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SUSITNA HYDROELECTRIC PROJECT

HYDRAULIC AND ICE STUDIES

MARCH 1982

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ACRES

ALASKA POWER AUTHORITY

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SUSITNA HYDROELECTRIC PROJECT

TASK 3 - HYDROLOGY

HYDRAULIC AND ICE STUDIES

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1 - INTRODUCTION

1.1 - Objectives

The objective of this task was to study the Susitna River reach below the proposed dams to establish the natural streamflow regime and predict post-project changes. It was decided that the best way to this was to mathematically model the river reach below the proposed damsites. With a model that is calibrated and verified to mathematically interpret river hydraulics, specific river reaches can be investigated and results delivered in a timely manner to interested parties. The Corps of Engineers HEC-2 model has been used for this purpose. The model was calibrated under pre-project flow conditions and is capable of simulating river hydraulics under proposed post-project flows. Model results include water surface elevations and hydraulic data which are used for several companion studies such as:

- Systems Operations Studies
- Ice Cover Process Model
- River Morphology Studies
- Flood Studies
- Fisheries Studies
- Vegetation Studies
- Navigation Studies

1.2 - Report Contents

This report includes a summary in Section 2 of the analyses performed and results obtained in both the hydraulic and the ice studies. The scope of work of each portion is discussed in Section 3, along with the type of field data collected for each. Section 4 details the hydraulic analyses, describing the river system and the study reaches, the study approach used, the method for selecting Manning's n values, and the computation results. The summary printout tables give values for all the pertinent hydraulic parameters at all surveyed river cross-sections. The ice processes analyses are described in Section 5, and Section 6 gives the references used for the analysis and report. Attachments provide stage-discharge rating curves at all the water level observation sites (Attachment A) and cross-section plots for both study reaches with computed water surface elevations marked (Attachments B and C).

2 - SUMMARY

2.1 - Open Water Studies

The open water hydraulic analysis was performed with the HEC-2 Water Surface Profile computer model of the U.S. Army Corps of Engineers. Two river reaches were analyzed: (1) the Upper Susitna Study Reach from Deadman Creek down to Devil Creek, containing the Watana damsite; and (2) the Middle Susitna Study Reach from the outlet of Devil Canyon down to the Susitna-Chulitna confluence.

Four river discharges were used to calibrate the model for each study reach, and two additional flows were used to verify the calibration. The upper reach flows ranged from 8100 to 46,400 cfs (at the Watana streamgage). The range of flow used for computations on the Middle Susitna was from 9700 to 52,000 cfs (observed at the Gold Creek gage). Channel flows upstream and downstream of the gaging sites were adjusted up or down based on drainage area. The upper limit in each case closely coincided with the mean annual peak flow. This level, represented by bank-full stage, was the upper boundary on the scope of the present study.

The Susitna River is heavily laden with sediment, and both study reaches have numerous islands, gravel bars, and split-channel conditions . This is more prevalent in the Middle Susitna reach, and two flow regimes were analyzed there - one for low flows and one for high flows. The low-flow regime was characterized by restriction of flow from certain side channels which were blocked off at their upstream ends by a gravel "berm". The cutoff flow between high and low was estimated to be 20,000 cfs.

The computer program uses the Manning equation for its computations. The Manning n, or roughness coefficient, was specified as an average value for the channel portion of each cross-section. Initial values were estimated by preliminary hydraulic calculations with observed flow conditions and adjusted based on local bed material, vegetation, channel geometry, and flow level. The range in coefficients for the "base" flows (opening parenthesis) (8,100 cfs in the upper reach and 9700 cfs in the middle Susitna) was from 0.040 to 0.060 and from 0.030 to 0.055 in the upper and middle reaches, respectively. N values at all sections were reduced for higher flows, in accordance with the observed trend.

The final results from the water surface computations are presented in two forms: (1) the summary printout tables in Section 4, and (2) marked water surface elevations on plots of each cross-section in Attachments B and C to the report.

Some prudence is required in interpreting the output results from the analysis. Uncertainties in field measurements of hydrographic and topographic parameters and limitations of the HEC-2 model itself limit the precision of the final answers. The computed water surface elevations, however, are expected to be accurate to within 0.5 foot of the true elevations in most cases and to within 1.0 foot at almost every cross-section (except as discussed below).

Potential problem areas where observed and computed water levels may not agree closely are at points widely separated from the observation sites and also at islands, sloughs, side channels, and river bends. The model, of necessity, assumes a uniform water surface all the way across the cross-section, a situation not always present under natural conditions. Further refinement of the model is possible, concentrating primarily on definition of water surface elevations in side channel areas. Additional field surveys would be necessary to determine the channel goemetry at the upper ends of the cut-off channels and to more closely identify the discharge or stage at which various channels of importance "open up" to main-channel flow.

2.2 - Ice Studies

The purpose of the ice studies was to simulate the river ice regime under natural and post-project conditions in the reach between Talkeetna and the proposed damsites. Acres' in-house computer simulation models were used in the studies. Results of the open water analyses, as described in Section 2.1, and field ice observation data (see "Ice Observations", R&M, 1981b) were input to the model for calibration purposes.

