3 % ; Silts+clays = 0.7 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S10

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	793 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
30	0.594	251.50	31.71	68.29
40	0.425	84.50	10.65	57.64
100	0.149	267.00	33.66	23.98
170	0.088	89.50	11.28	12.70
200	0.075	29.50	3.72	8.98
Pan	-	71.0	8.95	-0-

% passing = $100 - \sum$ % retained.

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S10

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Hydrometer analysis

Hydrometer no. ______ G_s of solids = 2.737 a = 0.997

Dispersing agent $NaPO_3$ Amount 125 ml(4%) Wt. of soil, W_s 50 g

Zero correction +4 Meniscus correction +1

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_c	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
		1	20.	34.	30.	59.8	35.	10.5	10.5	.0133	.0431
		2	20.	26.	22.	43.8	27.	11.9	5.95	.0133	.0324
		3	20.	21.5	17.5	34.9	22.5	12.6	4.2	.0133	.0273
		4	20.	20.	16.	31.9	21.	12.9	3.23	.0133	.0238
		8	20.	15.5	11.5	22.9	16.5	13.6	1.70	.0133	.0173
		15	20.	13.	9.	17.9	14.	14.0	.933	.0133	.0128
		30	20.	11.	7.	13.9	12.	14.3	.476	.0133	.0092
		60	20.	9.	5.	9.97	10.	14.7	.245	.0133	.0066
		120	20.	7.	3.	5.98	8.	15.0	.125	.0133	.0047
		251	20.	7.	3.	5.98	8.	15.0	.059	.0133	.0032
		====	====	====	====						

$R_c = R_{actual}$ − zero correction + C_T % finer = $R_c(a)/W_s$ $D = K\sqrt{L/t}$

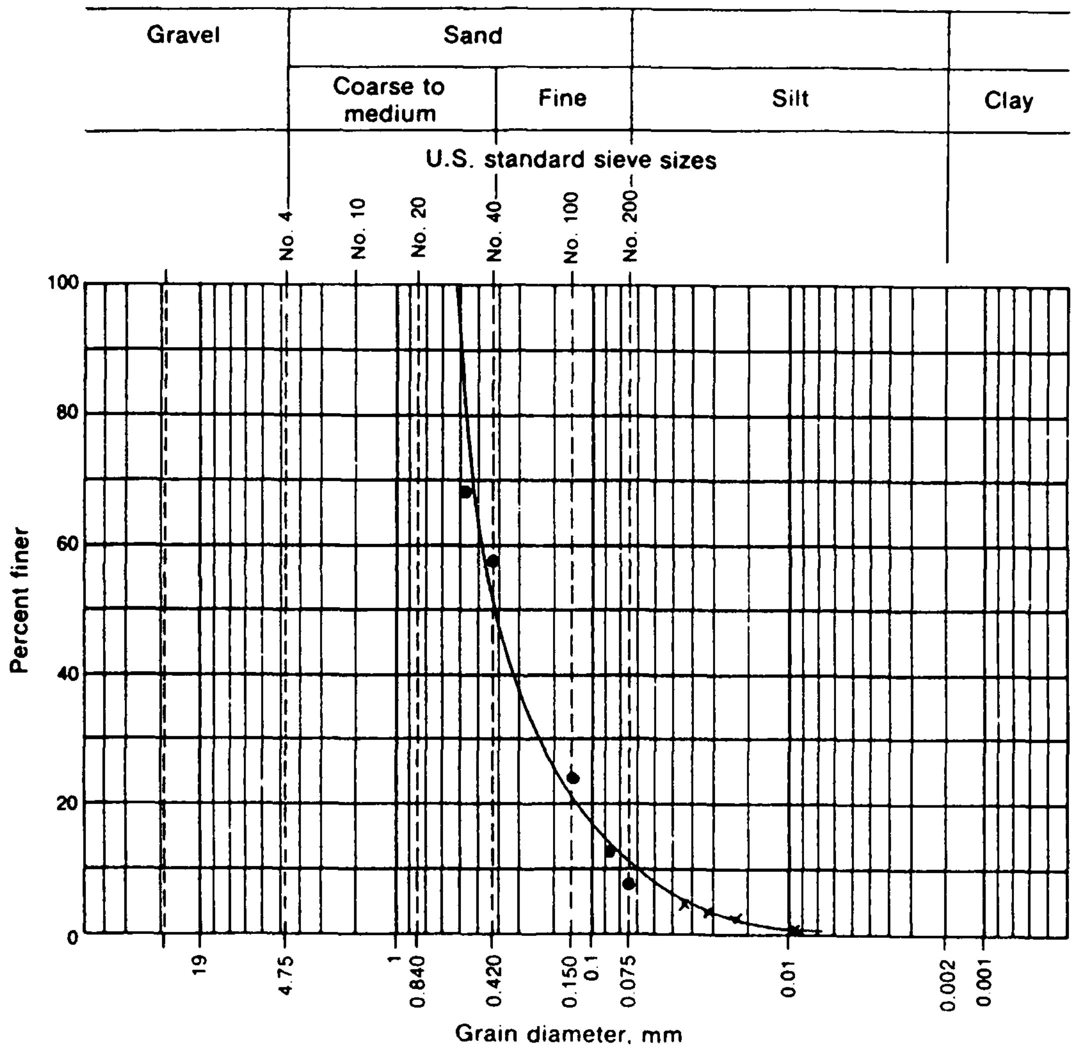
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ____

Location of Project ____ Boring No. ____ Sample No. S10

Description of Soil ____ Depth of Sample ____

Tested By. ____ Date of Testing ____



Visual soil description Poorly graded sand with fines, cu = 5.62

Soil classification:

SP System Unified Soil Classification

Gravels = 0 % ; Sands = 91 % ; Silts + clays = 9 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ____________

Location of Project ____________ Boring No. ____________ Sample No. S11

Description of Soil ____________ Depth of Sample ____________

Tested By ____________ Date of testing ____________

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,151.50 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
-	12.50	97.0	8.42	91.58
-	6.30	38.0	3.30	88.28
4	4.75	34.0	2.95	85.33
7	2.83	140.0	12.15	73.18
30	0.594	516.50	44.85	28.33
40	0.425	107.0	9.29	19.04
100	0.149	207.0	17.97	1.07
170	0.088	10.0	0.86	0.22
200	0.075	1.0	0.08	0.13
pan	-	1.0	0.08	-0-

% passing = $100 - \sum$ % retained.

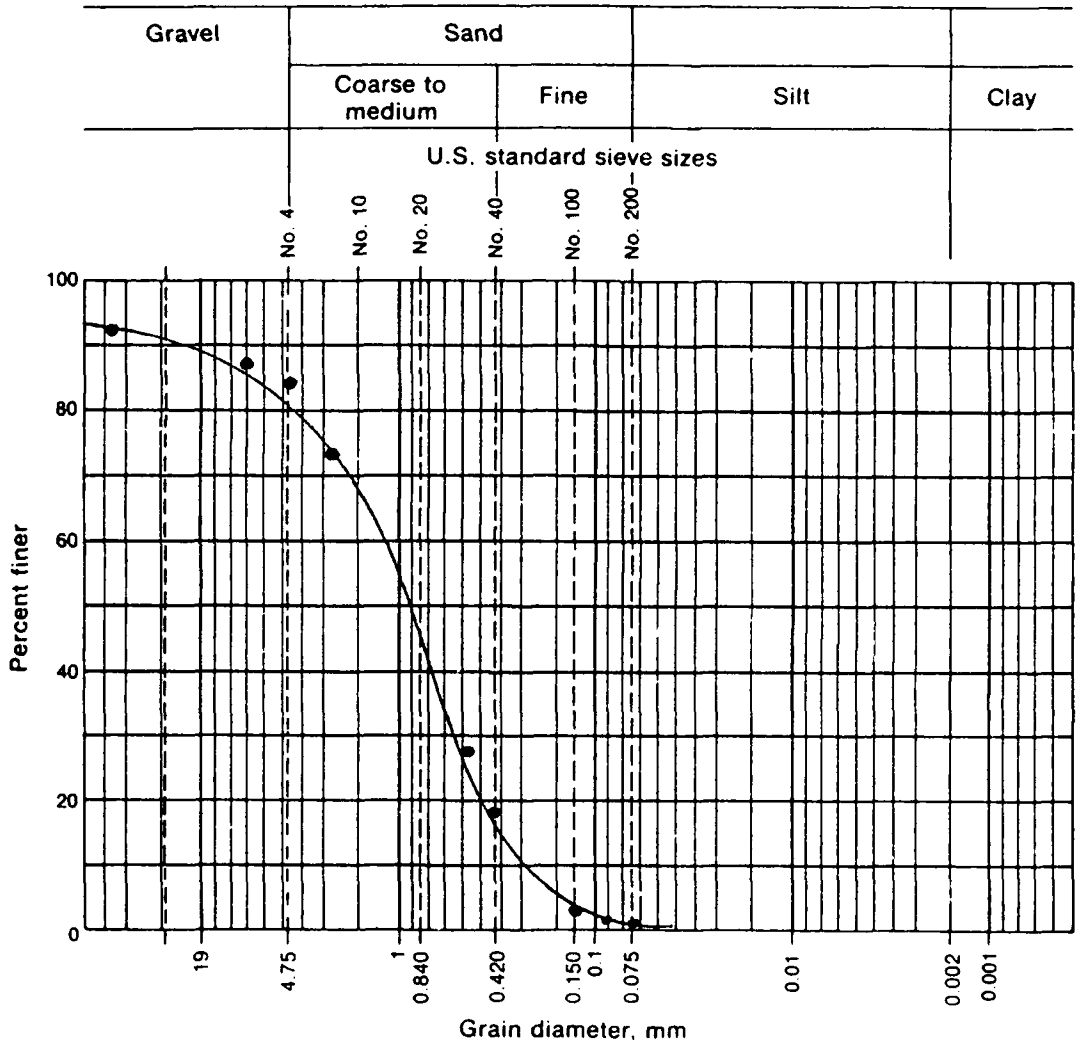
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ____

Location of Project ____ Boring No. ____ Sample No. S11

Description of Soil ____ Depth of Sample ____

Tested By. ____ Date of Testing ____



Visual soil description Well graded sand with some gravels
cu = 5.86

Soil classification:
SW System Unified Soil Classification

Gravels = 19 % ; sands = 80.87 % ; Silts + Clays = 0.13 %

GRAIN SIZE ANALYSIS-MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S12

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	770.50 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
7	2.83	82.0	10.64	89.36
30	0.594	259.50	33.67	55.69
40	0.425	103.0	13.36	42.33
100	0.149	272.0	35.30	7.03
170	0.088	35.0	4.54	2.49
200	0.075	7.0	0.90	1.59
pan	-	12.0	1.55	-0-

% passing = 100 − $\sum$ % retained.

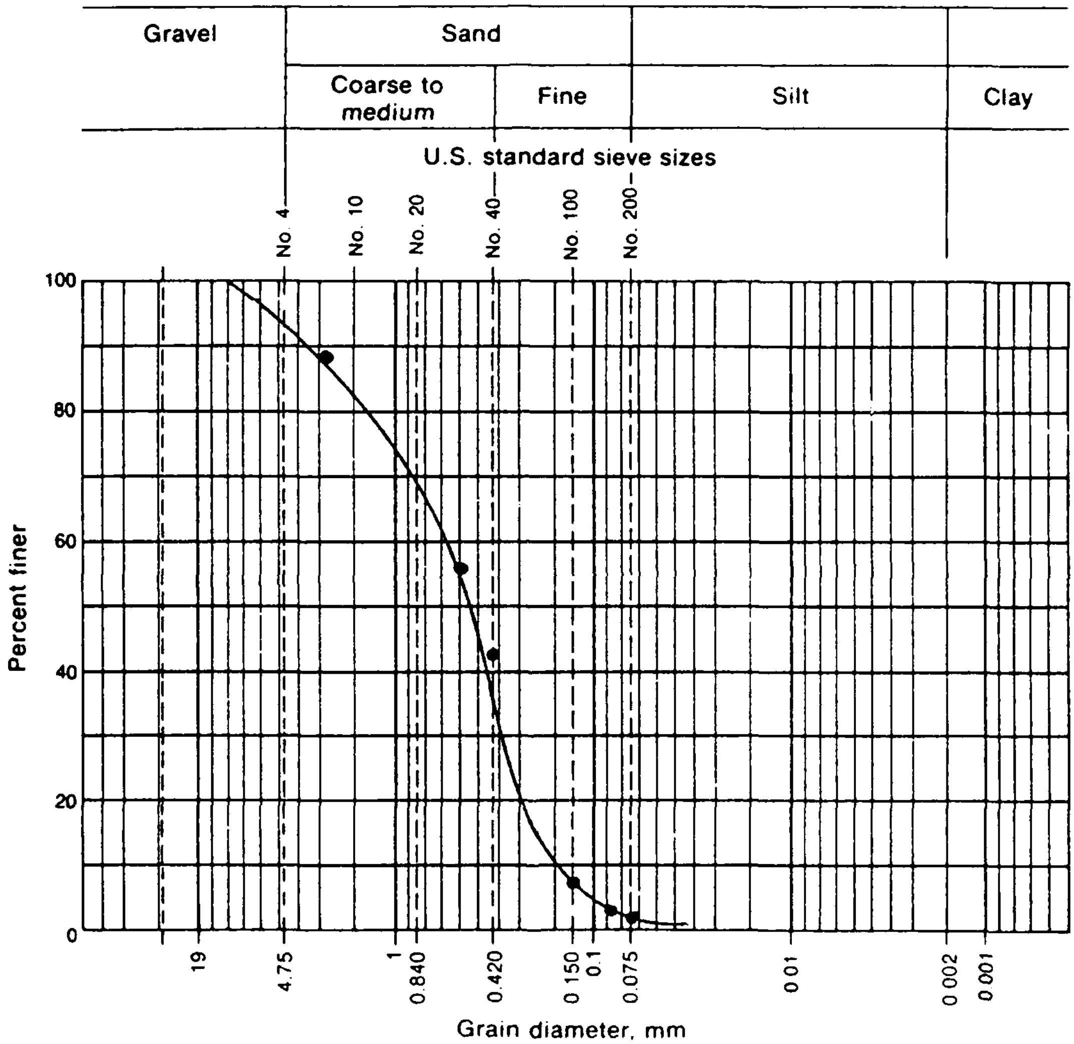
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ____

Location of Project ____ Boring No. ____ Sample No. S12

Description of Soil ____ Depth of Sample ____

Tested By. ____ Date of Testing ____



Visual soil description Poorly graded sand., cu = 3.57

Soil classification:
SP System Unified Soil Classification

Gravels = 5 % ; Sands = 93.50 % ; Silts+clays= 1.5 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ____

Location of Project ____ Boring No. ____ Sample No. S13

Description of Soil ____ Depth of Sample ____

Tested By ____ Date of testing ____

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	922.0 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
7	2.83	130.0	14.09	85.91
18	1.00	294.0	31.94	53.97
40	0.425	299.0	32.42	21.55
100	0.149	183.0	19.84	1.71
170	0.088	11.0	1.19	0.52
200	0.075	1.0	0.10	0.42
pan	–	4.0	0.43	-0-

% passing = 100 − $\sum$ % retained.

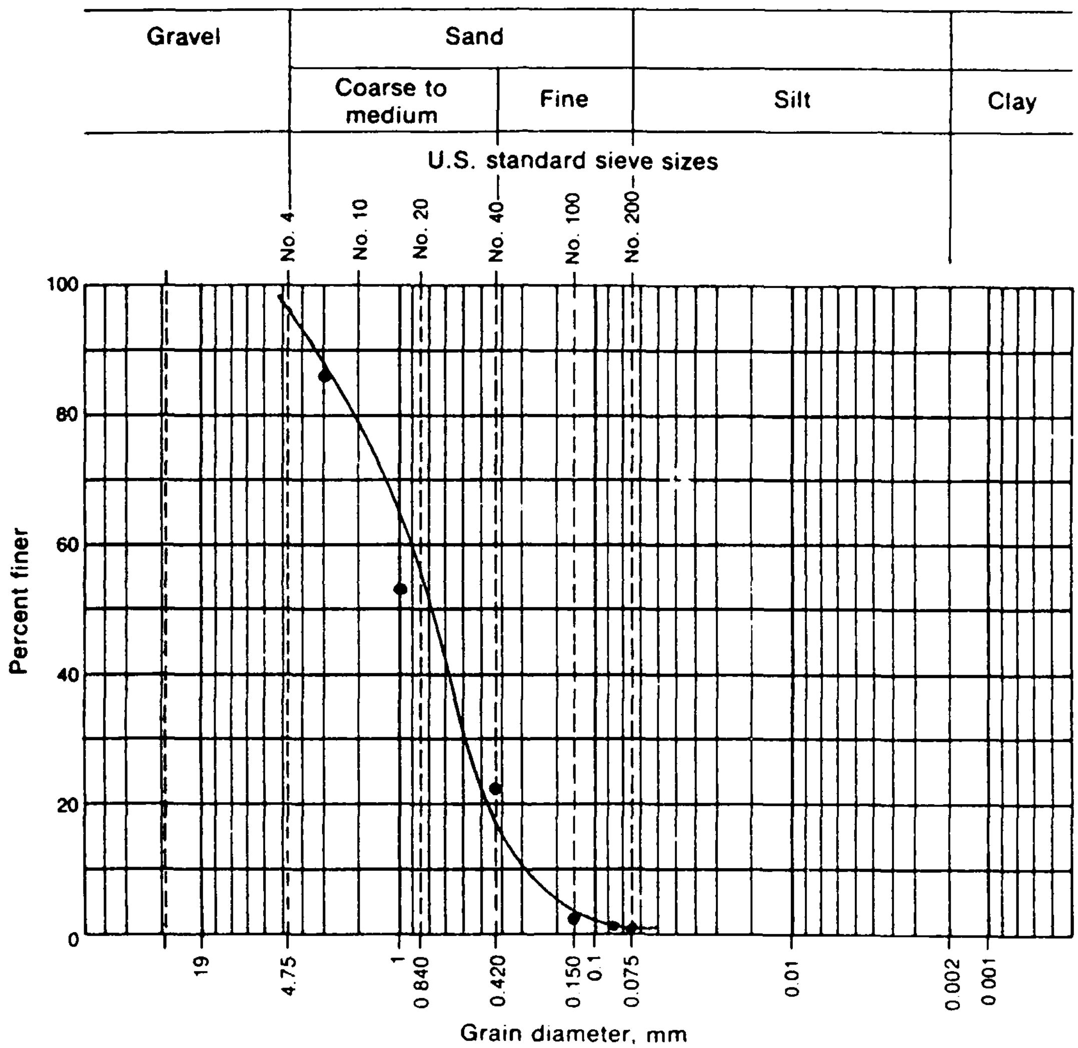
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ______

Location of Project ______ Boring No. ______ Sample No. S13

Description of Soil ______ Depth of Sample ______

Tested By. ______ Date of Testing ______



Visual soil description Poorly graded sand with little fines, cu = 4.28

Soil classification:

Sp-(SW) System Unified Soil Classification

Gravels = 7 % ; Sands = 92.5 % ; Silts+clays = 0.5 %

GRAIN SIZE ANALYSIS-MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S14

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	886.50 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
7	2.83	89.5	10.09	89.90
18	1.00	240.0	27.07	62.83
40	0.425	341.0	38.46	24.37
100	0.149	203.0	22.89	1.48
170	0.088	10.0	1.128	0.361
200	0.075	1.0	0.112	0.24
pan	-	2.0	0.22	-.0-

% passing = 100 − $\sum$ % retained.

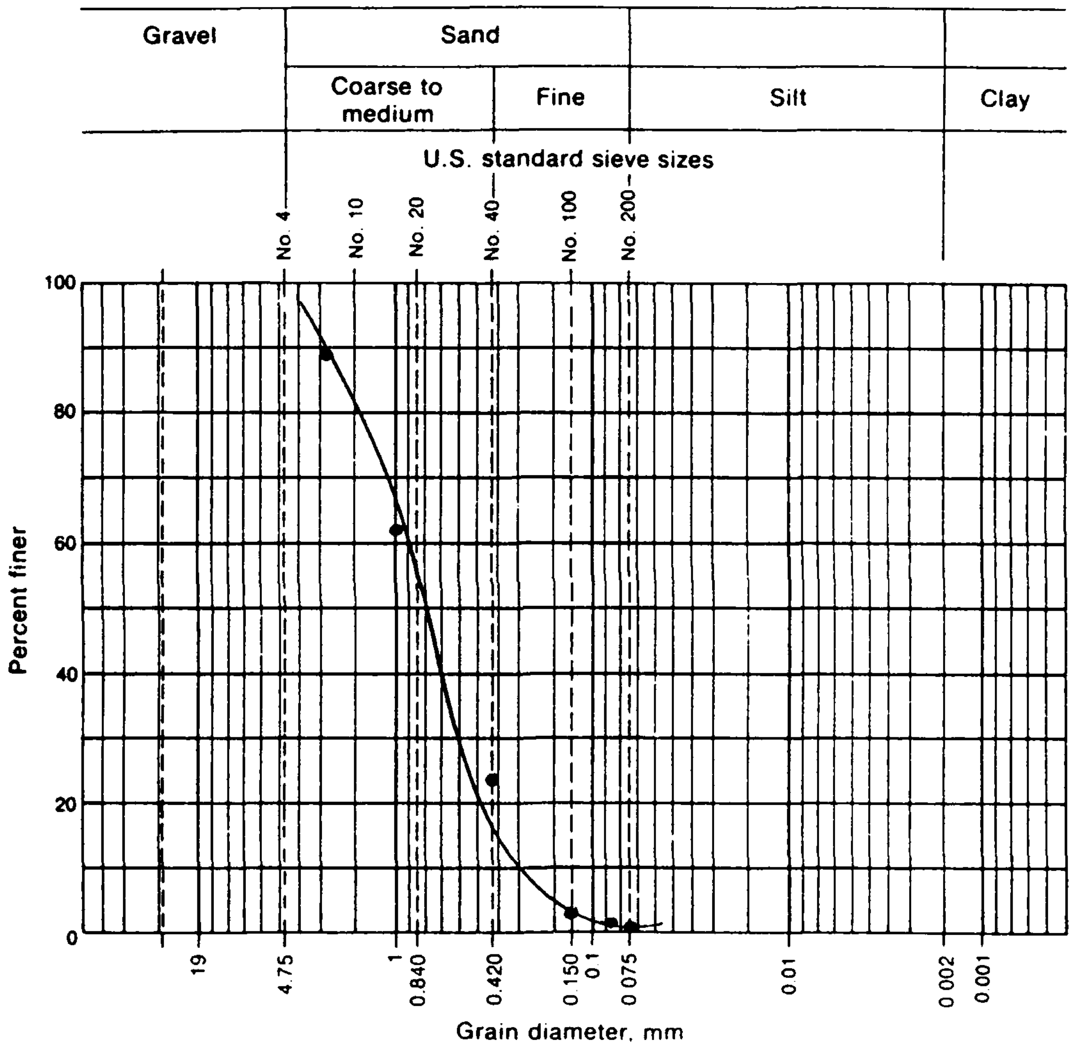
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No.