The analyses indicate that ice regime in the river reach above Talkeetna will be significantly altered after the projects are commissioned. When Watana development is on-line, it is expected that the ice cover formation above Talkeetna will be delayed by 2 to 3 weeks to the middle of December and will progress about 15 miles (to about LRX-15) by the end of January. It is unlikely that any significant ice cover will exist above this section under average weather conditions.

With both Watana and Devil Canyon Dams commissioned, it appears that little ice cover will form above Talkeetna except close to the Chulitna confluence in late January. Ice formation in the reservoirs will commence around the middle of October, as under natural conditions in the river, and reach a stable level by the end of January.

It has not been possible to estimate, with any accuracy, the post-project ice regime in the river below the Talkeetna confluence. Field observations of the freeze-up phenomena in 1980 indicate that about 80 percent of the frazil ice below the confluence is generated by the Susitna River. With both the projects in place, there is likely to be a significant drop in the amount of frazil ice generated in the Susitna River above the confluence, thus delaying the ice cover formation in the lower river.

Under natural conditions, the river ice breakup starts around mid-May with increases in air temperature and river discharge. Since the Susitna is a south-flowing river, breakup usually starts close to the river mouth and works its way up the river, thus reducing serious ice jamming in the river. The breakup is generally a mechanical process involving largely the physical movement of ice downstream with increased discharge. Partial thermal decay accompanies this process to accelerate breakup. However, under post-project conditions, the in-place thermal decay of the ice cover, at least above Talkeetna, is expected by the end of March. The effect of warmer waters from the reservoirs, coupled with higher air temperatures, would cause almost in-place melting of ice in the mainstem a few weeks before the natural breakup in the Talkeetna, the Chulitna, and the lower tributaries. More detailed river observation, cross-section surveys, and data collection in the lower river will be needed to model the lower river ice processes and to assess the effects of the projects in the reach.

3 - SCOPE OF STUDY

This report presents the results of hydraulic and ice studies performed on two reaches of the Susitna River. The two study reaches were (1) the 25-mile reach between Deadman Creek and Devil Creek, 90 percent of which is downstream of the proposed Watana Damsite, and (2) the 52-mile reach between Devil Canyon and Talkeetna, all of which is below the proposed Devil Canyon Damsite. They are referred to in this report as (1) the Upper Susitna Study Reach (or Upper Susitna), and (2) the Middle Susitna Study Reach (or Middle Susitna), respectively ("Lower Susitna" generally refers to the river downstream of Talkeetna). Analysis consisted essentially of collecting field data, of operating a computer water surface profile model, and of operating a computer ice cover process model.

3.1 - Related Field Data Collection

Field data required for hydraulic analyses were topographic and hydrographic information at river cross-sections, water-surface elevations at selected sites for a range of discharges, and qualitative information on vegetation and bed material. The ice analyses utilized the cross-section data and also required air temperature and water temperature data; timing, location, and extent of ice accumulations and bridging during freezeup and breakup; and site-specific hydraulic data from freezeup and breakup. Site-specific hydraulic data consisted of open-water width, surface velocity, water surface elevation, rate of rise of the water surface, and ice pan thickness.

Cross-section surveys on the Upper Susitna were made in March 1981 by drilling holes through the ice cover. The lower reach (i.e. Middle Susitna) was surveyed prior to and during freezeup in the fall of 1980. More detailed description of the field methods and the summarized survey data are presented in the report, "Hydrographic Surveys" (R&M, 1981a). Water elevation data were collected at crest-stage recorder sites periodically through the study period. The ice observations from fall 1980, winter 1980-81, and spring 1981 are contained in the report, "Ice Observations" (R&M, 1981b). Subsequent ice observations are to be reported in an addendum to the 1981 report.

3.2 - Open Water Analyses

The hydraulic analyses were done using the HEC-2 water surface profile model developed by the Hydrologic Engineering Center of the U.S. Army Corps of Enigneers. Model calibration and verification were made with data collected at crest-stage and continuous recorders located in the study reaches. Three crest-stage recorders and a continuous streamgage were established on the Upper Susitna. Six crest gages were installed on the Middle Susitna, and the USGS had a continuous recorder at Gold Creek. Stage levels were measured at each site in the two reaches for several river discharges. Four flows were used to calibrate the models, and two additional ones were used to verify it, making a total of six different flows for each study reach.

The scope of the study was limited to flows at or below bank-full conditions. Thus, no overbank floods were analyzed. Flood frequency analysis (R&M, 1981d) indicated that the mean annual flood for Gold Creek was 49,500 cfs. Observed peaks in the summers of 1980 and 1981 were just slightly higher than the mean annual peak flow. Both happened to roughly coincide with top-of-bank flows., so the this flow condition was well defined.

Two versions of the model were necessary to adequately describe the river behavior in the Middle Susitna reach. This was because two regimes were apparent, a low-flow regime and a high-flow regime. Examination of aerial photos and field conditions revealed a number of side channels and sloughs that received substantial river flow at high discharges but negligible flow below a certain threshold value. Thus, a high-flow version was set up wherein river flow was permitted in these channels, and another, low-flow version was set up assuming no flow there. The threshold was estimated at 20,000 cfs for the Middle Susitna.