Location of Project Boring No. Sample No. S14

Description of Soil Depth of Sample

Tested By. Date of Testing



Visual soil description Poorly graded sand, cu = 3.92

Soil classification:
SP System Unified Soil Classifcation

Gravels = 4 % ; Sands = 95.75 % ; Silts+clays = 0.25 %

GRAIN SIZE ANALYSIS-MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S15

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of testing ______

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,027.5 gram

Sieve analysis and grain shape

Sieve no.	Diam. (mm)	Wt. retained	% retained	% passing
-	12.50	43.0	4.18	95.82
4	4.75	89.0	8.66	87.16
7	2.83	99.0	9.63	77.53
18	1.00	384.50	37.42	40.11
40	0.42	283.50	27.59	12.52
100	0.149	107.00	10.41	2.11
200	0.075	13.5	1.31	0.80
pan	-	8.0	0.77	-0-

% passing = 100 − $\sum$ % retained

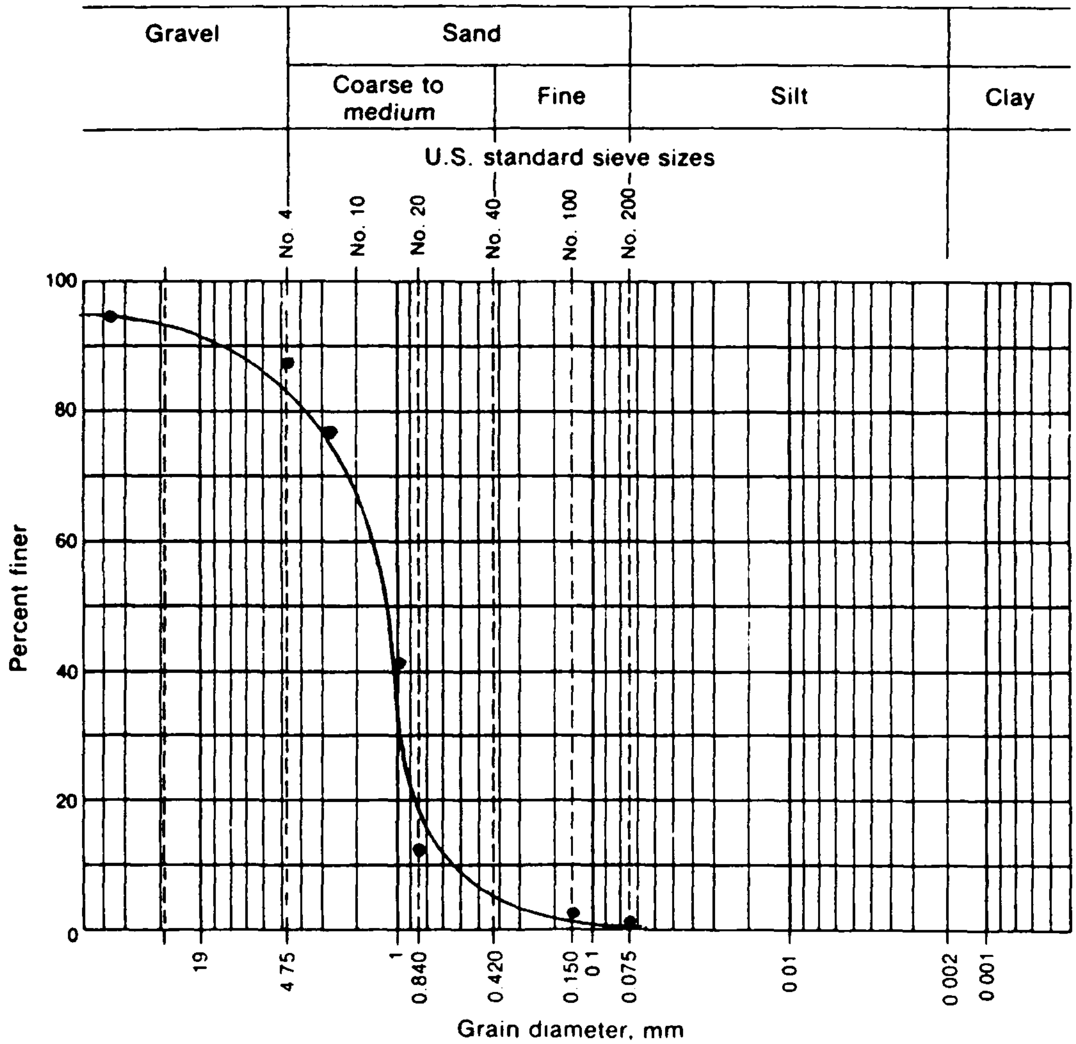
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No. ____

Location of Project ____ Boring No. ____ Sample No. S15

Description of Soil ____ Depth of Sample ____

Tested By. ____ Date of Testing ____



Visual soil description Poorly graded sans with little gravels
cu = 2.13

Soil classification:
SP System Unified Soil Classification

Gravels = 12.5 % ; Sands = 86.5 % ; Silts+clays = 1 %

GRAIN SIZE ANALYSIS–MECHANICAL Data Sheet 5

Project CALIENTE CREEK Job No. ____________

Location of Project ____________ Boring No. ____________ Sample No. S16

Description of Soil ____________ Depth of Sample ____________

Tested By ____________ Date of testing ____________

Soil Sample Size (ASTM D1140-54)

Nominal diameter of largest particle	Approximate minimum Wt. of sample, g
No. 10 sieve	200
No. 4 sieve	500
3/4 in.	1500

Wt. of dry sample + container	
Wt. of container	
Wt. of dry sample, W_s	1,673.50 gram

Sieve analysis and grain shape

Sieve no.	Diam (mm)	Wt. retained	% retained	% passing
-	19.0	306.5	18.31	81.69
-	12.50	127.50	7.61	74.08
-	6.3	216.50	12.93	61.15
4	4.75	74.0	4.42	56.73
7	2.83	149.0	8.90	47.83
18	1.0	362.0	21.63	26.20
40	0.42	234.50	14.01	12.19
100	0.149	152.0	9.08	3.11
200	0.075	34.5	2.06	1.05
pan	-	17.0	1.015	-0-

% passing = 100 − $\sum$ % retained.

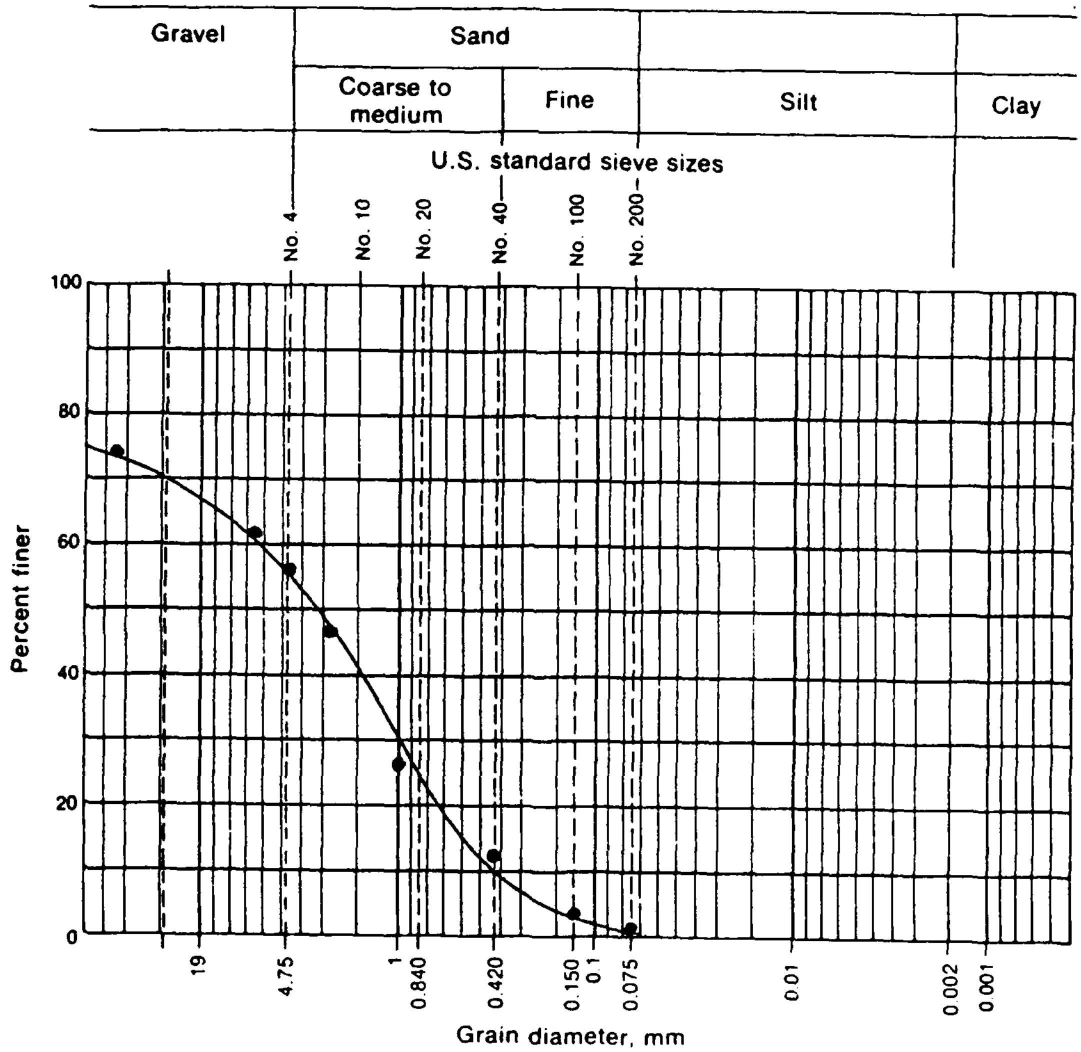
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project CALIENTE CREEK Job. No.

Location of Project Boring No. Sample No. S16

Description of Soil Depth of Sample

Tested By. Date of Testing



Visual soil description Well graded sand, cu = 14.5

Soil classification:

SW System Unified Soil Classification

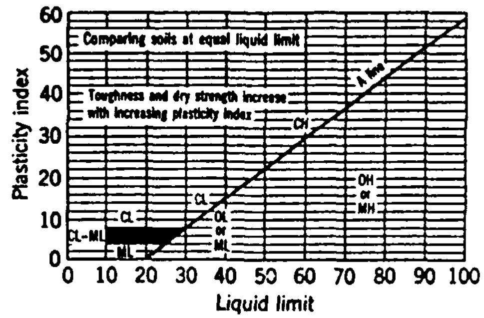
Gravels = 43.25 % ; Sands = 55.75 % ; Silts+clays = 1.0 %

Table 3.5 Unified Soil Classification

Major divisions			Field Identification Procedures (Excluding particles larger than 75 μm and basing fractions on estimated weights)	Group Symbols [a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria	
Coarse-grained soils. More than half of material is *larger* than 75 μm sieve size[b] (The 75 μm sieve size is about the smallest particle visible to naked eye)	Gravels. More than half of coarse fraction is larger than 4 mm sieve size	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than 75 μm sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of 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
			Predominantly one size or a range of sizes with some intermediate sizes missing	*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)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures			Atterberg limits below "A" line, or *PI* less than 4 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures			Atterberg limits above "A" line, with *PI* greater than 7
	Sands. More than half of coarse fraction is smaller than 4 mm sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*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
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines			Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures			Atterberg limits below "A" line or *PI* less than 5 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures			Atterberg limits below "A" line with *PI* greater than 7

Identification Procedures on Fraction Smaller than 380 μm Sieve Size

Major divisions		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols [a]	Typical Names	Information Required for Describing Soils
Fine-grained soils. More than half of material is *smaller* than 75 μm sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions. Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart for laboratory classification of fine grained soils

From Wagner, 1957.

[a] *Boundary classifications*. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW–GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus 380 μm sieve size particles. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):

After removing particles larger than 380 μm sieve size, prepare a pat of moist soil with a volume of about 8000 mm³. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than 380 μm sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the 380 μm sieve size, a specimen of soil about 12 mm cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about 3 mm in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s)

Data Sheet 8

Project CALIENTE CREEK

Job No. ____

Location of Project ____

Boring No. ____ Sample No. S1

Description of Soil ____

Depth of Sample ____

Tested By ____

Date of Testing ____

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	403.99			
Temperature, °C	19 °C			
Wt. flask + water[b] = W_{bw}	357.41			
Evap. dish no.	--			
Wt. evap. dish + dry soil	150.81			
Wt. of evap. dish	76.53			
Wt. of dry soil = W_s	74.28			
$W_w = W_s + W_{bw} - W_{bws}$	27.70			
$G_s = \alpha W_s / W_w$	2.682			

[a] Indicate vacuum or aspirator for air removal.

[b] W_{bw} is the weight of the flask filled with water at same temp. ± 1° C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ____

Average specific gravity of soil solids (G_s) = 2.682

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ____

Location of Project ____ Boring No. ____ Sample No. S2

Description of Soil ____ Depth of Sample ____

Tested By ____ Date of Testing ____

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	435.35			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	366.88			
Evap. dish no.	-			
Wt. evap. dish + dry soil	216.70			
Wt. of evap. dish	109.40			
Wt. of dry soil = W_s	107.30			
$W_w = W_s + W_{bw} - W_{bws}$	38.83			
$G_s = \alpha W_s / W_w$	2.76			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ____

Average specific gravity of soil solids (G_s) = 2.76

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S3

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	411.38			
Tem - ature, °C	20.5			
Wt. flask + water[b] = W_{bw}	348.02			
Evap. dish no.	-			
Wt. evap. dish + dry soil	285.21			
Wt. of evap. dish	184.96			
Wt. of dry soil = W_s	100.25			
$W_w = W_s + W_{bw} - W_{bws}$	36.89			
$G_s = \alpha W_s / W_w$	2.717			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.717

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S4

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	463.56			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	423.64			
Evap. dish no.	--			
Wt. evap. dish + dry soil	167.89			
Wt. of evap. dish	104.57			
Wt. of dry soil = W_s	63.32			
$W_w = W_s + W_{bw} - W_{bws}$	23.40			
$G_s = \alpha W_s / W_w$	2.705			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.705

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S5

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	398.75			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	366.56			
Evap. dish no.	-			
Wt. evap. dish + dry soil	127.54			
Wt. of evap. dish	76.44			
Wt. of dry soil = W_s	51.10			
$W_w = W_s + W_{bw} - W_{bws}$	18.91			
$G_s = \alpha W_s / W_w$	2.702			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.702

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S6

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	395.70			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	348.23			
Evap. dish no.	-			
Wt. evap. dish + dry soil	144.77			
Wt. of evap. dish	69.16			
Wt. of dry soil = W_s	75.61			
$W_w = W_s + W_{bw} - W_{bws}$	28.14			
$G_s = \alpha W_s / W_w$	2.687			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.687

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No.

Location of Project Boring No. Sample No. S7

Description of Soil Depth of Sample

Tested By Date of Testing

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	381.56			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	348.23			
Evap. dish no.	-			
Wt. evap. dish + dry soil	167.39			
Wt. of evap. dish	114.87			
Wt. of dry soil = W_s	52.52			
$W_w = W_s + W_{bw} - W_{bws}$	19.19			
$G_s = \alpha W_s / W_w$	2.737			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks

Average specific gravity of soil solids (G_s) = 2.737

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S8

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	405.55			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	366.61			
Evap. dish no.	--			
Wt. evap. dish + dry soil	138.32			
Wt. of evap. dish	76.35			
Wt. of dry soil = W_s	61.97			
$W_w = W_s + W_{bw} - W_{bws}$	23.03			
$G_s = \alpha W_s / W_w$	2.69			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.69

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ____

Location of Project ____ Boring No. ____ Sample No. S9

Description of Soil ____ Depth of Sample ____

Tested By ____ Date of Testing ____

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	396.82			
Temperature, °C	19.0			
Wt. flask + water[b] = W_{bw}	348.13			
Evap. dish no.	--			
Wt. evap. dish + dry soil	146.66			
Wt. of evap. dish	69.18			
Wt. of dry soil = W_s	77.48			
$W_w = W_s + W_{bw} - W_{bws}$	28.79			
$G_s = \alpha W_s / W_w$	2.69			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}

Remarks ____

Average specific gravity of soil solids (G_s) = 2.69

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S10

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	386.10			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	346.94			
Evap. dish no.	--			
Wt. evap. dish + dry soil	138.0			
Wt. of evap. dish	76.30			
Wt. of dry soil = W_s	61.70			
$W_w = W_s + W_{bw} - W_{bws}$	22.54			
$G_s = \alpha W_s / W_w$	2.7373			

[a] Indicate vacuum or aspirator for air removal.
[b] W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.737

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. _____

Location of Project _____ Boring No. _____ Sample No. S11

Description of Soil _____ Depth of Sample _____

Tested By _____ Date of Testing _____

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	390.29			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	346.45			
Evap. dish no.	--			
Wt. evap. dish + dry soil	146.57			
Wt. of evap. dish	76.88			
Wt. of dry soil = W_s	69.69			
$W_w = W_s + W_{bw} - W_{bws}$	25.85			
$G_s = \alpha W_s / W_w$	2.695			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws}, or value from calibration curve at T of W_{bws}

Remarks _____

Average specific gravity of soil solids (G_s) = 2.695

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALINETE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S12

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	389.30			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	348.31			
Evap. dish no.	--			
Wt. evap. dish + dry soil	250.26			
Wt. of evap. dish	184.93			
Wt. of dry soil = W_s	65.33			
$W_w = W_s + W_{bw} - W_{bws}$	24.34			
$G_s = \alpha W_s / W_w$	2.684			

[a] Indicate vacuum or aspirator for air removal.
[b] W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.684

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project Caliente Creek Job No. ____

Location of Project ____ Boring No. ____ Sample No. S13

Description of Soil ____ Depth of Sample ____

Tested By ____ Date of Testing ____

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	385.83			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	346.73			
Evap. dish no.	--			
Wt. evap. dish + dry soil	247.05			
Wt. of evap. dish	185.08			
Wt. of dry soil = W_s	61.97			
$W_w = W_s + W_{bw} - W_{bws}$	22.87			
$G_s = \alpha W_s / W_w$	2.709			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}

Remarks ____

Average specific gravity of soil solids (G_s) = 2.709

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S14

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	397.34			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	346.87			
Evap. dish no.	--			
Wt. evap. dish + dry soil	190.22			
Wt. of evap. dish	109.44			
Wt. of dry soil = W_s	80.78			
$W_w = W_s + W_{bw} - W_{bws}$	30.31			
$G_s = \alpha W_s / W_w$	2.665			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.665

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project CALIENTE CREEK Job No. ______

Location of Project ______ Boring No. ______ Sample No. S15

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	414.94			
Temperature, °C	20.50			
Wt. flask + water[b] = W_{bw}	365.65			
Evap. dish no.	--			
Wt. evap. dish + dry soil	153.38			
Wt. of evap. dish	76.80			
Wt. of dry soil = W_s	76.58			
$W_w = W_s + W_{bw} - W_{bws}$	27.29			
$G_s = \alpha W_s / W_w$	2.806			

[a]Indicate vacuum or aspirator for air removal.
[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.806

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project Calente Creek Job No. ______

Location of Project ______ Boring No. ______ Sample No. S16

Description of Soil ______ Depth of Sample ______

Tested By ______ Date of Testing ______

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	asp			
Wt. flask + water + soil = W_{bws}	403.16			
Temperature, °C	20.5			
Wt. flask + water[b] = W_{bw}	365.65			
Evap. dish no.	--			
Wt. evap. dish + dry soil	135.03			
Wt. of evap. dish	76.48			
Wt. of dry soil = W_s	58.55			
$W_w = W_s + W_{bw} - W_{bws}$	21.04			
$G_s = \alpha W_s / W_w$	2.782			

[a]Indicate vacuum or aspirator for air removal.

[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks ______

Average specific gravity of soil solids (G_s) = 2.782

Untitled Data #1 Fri, Oct 27, 1989

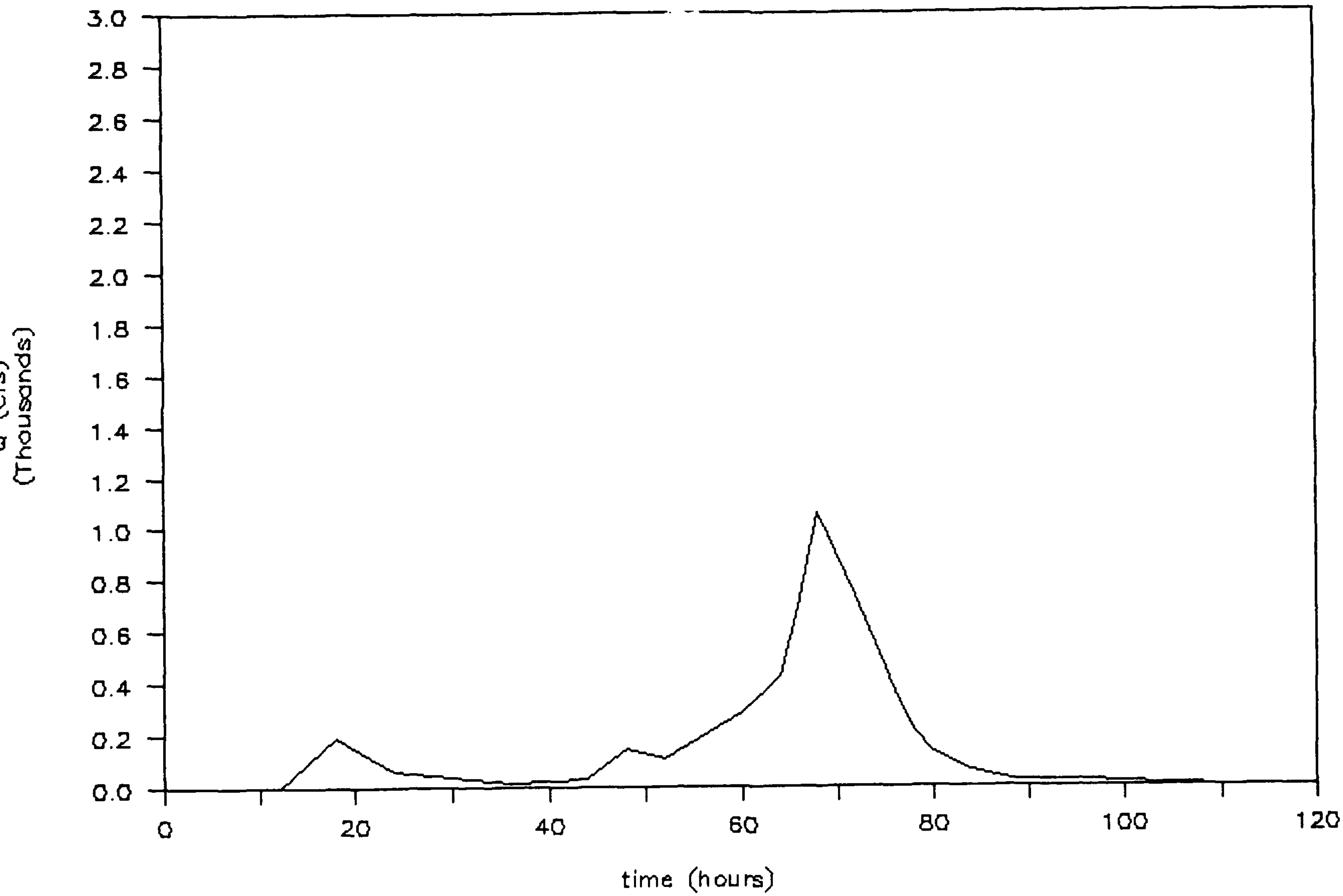
	Oven dry	Dry at 550 F	organic	Organic, %
1	44.155	43.877	0.278	0.630
2	56.641	56.165	0.477	0.841
3	45.227	44.932	0.295	0.652
4	43.248	42.968	0.280	0.647
5	44.589	43.944	0.645	1.446
6	58.830	58.583	0.248	0.421
7	26.005	25.511	0.494	1.900
8	49.242	49.023	0.219	0.444
9	50.205	50.004	0.202	0.402
10	42.658	42.278	0.380	0.891
11	50.844	50.622	0.222	0.436
12	51.171	50.858	0.313	0.612
13	57.410	57.067	0.343	0.598
14	61.170	60.933	0.237	0.388
15	52.486	52.260	0.226	0.430
16	66.783	66.363	0.421	0.630