3.3 - Ice Process Analyses

Acres' in-house computer models were used to analyze the ice regime of the two river reaches above Talkeetna up to the damsites under natural and post-project conditions using field data collected during the river freezeup/breakup in 1980-81 and open water calculations as discussed in Section 3.2.

Estimates of ice cover formation and development in the reservoirs were made using standard heat balance equations. It has not been possible to analyze ice regime below the Talkeetna confluence under natural or post-project conditions due to lack of field data and river cross sections. However, an attempt has been made to estimate qualitatively the effect of the proposed projects on the ice regime of the river in the lower reach. Salient details of the analyses are presented in Section 5.

4 - HYDRAULIC ANALYSES

The hydraulic analyses involved assessment of river hydraulic data collected during the study period and computation of water surface profiles in two study reaches for a range of discharges. This portion of the report describes the analyses performed and the results obtained. It is organized to first give a brief description of the Susitna River system and the two study reaches, followed by discussion of the study approach and detailed information on development of the roughness coefficients used in the computer model. Finally, Section 4.4 discusses the results.

4.1 - Description of River System

4.1.1 General

The Susitna River drainage basin is the sixth largest system in Alaska. From the terminus of Susitna Glacier to its mouth in Cook Inlet, the Susitna River flows 320 miles and drains 19,600 square miles. Major tributaries include the Talkeetna, Chulitna, and Yentna Rivers. Plate 1 in the back folder shows the river location and regional topography for the lower 230 miles. River cross-section locations are shown in greater detail on Figure 4.1.

Tributaries in the northern portions of the basin originate in the glaciers of the eastern Alaska Range. The East and West Forks of the Susitna and the Maclaren River join the mainstem Susitna River above river mile 260 and contribute roughly 38 percent of the average annual streamflow at Gold Creek.

Streamflow is characterized by moderate to high flows between May and September and low flows from October to April. High summer discharges result from snowmelt, rainfall, and glacial melt. Winter flows consist almost entirely of groundwater inflow. Freeze-up starts in the higher regions in early October, and most of the river is ice-free by early to mid-May.

Below the glaciers, the braided channel traverses a high plateau consisting of aggraded alluvial sediment and then meanders south for several miles to the Oshetna River confluence. There it takes a sharp turn west and flows though a steeply cut, degrading channel down to Gold Creek. The Watana and Devil Canyon damsites are both located in this latter reach. Below Gold Creek, the river follows a fairly straight course that alternates between single and split channels until joined by the Chulitna River just above Talkeetna. Joined shortly thereafter by the

Talkeetna River, the Lower Susitna flows on a lower gradient than the upper river. It flows primarily through widely braided channels over its last 97 miles to Cook Inlet.

Vegetation in the basin is predominately muskeg in poorly-drained valley bottom soils, white spruce and grasses in well-drained upland soils, and alpine tundra in steep, rocky soils above timberline.

4.1.2 Upper Susitna Study Reach

The reach of river from Deadman Creek, 2 miles above the Watana Damsite, to Devil Creek, 23 miles below the damsite, is characterized by a narrow, steep-walled canyon and a moderately steep overall river gradient (12.1 feet/mile). Figure 4.2 shows the profile of the thalweg through the study reach, and Table 4.1 gives the river mile and thalweg elevation for each cross-section. There are generally narrow floodplains and a few vegetated islands within the reach. The river width varies from 200 to 300 feet at the narrowest to 1000 to 2000 feet at several islands.

One particularly steep local reach just above the damsite has a channel gradient of 48 feet per mile over its half-mile length. This reach, between cross-sections 103 and 104, is quite broad, in addition to being steep. The depth of flow is comparatively shallow, and standing waves are common in the vicinity. Flow is thus close to critical much of the time.

4.1.3 Middle Susitna Study Reach

After emerging from Devil Canyon one mile below the Devil Canyon Damsite, the Susitna River broadens somewhat but is still essentially confined to a canyon as far down as Gold Creek, 13.5 miles downstream. Below Gold Creek, the valley widens, bounded still between high hills on each side. River width is less than 300 feet in some sections at the upper end, and it expands to almost 3000 feet wide near the confluence with the Chulitna.

Quite a number of islands and gravel bars exist throughout the reach. Flow alternates between a single channel and split channels through its 52-mile extent. The bed profile of the entire reach is plotted in Figure 4.3, with the pertinent data tabulated in Table 4.2.

A ten-mile river reach between Devil Creek and about a mile below the Devil Canyon damsite could not be surveyed due to steep gradients and significant rapids. During the winter of 1980-81, however, a longitudinal river survey through Devil Canyon from upstream of the damsite for a distance of 8400 feet was completed. Salient results of the survey have been incorporated in the analyses presented below.

4.2 - Approach to Open Water Analyses

The primary approach of the hydraulic analyses was to use the HEC-2 Water Surface Profiles computer model to compute water surface elevations and hydraulic parameters at numerous points of interest through a range of pre-project and expected post-project discharges. The HEC-2 computer model was developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC). The standard step method is used to compute water surface profiles, using the Bernoulli Theorem for total energy at a cross-section and the Manning equation for friction head loss between river cross-sections. The program is widely used in hydraulic engineering studies. A detailed description is not provided here. If desired, details of the program may be obtained from the program users manual. The program version of November 1976 (updated April 1980) was used for the current study.

Surveying of the river cross-sections comprised the major data-collection effort. The Upper Susitna Study Reach had 23 surveyed cross-sections over 25 miles. A total of 68 cross-sections was surveyed on the Middle Susitna Study Reach. As two of these were below the Susitna-Chulitna confluence and hence outside the scope of this analysis, only 66 cross-sections were used in the water surface profile computations.

Periodic measurements of water surface elevations were made at crest gage and streamgage sites. These data were used in the calibration and verification of the computer model for both study reaches.

The Manning roughness coefficient was an important input parameter to define at each river cross-section. Values used herein were selected based on observed hydraulic conditions (i.e. known water surface elevations at various discharges), and adjusted with consideration for bed material, vegetation, channel geometry, and other factors. An inverse relationship of "n" value with discharge was observed and incorporated into the modeling process. The procedure adopted is described in Section 4.3.

River lengths between cross-sections and general bank features were determined from aerial photographs and enlarged topographic maps. Maps at scales of 1" = 400' and 1" = 200' were used on the upper reach, which encompasses channel areas that will be inundated by the proposed reservoirs. Photos enlarged to a scale of 1" = 500' were used for the Middle Susitna.

The model was calibrated at four separate discharges for each study reach. These calibration flows ranged from 8,100 to 46,400 cfs at Watana for the upper reach and from 9,700 to 52,000 cfs at Gold Creek on the Middle Susitna. The model parameters were adjusted slightly as necessary to obtain agreement between the observed and computed stages within acceptable limits. The criterion for acceptability was deviation of not more than 0.5 feet. Agreement of the computed and observed water surface elevations to within this limit was sought and attained in most cases. The calibrated model was verified for each reach with two additional stream discharges.

Flows used in the computations were adjusted above and below the gage sites, based on drainage area, to account for tributary inflow. The flows used for each sub-reach are listed in Tables 4.3 and 4.4.

The HEC-2 program provides an excellent tool for computing water surface profiles in open-channel flow conditions. However, as does any model, it makes certain assumptions to facilitate calculation. In order to best interpret the results of the analysis, the assumptions and limitations should be understood. A few of these relevant to the current study reaches are briefly discussed below.

First, the program assumes a uniform, level water surface across a given cross-section. While this is necessary to perform the analysis within reasonable computation time and cost, it is not always a true condition in the river itself. Especially at river bends, there may be quite a disparity in water level from one side of the cross-section to the other. The difference depends on river width, velocity, and radius of bend. Also, in the case of multiple channels at a cross-section, each channel may realistically have a slightly different water surface elevation, as illustrated in Tables 4.5 and 4.6. The model, however, assumes it to be uniform across. Thus, care should be taken in interpreting the computed results in channel bends and and multiple channels.

Another concern in certain portions of both study reaches was occasional overbank areas that were at lower elevations than the bank or, in some cases, below the bed of the main channel itself. Many of these areas were not hydraulically connected to the channel at lower discharges, if at all, so they were not included in the flow computations. In such situations, "ground levees" were used on the appropriate bank. Ground levees are imaginary levees with their tops at ground level to confine the flow to the channel until the levee (bank) is overtopped. Once the bank is overtopped, however, the model assumes complete hydraulic connection of the low area with the channel. It was not always appropriate to permit full flow in all the lower areas, so in some cases the "levee" was left in place even at higher flow. Also, as noted above, some side channels were effectively blocked off at low flows by upstream "berms," which were overtopped at higher flows. Definition of this condition required the use of the two models for each study reach, one permitting flow in the side channels and the other restricting it to the main channel.

One final point regards the velocity computed by the model at each cross-section. This value is the mean flow velocity, averaged across the entire flow area. Field observations would most likely indicate faster flow in the center of the channel at the water surface and slower velocities at all the boundaries, but the mean is useful as an indicator of magnitude and for comparisons between cross-sections.

Analysis results include water surface elevations and other hydraulic parameters at each of the cross-sections for both study reaches. No bridge or culvert analyses were required since the only bridge in either of the study reaches, the Alaska Railroad bridge at Gold Creek, was far above the bank-full level.

4.3 - Development of Roughness Coefficients

The computer program HEC-2 uses the Standard Step Method described by Chow (1959) to compute the water surface profile of a river where the discharge, geometry, and channel roughness are known or can be assumed. The model uses Bernoulli's Theorem for the total energy at each cross-section and the Manning formula for the friction head loss between cross-sections.

Discharges can be defined fairly well either by calculation or by direct measurement. Cross-section geometry and distances between cross-sections can similarly be determined quite closely by field surveys and measurements on aerial photos. However, estimation of channel roughness coefficients (Manning's "n") cannot be done by direct measurement. Engineering judgment must be applied and estimates made based on past experience.

Manning's roughness coefficient varies with type and amount of vegetation encountered by the flow, relative size of bed material, channel shape, degree of meandering, and river stage, so the HEC-2 program permits definition of the "n" values in any of three different manners. Each of these was used at one time or another in the Susitna Project hydraulic analysis; their use is described in the following three sections.