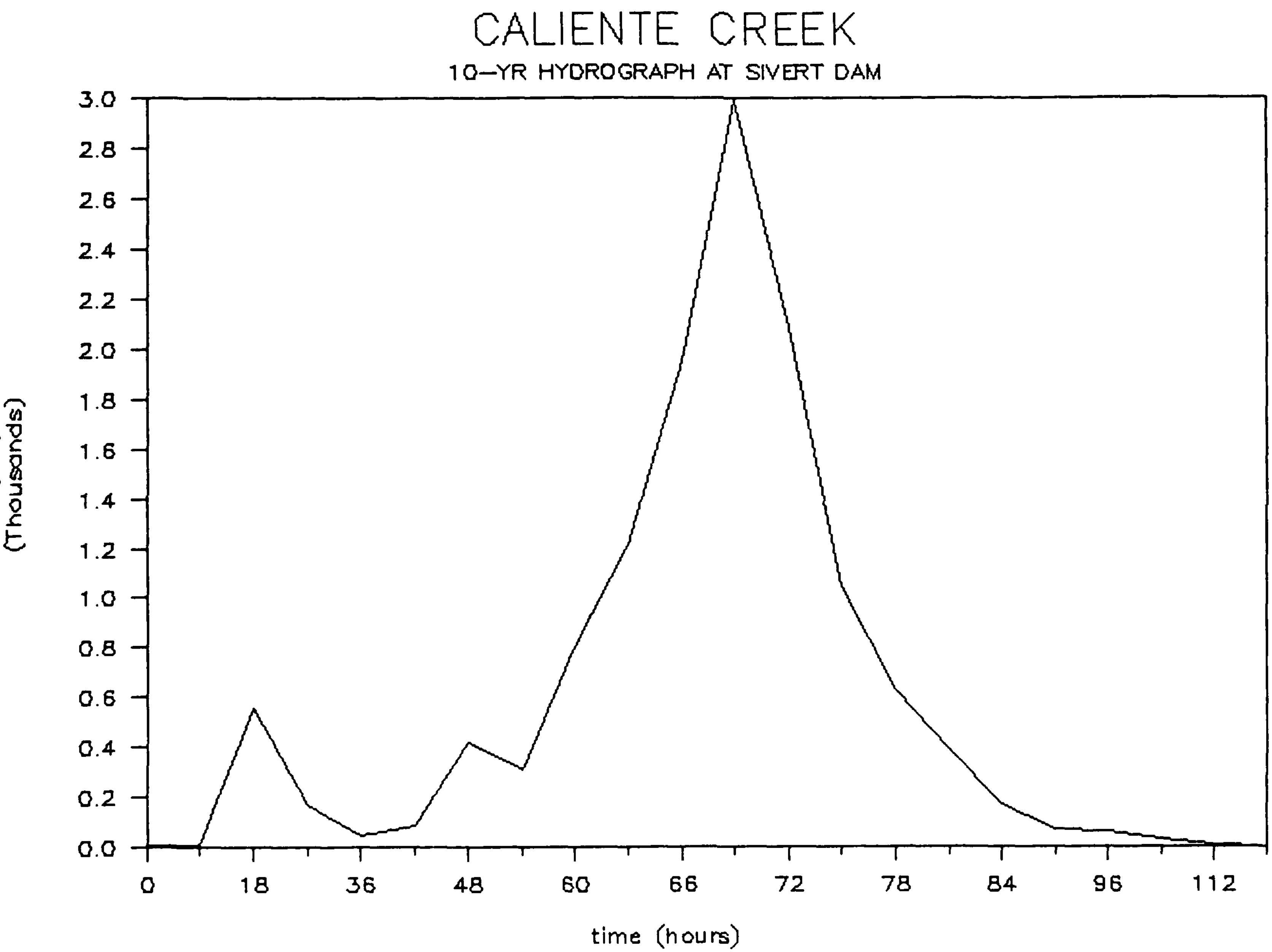
APPENDIX C

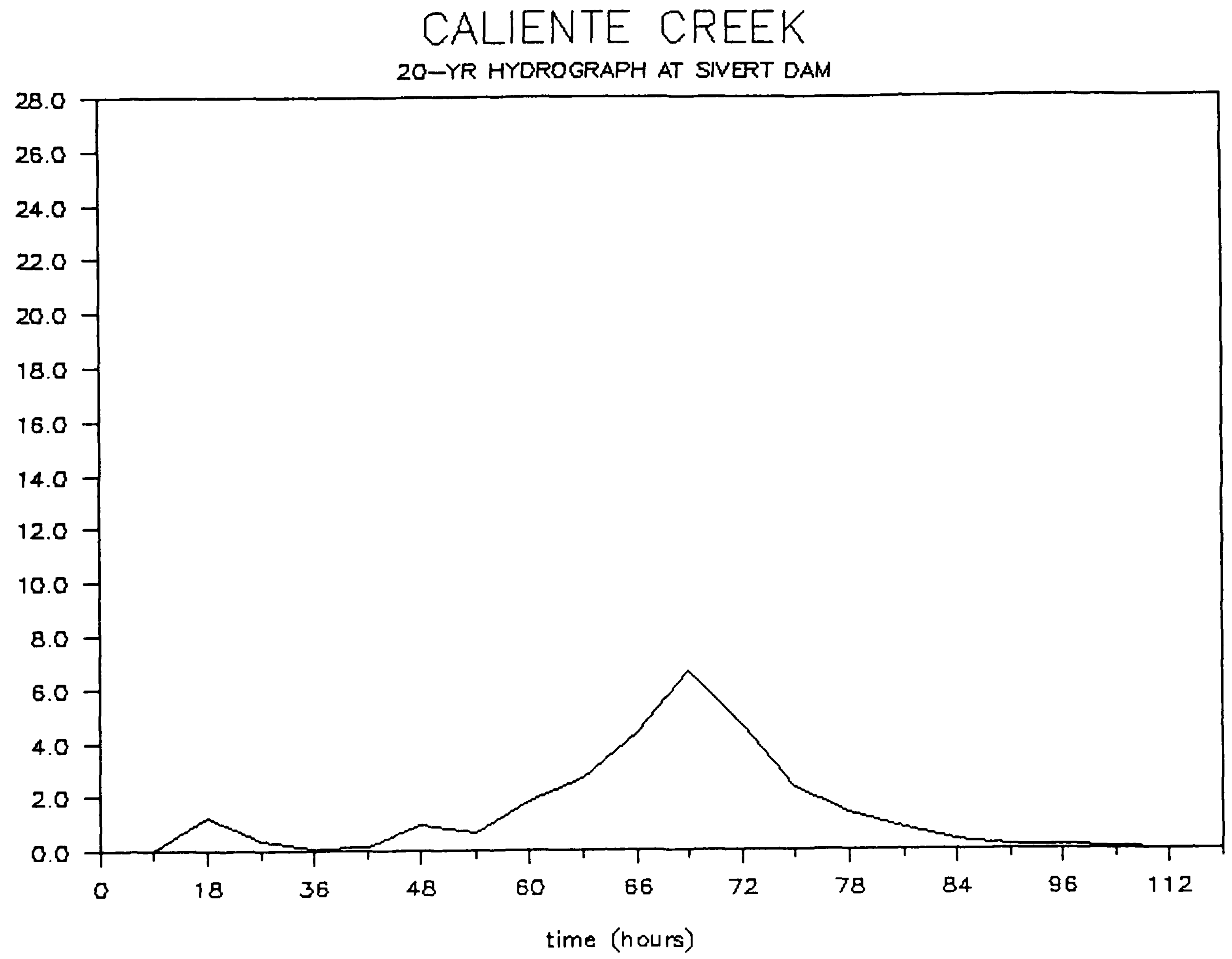
Synthesized Single Event Flood Hydrographs

CALIENTE CREEK

5—YR HYDROGRAPH AT SIVERT DAM

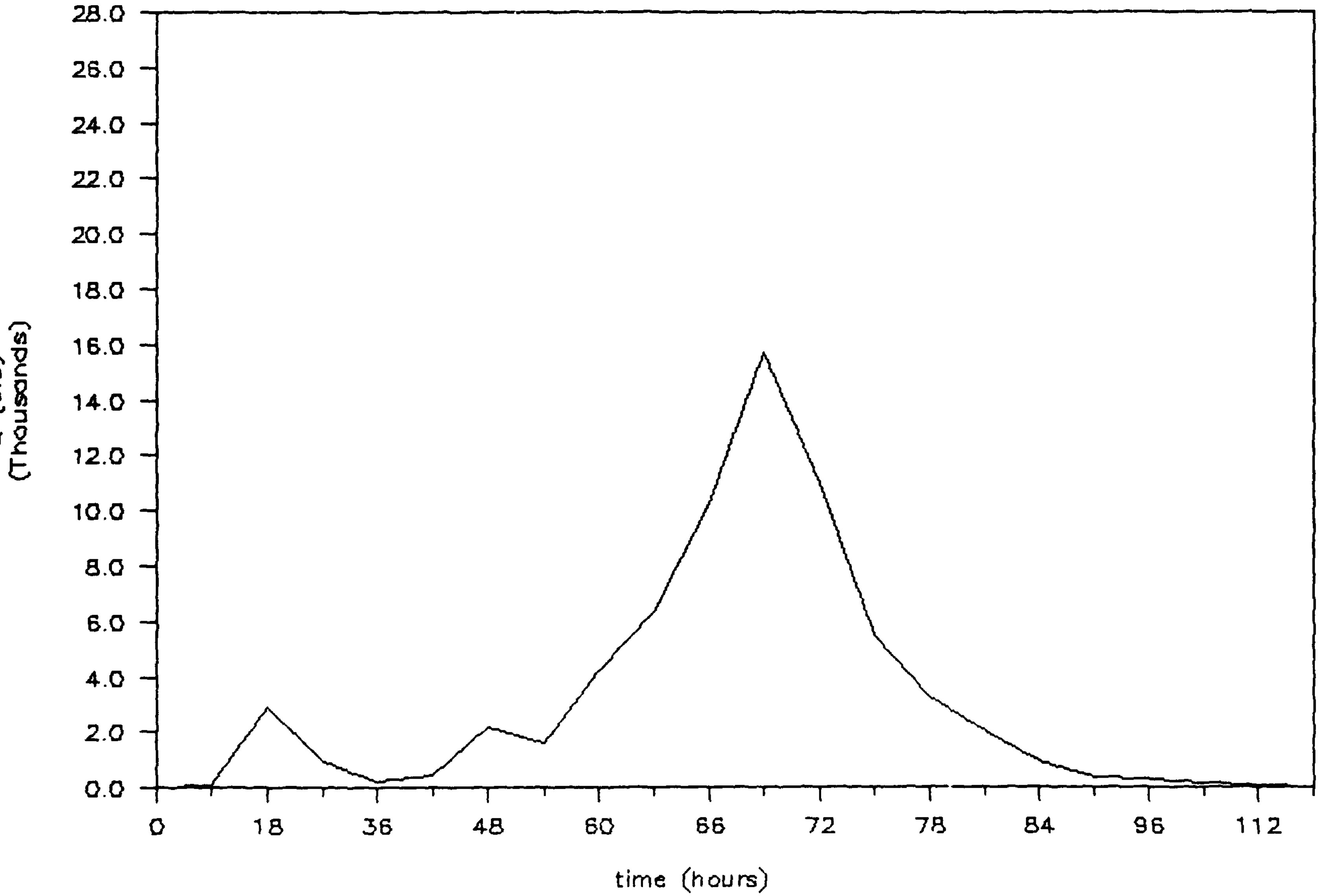



CALIENTE CREEK
10-YR HYDROGRAPH AT SIVERT DAM
Q (cfs)
(Thousands)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
18
36
48
60
66
72
78
84
96
112
time (hours)


CALIENTE CREEK
20-YR HYDROGRAPH AT SIVERT DAM
Q (cfs)
(Thousands)
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
18
36
48
60
66
72
78
84
96
112
time (hours)