The Middle Susitna study reach had more data readily available at the start of the hydraulic analysis. Thus, it was selected as the initial reach. Roughness coefficients were developed for the Middle Susitna reach, then experience from that analysis was used to estimate the n values in the Upper Susitna reach.

(a) Variation of Manning's n with Stage

When preliminary hydraulic computations were performed on several reaches of the Susitna River (Giessel, 1981), substantial variation of n value with stage (or discharge) was indicated. Over a range in flow from 3,000 cubic feet per second (cfs) up to 34,000 cfs in the vicinity of Gold Creek, Manning's n varied from 0.090 down to 0.035. The n is higher at low flows because the water depth decreases relative to the size of the bed material, increasing the effects of channel roughness.

The HEC-2 program allows input of n-vs.-stage data through the use of NV data input cards (HEC, 1976), in which a rating table is specified and effective roughness coefficients given for the corresponding water surface elevations at each cross-section. However, the results from HEC-2 were to be used to help verify the ICESIM ice simulation model, which does not have provisions for directly varying Manning's n with stage. Consequently, changes in n values with stage had to be made either by an adjustment coefficient or by directly changing n values at different flow stages, although several runs of HEC-2 were made initially to assess the potential of using the NV cards. Problems were encountered at several cross-sections with the assumed water surface elevations falling outside the range of elevations on the NV cards. In view of the need to have comparable data bases for both HEC-2 and ICESIM, the use of NV cards was not pursued further. However, the analysis of n-vs.-stage is pertinent to the final Manning n values, and is presented below.

N Value Determination

The first step in the definition of n values was calculation of hydraulic parameters at certain cross-sections where water-surface elevations (W.S.E.) had been observed. The hydraulic parameters of area, wetted perimeter, and hydraulic radius were computed from the surveyed cross-section geometry and known W.S.E. at each of the water-observation sites listed in Table 4.7 (the sites for the Upper Susitna are listed in Table 4.8). A program prepared for the HP-25 hand-held calculator (Croley, 1977) was used for the computations. Mean daily streamflows at Gold Creek for the dates of observation were obtained from the USGS rating table or from USGS records and assumed roughly equal to the flow at each of the crest gage sites (some error was expected with this assumption, but analysis indicated it would probably be only about 6% high at the upper end - Portage Creek - and about 3% low at the Susitna-Chulitna confluence). The friction slope at the cross-section was assumed approximately equal to the average bed slope over the reach from the next-upstream cross-section to the next-downstream cross-section (this assumption is adequate as a first approximation but it is less valid at high flows, with the friction slope increasing rapidly. Also, some problems were believed introduced by the presence of adverse bed slopes at a few of the cross-sections). Then, using an inverted form of the Manning equation:

$$n = \frac{1.49\ AR^{2/3}\ S^{\frac{1}{2}}}{Q},$$

where:
- n = Manning roughness coefficient,
- A = cross-sectional area,
- R = hudraulic radius,
- S = friction slope, and
- Q = discharge,

n values were computed for each flow and corresponding observed W.S.E. The results for a sample cross-section (LRX-35) are shown in Table 4.9. The computed n values were plotted against corresponding flows for comparison. Very consistent variation was noted for four of the six cross-sections plotted, which can be seen in Figure 4.4. LRX-9 had higher computed n values than did the others. LRX-4 has several islands and channels, and consequently probably has a poorly-defined stage-discharge relationship, especially for stages observed on the far left bank (where the crest gage site is located). For the four consistent plots, however, an "average" curve was drawn in, and a preliminary relationship of n vs. Q established.

A comparison was then made at the remaining cross-sections, where only limited water surface data were available. All cross-sections had at least one observed water surface elevation, which was on the date they were surveyed. Elevation differences between adjacent cross-sections were noted if they were surveyed on the same day or at nearly the same flow. These differences were compared with elevation differences obtained with a slope-times-distance computation using average bed slope and channel reach length, and the two differences were averaged. This gave a method for "stepping" the estimated water surface elevation from the known points at the crest gage sites to each of the other cross-sections. These "constant differences" were then used to obtain preliminary water surface elevations to relate to flow and n value. Five flows were selected from Figure 4.4, from 3000 cfs to 50,000 cfs with corresponding n's ranging from .093 to .028 determined from the "average" curve. These five n values and stages were then used as input to the HEC-2 program, and the model was operated for the whole reach.

(b) Variation of Manning's n with Horizontal Stations

The NH card format in the HEC-2 program input permits identification of n value changes between any stations in the cross-section. The program then computes the conveyance of each wetted subsection, based on the subsection's flow area, wetted perimeter, and specified roughness. As many as 20 different subsections may be identified for designation of n value at each cross-section.

Basic criteria for adoption of the n values consisted of two different methods, one for the channel portion and one for the overbank portion of the cross-section. Coefficients for the channel portions of the cross-sections were determined by comparison with values obtained in the n-versus-stage analysis. The value printed out in the HEC-2 summary for each cross-section was used as a guide. Again, weight was given to variation of effective roughness with stage, so high values were assigned to a short portion of the cross-section at the bottom of the channel, intermediate values to the major extent of the channel just above that, and relatively low values to the top portions of the channel on each side. The intent was that the effective n for the cross-section would be high at low flows and would decrease as the flow increased, as had been observed previously.

The criteria developed for the overbank portions of the cross-sections are shown in Table 4.10. These were patterned after a method presented in Chow (1959, p. 106).

The roughness coefficients were thus assigned to the channel portions of the cross-sections. After trying the new values on a short reach, the whole study reach was attempted. The discharge used for the early calibration runs was 9700 cfs, considerably less than bankfull, so little attention was given to careful definition of the overbank values at this point. A nominal value of 0.080 was arbitrarily assigned to all the areas outside the riverbanks.

Problems encountered with the horizontal definition of the n values were essentially related to the ability to accurately define the roughness conditions in the channel portion. Having to specify three widely-varied values within the channel at each cross-section was somewhat time-consuming. In addition, the "effective" n value obtained could not be checked until the program had been run (since it depended on the relative extent of each roughness inundated). Even then, there did not always appear to be a correlation between the numbers input and the value computed for the effective channel n. Also, the level of detail necessary to define the various n's within the cross-section geometry did not seem to be justified. As has been mentioned, special care was not taken with the overbank areas, but it was taken with the channel areas in assigning n values. Care also had to be given to making sure the stationing was changed accordingly on the NH cards whenever it was changed on the X1 or GR cards (e.g. if bank definitions were changed or if the cross-section shape were modified). In essence, since an option existed that permitted simpler specification of the channel n values, and since this option appeared to demonstrate better control over the effective channel n values obtained, this option was pursued. This is described in the following section.

(c) Definition of Manning's n by Cross-Section

The final method selected for specifying n values was the simplest, that of entering the values on the NC cards alone. This consisted of defining three numbers at each cross-section: one for the left overbank area, one for the right overbank, and one for the channel portion. The program considers the "channel" to be all that area between the defined left and right banks, so all flow within these limits will use the channel n for its computations. If the locations of the banks are changed for some reason, the n value corresponding to the channel will still be used for the channel portion (i.e. between the two new bank locations). Also, if subsequent runs are desired to have a uniform percentage increase or decrease in all the channel roughness coefficients, this is easily accomplished by changing a single input parameter.

Determination of n Values

The first cut at the channel n values was based on the results from the n-versus-stage analyses. For the first trial run at the 9,700-cfs flow level, an intermediate value of n = .050 was used for the whole study reach. This caused the computed water surface elevations to significantly rise above earlier runs and also above observed levels. Subsequent runs were tried with lower n values to observe the effect on the computed elevations. An improvement was noted, and the model's sensitivity to n value changes was roughly gaged.

One noteworthy exception to the NC-card designation of n values was at cross-section LRX-25. This section is relatively wide, about 2,500 feet, and has as many as ten different flow channels at certain flow levels. The primary channels are the ones on the far left and the far right of the cross-section, with little effective flow in-between. The nature of the HEC-2 program is such that all the channels are filled up with flow from the bottom. Channels outside the main channel can be excluded by specifiying artificial encroachments, but this cannot easily be done for ineffective flow areas within the main channel. The technique used was assignment of a very high n value to these areas, which permitted water there but allowed for almost no conveyance. This designation was made by using NH cards at LRX-25. All other cross-sections used the NC card format.

Adjustments to n Values

Refinements were made to the initial estimates of Manning's n's based on several criteria. These criteria included bed material size, river sinuosity, presence of and type of vegetation, existence of multiple channels, and level of discharge.

The bed material size was evaluated systematically at most of the river cross-sections by the "Grid-by-Number" technique described by Kellerhals and Bray (1971). Preliminary bed material distributions were obtained in the analysis, and are presented in

Table 4.11. The complete application and results from the analysis are described in "Hydrographic Surveys" (R&M, 1981a). Limerinos (1970) investigated the existence of a relationship between Manning's n and bed material particle size in several rivers of varied size in California. A definite correlation was observed in the study, relating weighted intermediate particle diameter (d_w) and hydraulic radius (R) to Mannings's n by the equation

$$n = \frac{.0926R^{1/6}}{.90 + 2.0 \log (R/d_w)}$$

To get an idea of the magnitude of n to be expected on the Middle Susitna study reach, the Limerinos formula was applied to the bed particle sizes from Table 4.11. Hydraulic radii were calculated from cross-section data using observed water surface elevations at crest gage sites. Results are shown in Table 4.12. Items worthy of note are that the computed n values are quite insensitive to changes in flow and also that the values are all consistently in the .030 - .040 range. These numbers were used as a guide in judging the "proper" value for Manning's n over the reach. It should be noted that these figures could probably be considered to be at the low-end of the roughness coefficient range since the analysis essentially assumed no effects from other factors, which would all tend to increase the apparent roughness.

Several other factors were considered in making assignments of n value for the various sub-reaches in the study reach. The sinuosity of the river in the local area, the presence and type of vegetation in the flow area, and the existence of islands and multiple channels at or between cross-sections all contributed to the n value determinations. Generally, existence of these conditions led to an n value increase above the base value in a sub-reach.