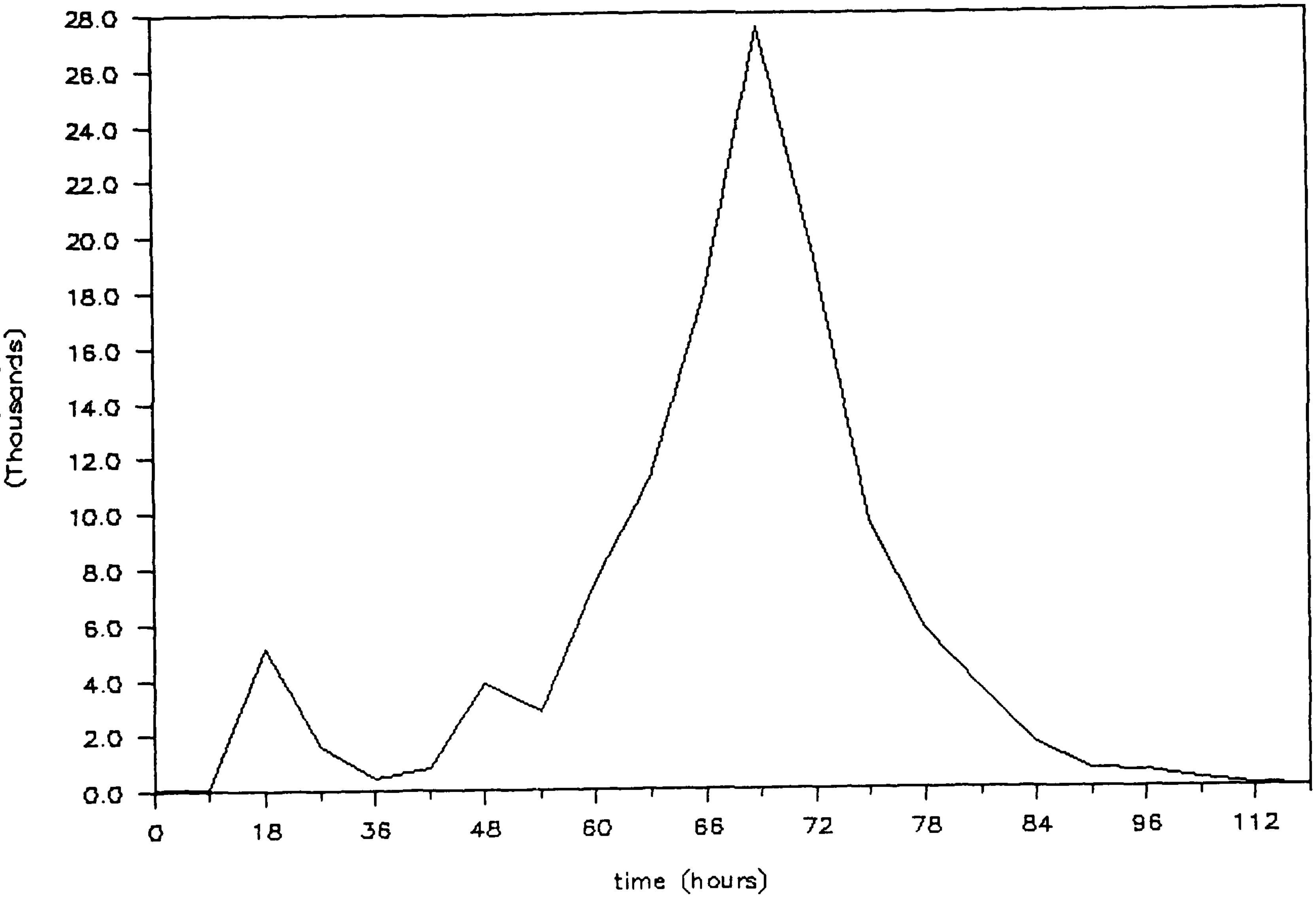
CALIENTE CREEK

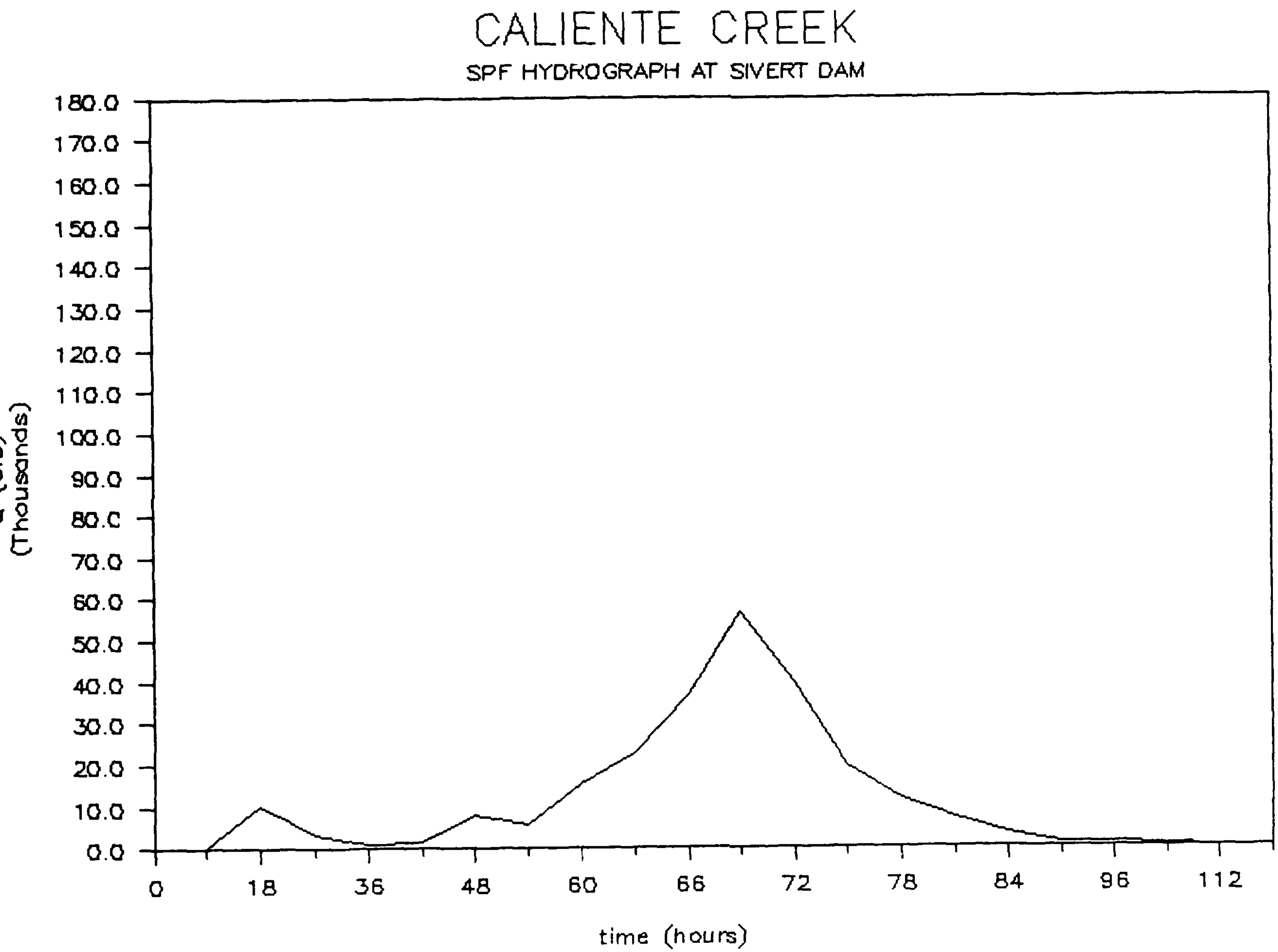
50–YR HYDROGRAPH AT SIVERT DAM

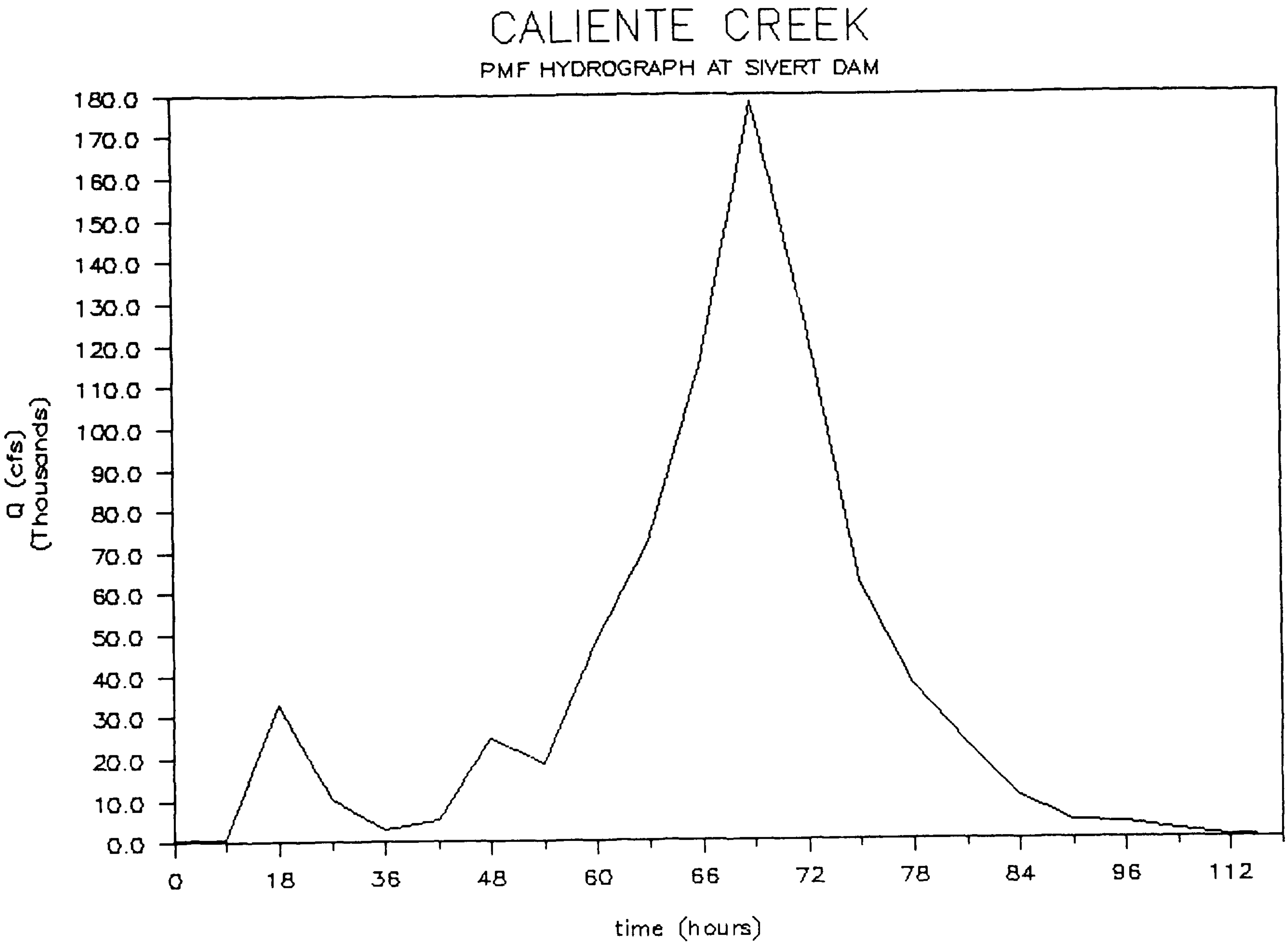


CALIENTE CREEK

100-YR HYDROGRAPH AT SIVERT DAM

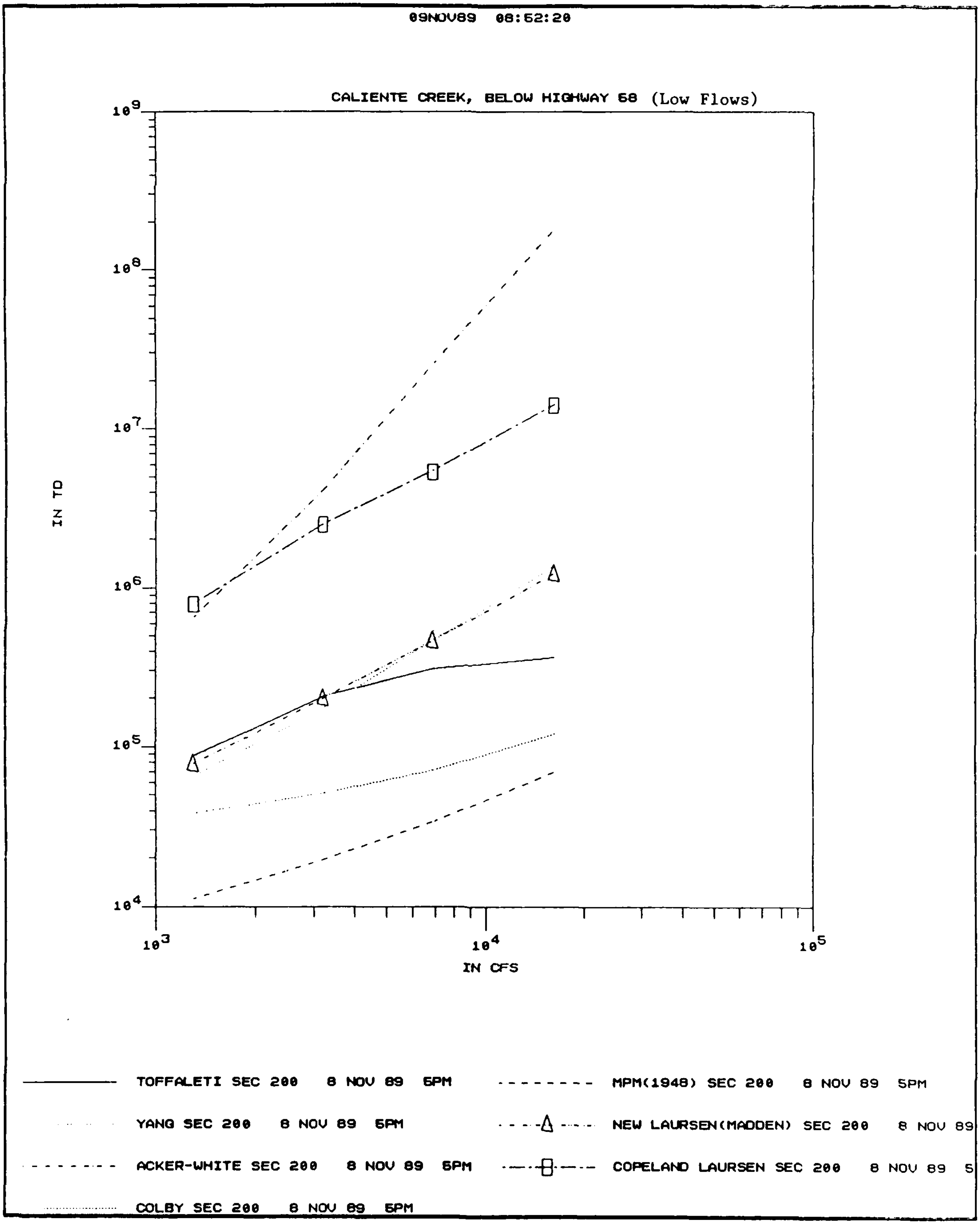


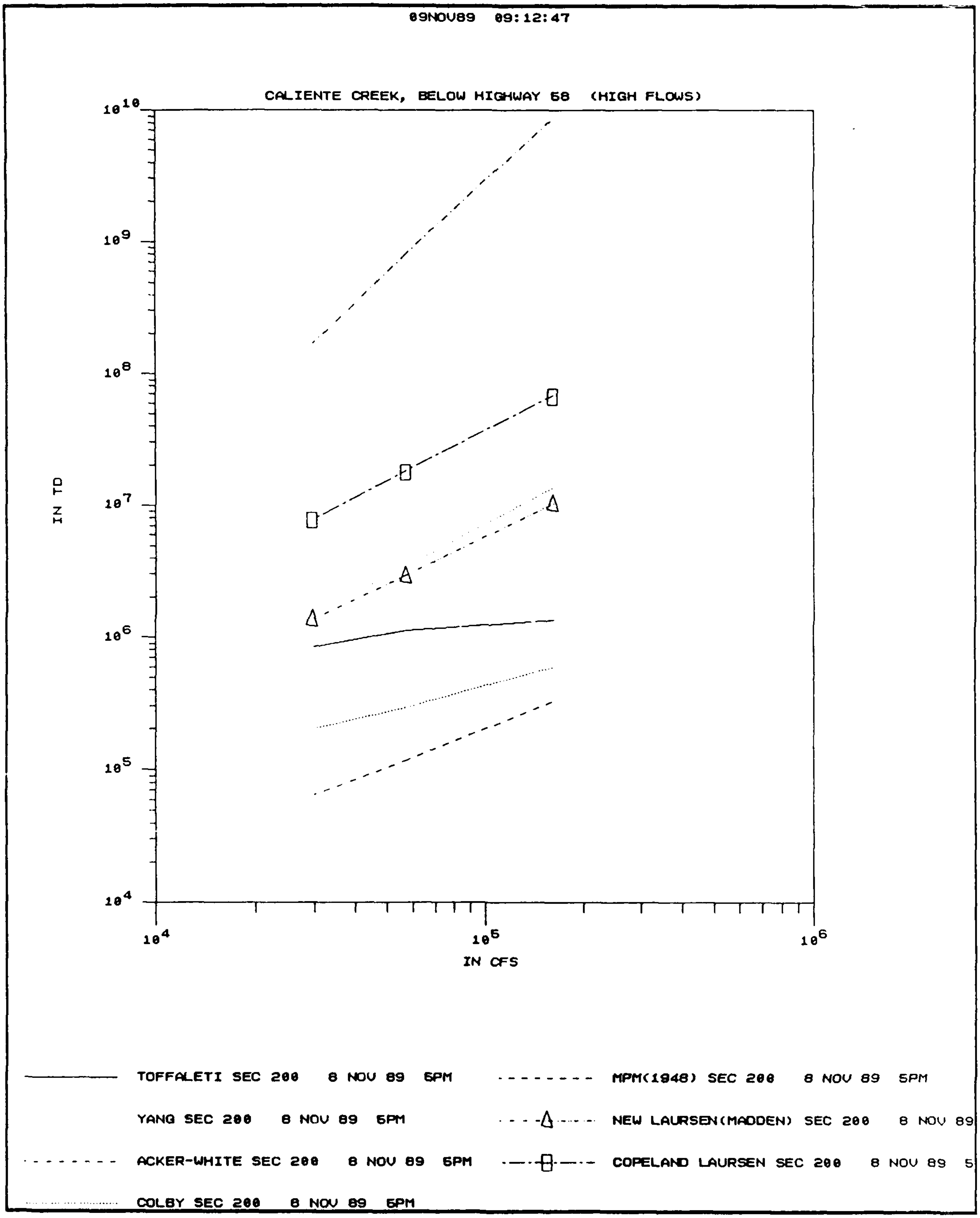

CALIENTE CREEK
SPF HYDROGRAPH AT SIVERT DAM
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Q (cfs)
(Thousands)
0
18
36
48
60
66
72
78
84
96
112
time (hours)


CALIENTE CREEK
PMF HYDROGRAPH AT SIVERT DAM
Q (cfs)
(Thousands)
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
18
36
48
60
66
72
78
84
96
112
time (hours)