A final factor which ultimately had a large apparent effect on the channel roughness in a reach or at a cross-section was the discharge level. As was indicated somewhat in Table 4.12, there is a decrease in n value as the flow increases. This trend had been generally observed in the original bed roughness study (Limerinos, 1970). It is also documented in a British report on several streams of various sizes (Sargent, 1980). At one site in Sargent's study, the computed n value increased from .026 to .044 when the flow dropped from 3,250 to 500 cfs, a percentage increase in n of over 65%.

Thus, it was felt in the present study that a decrease in n value as the flow increased would be justified and appropriate. The four flow levels used for calibration of the model were 9,700; 17,000; 34,500; and 52,000 cfs. As has been noted above, two versions of the HEC-2 model were operated on the study reach - one for flows below 20,000 cfs and one for flows above 20,000. This level was significant because it marked the estimated threshold for the river flowing into selected side channels and sloughs, which was an important part of the analysis. Most of the preliminary calibration runs were done with the 9,700-cfs flow, so a feeling was gained for the high-end n values in the study reach. When the next-higher calibration flow (17,000 cfs) was run, use of the same n values produced computed water surface elevations that were above the observed ones at almost all the observation sites (the one exception was LRX-28, where the reliability of the stage-discharge rating curve was highly questionable). A reduction in all the n values of 10%, however, bought all the computed water surface levels very close to the observed levels.

In calibration of the high-flow version of the model, the two flows tested were 34,500 and 52,000 cfs. A reduction of 10% in n value was made in going from 17,000 to 34,500 cfs, and good matches were obtained at all the observation sites. Above 34,500 cfs, the channel n value was assumed relatively constant and was not decreased further. The n value for 34,500 cfs was used with the 52,000-cfs flow, again with good results at all the observation sites.

Following the four calibration flows used with the program, two verification runs were made, one with each regime. The low-flow version was run with 13,400 cfs, and n values used were 5% less than those at 9,700 cfs. The high-flow version was run with 23,400 cfs, with the same n values as were used at 17,000 cfs. Good results were seen in both runs. The final n values assumed are presented in Table 4.13. Only the values for 9,700 cfs are given since other flow levels are uniform factors times these numbers.

(d) Upper Susitna Study Reach

Starting values for the upper reach roughness coefficients were estimated from experience with the lower reach. Definition was made by cross-section. Values from cross-sections with comparable bed material and geometry were applied and modified as necessary. Effects of islands and bends were also considered.

The final assumed n values are shown in Table 4.14, for the base flow of 8,100 cfs. Factors are also given for the adjustments used at high flows.

(e) Summary

The initial Manning's n values were estimated by computing them from the Manning equation, using observed water surface information at each of six different cross-sections in the Middle Susitna. The definition of Manning's n as a function of stage at a cross-section was attempted but was abandoned because of operational problems and incompatibility with the ice processes model.

Assignment of n values by horizontal stations at the cross-section was also used for a time but it was determined to be time-consuming, to require considerable cross-referencing of the stationing, and to be more refined than necessary. Thus, the method finally selected and utilized was that of n value designation by cross-section. Actually, several consecutive cross-sections were felt to exhibit similar roughness characteristics, so the same coefficient was used within whole sub-reaches. The substantial variation of n value with river discharge was noted and applied by reducing the coefficient for higher flows.

4.4 - Results

(a) Upper Susitna Study Reach

The HEC-2 model was calibrated with Watana discharges of 8,100; 17,200; 30,700; and 46,400 cfs. The continuous gage two miles below the Watana damsite was used as the standard for defining flow levels on dates of water level observations, but adjustments were made based primarily on drainage area above and below the gage vicinity. The mainstem flow was reduced above the Deadman Creek confluence and increased below the Tsusena Creek and Fog Creek confluences, all the major tributaries in the study reach. Flows used for each of the sub-reaches are given in Table 4.3. It should be noted that flows given in the computer printout do not precisely agree with all of these since a factor was used to change flow from one reach to the next and from one run to the next and the table values are round numbers.

The model was verified with streamflows of 26,700 and 42,200 cfs. Comparison of the six computed and corresponding observed water surface elevations at the crest gage and stream gage sites is given in Table 4.15. Stage-discharge rating curves (based on observations) are given in Attachment A for all the study reach observation sites. Results of all six runs for the whole study reach are shown in the summary output tables, Tables 4.16 and 4.17. There are two complete tables, one for the low-flow case and one for the high-flow case, with three discharges in each case. Each column is explained on the last page of each table. Plots of the 23 cross-sections are presented in Attachment B, with all six computed water levels sketched on them.

Several items from the analysis are worthy of discussion:

- Critical flow was computed for several discharges at Cross-section 103. This appears reasonable from field observations and for reasons given above in the discussion of the study reach characteristics.

- Cross-section 106.3 is not truly a surveyed cross-section. The original survey of cross-section 106, slightly upstream from 106.3, had some suspect data. The bottom elevations seemed higher than they should reasonably have been. However, no specific errors in the survey could be identified, so the cross-section was merely omitted. Other observations were available (at 106.3) of the river channel, so these were used, and approximate bank profiles were assumed. Slight inaccuracy may be present at this cross-section as a consequence.