APPENDIX D

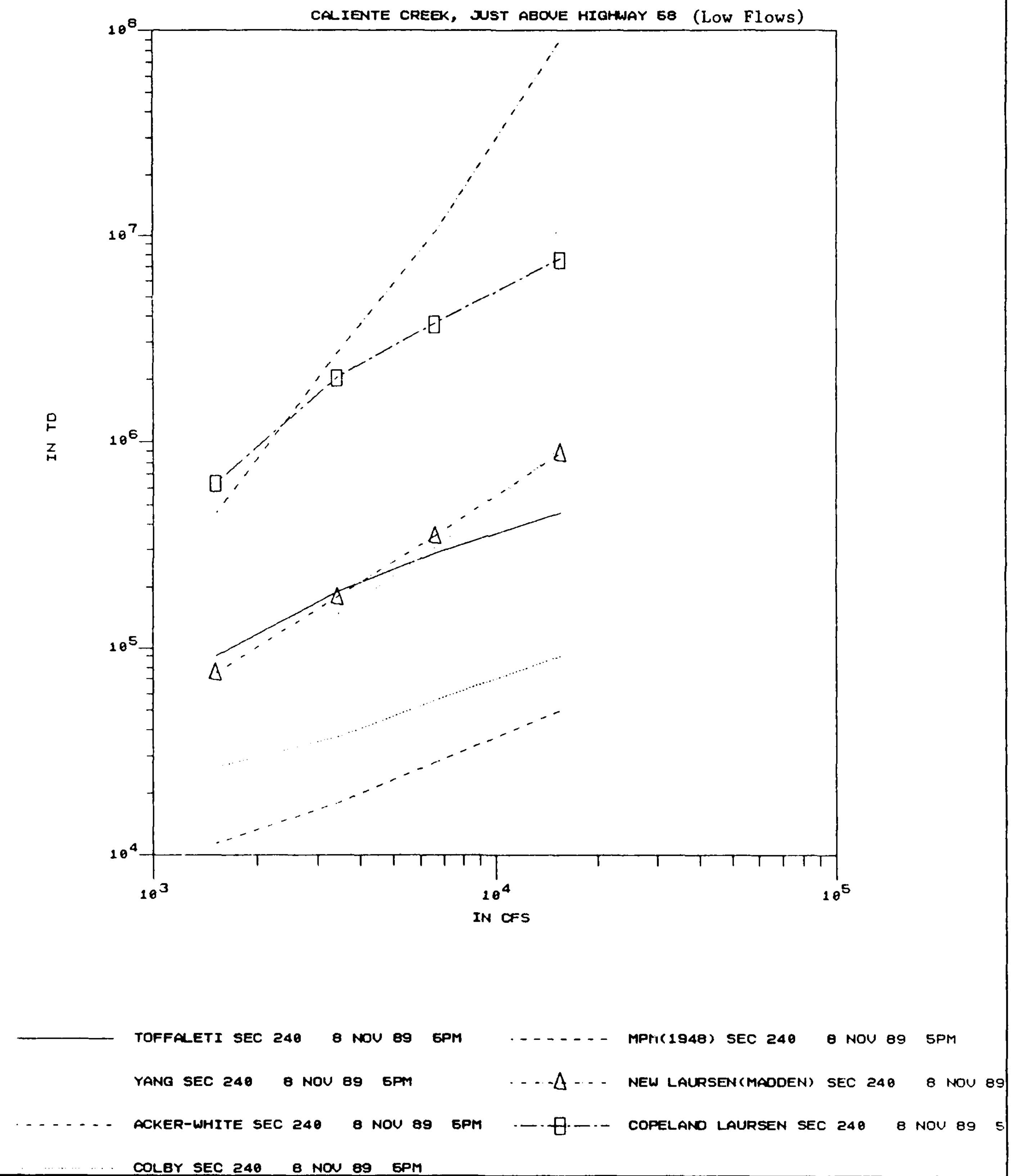
Sediment-Discharge Rating Curves

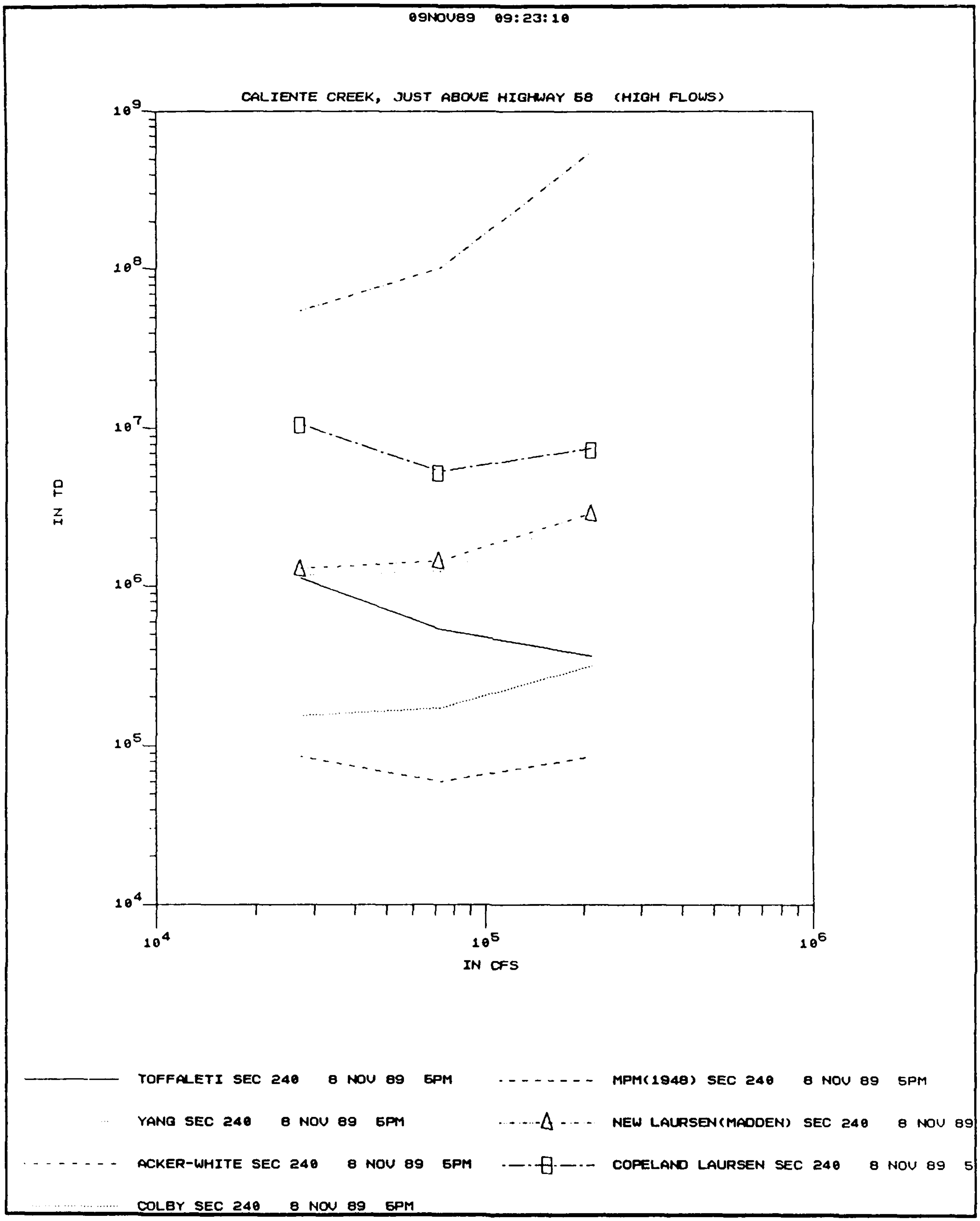

09NOV89 08:52:20
CALIENTE CREEK, BELOW HIGHWAY 58 (Low Flows)
10^9
10^8
10^7
10^6
10^5
10^4
IN TD
10^3
10^4
10^5
IN CFS
TOFFALETI SEC 200 8 NOV 89 5PM
MPM(1948) SEC 200 8 NOV 89 5PM
YANG SEC 200 8 NOV 89 5PM
NEW LAURSEN(MADDEN) SEC 200 8 NOV 89
ACKER-WHITE SEC 200 8 NOV 89 5PM
COPELAND LAURSEN SEC 200 8 NOV 89 5
COLBY SEC 200 8 NOV 89 5PM



09NOV89 09:12:47
CALIENTE CREEK, BELOW HIGHWAY 58 (HIGH FLOWS)
IN TD
IN CFS
TOFFALETI SEC 200 8 NOV 89 6PM
YANG SEC 200 8 NOV 89 6PM
ACKER-WHITE SEC 200 8 NOV 89 6PM
COLBY SEC 200 8 NOV 89 6PM
MPM(1948) SEC 200 8 NOV 89 6PM
NEW LAURSEN(MADDEN) SEC 200 8 NOV 89
COPELAND LAURSEN SEC 200 8 NOV 89 5

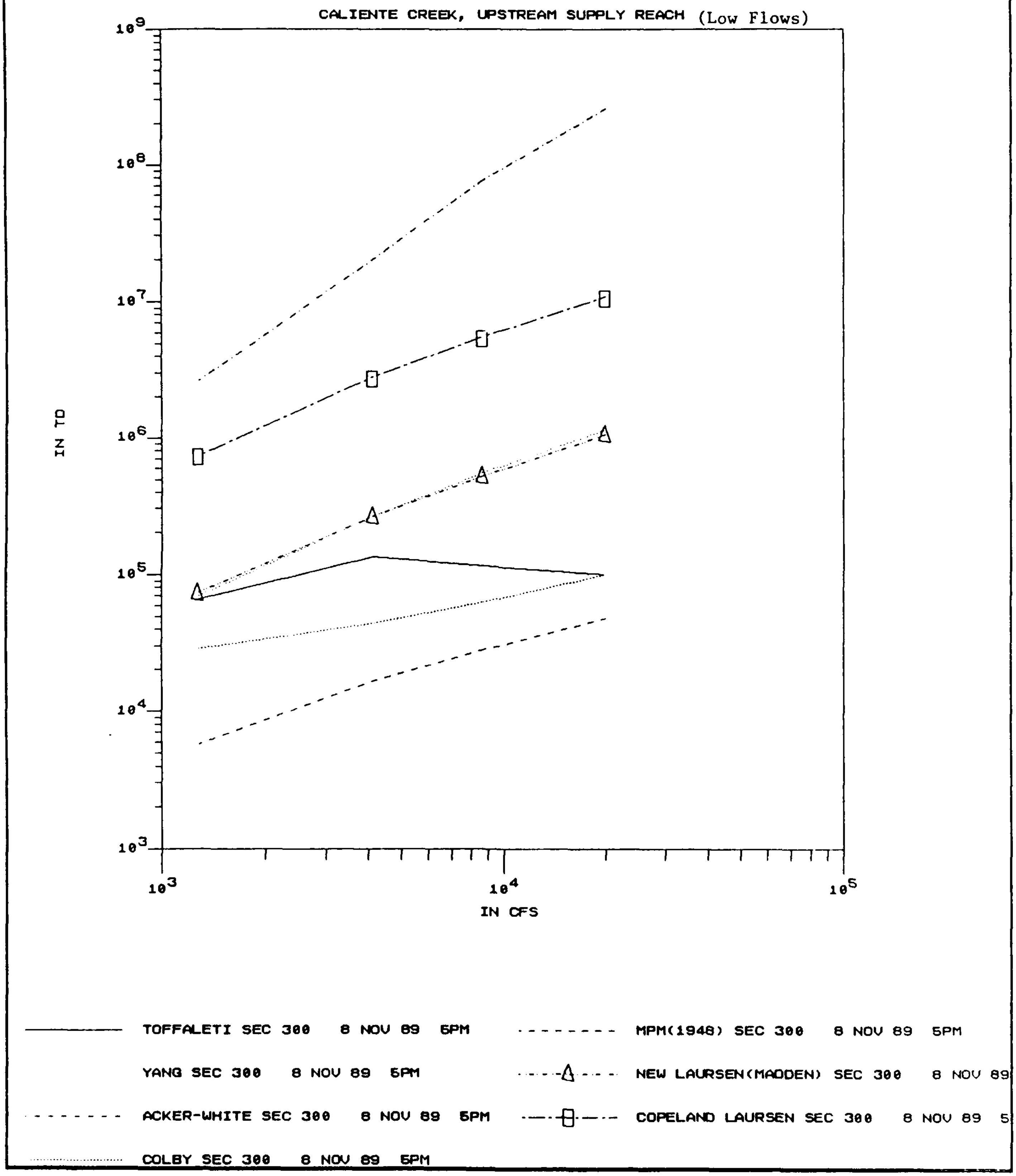
09NOV89 08:57:38

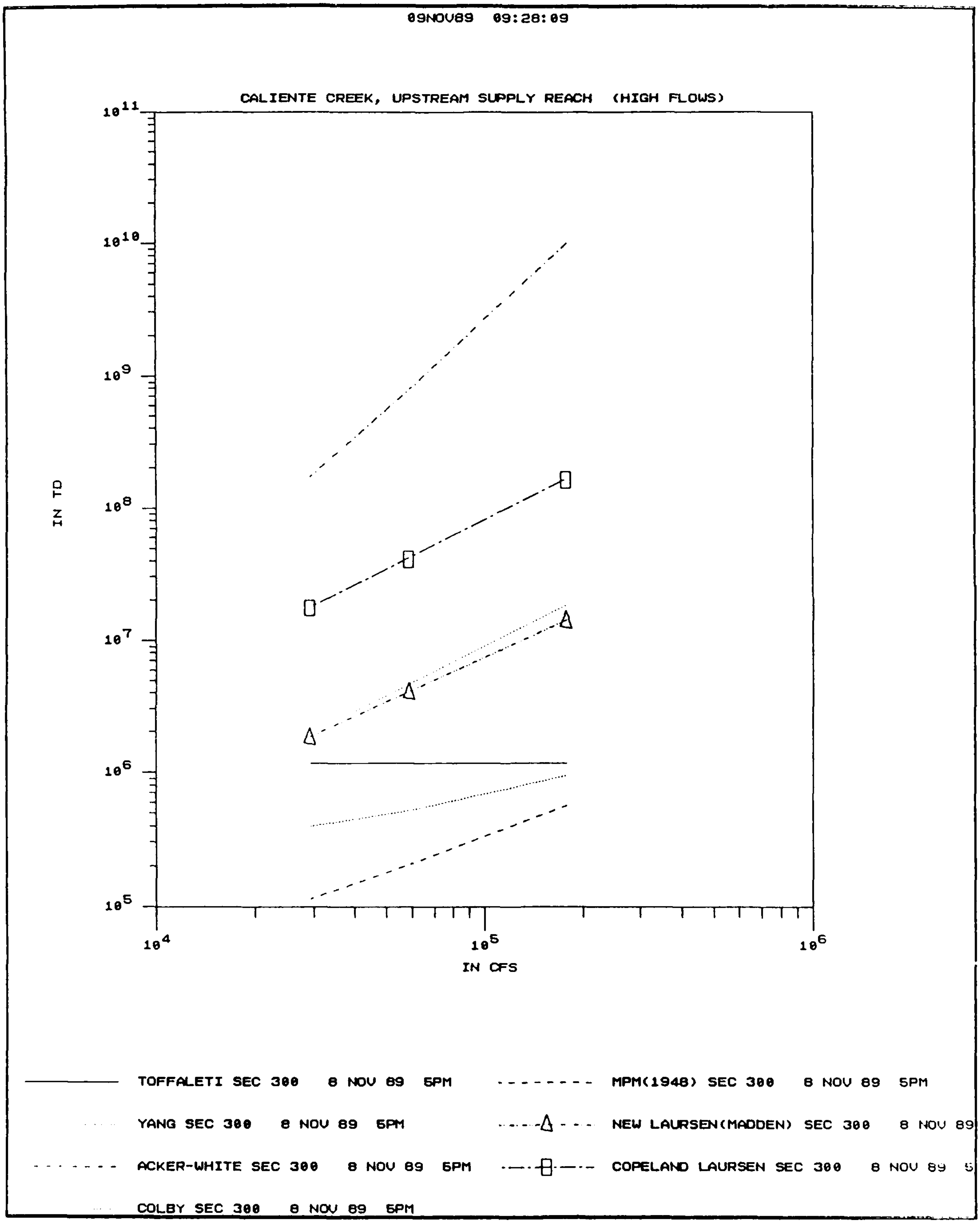




09NOV89 09:23:10
CALIENTE CREEK, JUST ABOVE HIGHWAY 58 (HIGH FLOWS)
IN TD
IN CFS
TOFFALETI SEC 240 8 NOV 89 5PM
YANG SEC 240 8 NOV 89 5PM
ACKER-WHITE SEC 240 8 NOV 89 5PM
COLBY SEC 240 8 NOV 89 5PM
MPM(1948) SEC 240 8 NOV 89 5PM
NEW LAURSEN(MADDEN) SEC 240 8 NOV 89
COPELAND LAURSEN SEC 240 8 NOV 89 5

09NOV89 09:07:15




09NOV89 09:28:09
CALIENTE CREEK, UPSTREAM SUPPLY REACH (HIGH FLOWS)
IN TD
IN CFS
TOFFALETI SEC 300 8 NOV 89 5PM
YANG SEC 300 8 NOV 89 5PM
ACKER-WHITE SEC 300 8 NOV 89 5PM
COLBY SEC 300 8 NOV 89 5PM
MPM(1948) SEC 300 8 NOV 89 5PM
NEW LAURSEN(MADDEN) SEC 300 8 NOV 89
COPELAND LAURSEN SEC 300 8 NOV 89 5

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FINAL REPORT

12. PERSONAL AUTHOR(S)
Dr. Robert C. MacArthur

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
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16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Alluvial Fans; Sediment Production; Sediment Yield; Transport Capacity; Geomorphology; Single Event Analyses; Episodic Flows, Average Annual Sediment Yield, (continued)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report summarizes the procedures used for computing the basinwide annual yields and single event sediment production for ephemeral channels located on an incised alluvial fan in Central California. Unique geomorphic characteristics of the basin and alluvial fan are discussed in light of data and analytical methods necessary to compute sediment delivery and yield at a proposed damsite.

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18. SUBJECT TERMS (Continued)

Flow Duration and Regional Methods.