(b) <u>Middle Susitna Study Reach</u>

The Middle Susitna model was calibrated with Gold Creek discharges of 9,700; 17,000; 34,500; and 52,000 cfs. The USGS gage at Gold Creek was used as the standard for describing flows, but adjustments were made upstream and downstream of the gage locale. As in the upper study reach, modifications were based essentially on drainage area. Excepting Portage Creek and Indian River, both above Gold Creek, there are no significant tributaries to the Susitna within the reach. Thus, adjustment below Gold

Creek was made at Curry, which is about halfway down the sub-reach from Gold Creek to the Chulitna confluence. Flows used for the various sub-reaches are shown in Table 4.4.

Verification of the model was accomplished with discharges of 13,400 and 23,400 cfs, one for the low flow regime and one for the high-flow regime. All six computed and observed water surface elevations at the observation sites are tabulated for comparison in Table 4.18. Stage-discharge rating curves for all the observation sites (based on observed water-surface elevations) are shown in Attachment A. The summary output tables are presented in Tables 4.19 and 4.20 (column headings are explained at the end of each table), and Attachment C gives the cross-section plots with computed water surface elevations for all 66 cross-sections.

Points of interest in the analysis:

- Cross-section LRX-28 did not yield good comparisons between computed and observed water levels all the time, particularly at the lower flows. This is probably due to the multi-channel situation at the cross-section. With the crest gage being located on a side channel on the left bank, it may not be hydraulically connected with the main channel and thus have a water surface above or below the main channel's.

- Cross-section LRX-4 had a location similar to that at LRX-28, with several islands in the main channel and the crest gage adjacent to a side channel on the left bank. Its reliability is also somewhat suspect. However, all the other crest gages, the streamgage, and the staff gages are at single-channel cross-sections.

- The model initially computed critical flow at two cross-sections at certain flow levels. While these two cross-sections (LRX-25 and LRX-44) had steep or swiftly-flowing reaches near by, the determination of critical flow did not appear justified. It was felt that the problem showed up due to the long inter-reach distances. Thus, an "interpolated" cross-section was added downstream of each of the areas. The two interpolated sections, LRX-24.5 and LRX-43.5, were determined from elevation information upstream and downstream and integration of features from the aerial photographs. These cross-sections show up in the summary Tables 4.19 and 4.20, but they are not plotted in Attachment C since they are not "true" cross-sections.

TABLE 4.1

RIVER MILES AND THALWEG ELEVATIONS FOR UPPER SUSITNA RIVER CROSS-SECTIONS

Cross Section	River Mile	Thalweg Elevation (ft. msl.)
URX - 121	162.1	1205.7
URX - 120	167.0	1269.4
URX - 119	173.1	1324.5
URX - 118	174.0	1332.0
URX - 117	176.0	1357.6
URX - 116	176.7	1361.7
URX - 115	178.8	1385.1
URX - 114	180.1	1404.4
URX - 113	181.0	1407.3
URX - 112	181.8	1419.4
URX - 111	182.1	1430.1
URX - 110	182.5	1435.2
URX - 109	182.8	1437.3
URX - 208	183.5	1443.0
URX - 108	183.8	1443.4
URX - 207	184.0	1443.9
URX - 107	184.2	1445.1
URX - 106.3	184.4	1448.1
URX - 105	184.8	1451.0
URX - 104	185.4	1467.1
URX - 103	185.9	1491.2
URX - 102	186.5	1491.7
URX - 101	186.8	1504.0

Note: Elevations are approximate since survey was done through ice cover and thalweg location was not certain.

TABLE 4.2

RIVER MILES AND THALWEG ELEVATIONS FOR MIDDLE SUSITNA RIVER CROSS-SECTIONS

Cross Section	River Mile	Thalweg Elevation (ft. msl.)
LRX-3	98.59	332.6
4	99.58	344.4
5	100.36	352.6
6	100.96	357.1
7	101.52	359.4
8	102.38	364.1
9	103.22	366.6
10	104.75	386.2
11	106.68	401.0
12	108.41	414.4
13	110.36	426.5
14	110.89	437.2
15	111.83	446.1
16	112.34	449.7
17	112.69	453.4
18	113.02	452.9
19	116.44	481.7
20	117.19	483.3
21	119.15	500.9
22	119.32	503.4
23	120.26	515.5
24	120.66	507.6
25	121.63	526.2
26	122.57	532.1
27	123.31	533.8
28	124.41	549.8

TABLE 4.2 - (Continued)

Cross Section	River Mile	Thalweg Elevation (ft. msl.)
LRX-29	126.11	563.3
30	127.50	578.4
31	128.66	586.8
32	129.67	597.2
33	130.12	607.0
34	130.47	608.9
35	130.87	605.5
36	131.19	614.0
37	131.80	618.8
38	132.90	634.7
39	133.33	641.5
40	134.28	650.0
41	134.72	655.3
42	135.36	663.9
43	135.72	657.6
44	136.40	674.6
45	136.68	673.5
46	136.96	681.4
47	137.15	681.9
48	137.41	685.3
49	138.23	694.2
50	138.48	693.5
51	138.89	701.9
52	139.44	707.2
53	140.15	717.2
54	140.83	726.3
55	141.49	735.2

TABLE 4.2 - (Continued)

Cross Section	River Mile	Thalweg Elevation (ft. msl.)
LRX-56	142.13	744.4
57	142.34	745.5
58	143.18	756.9
59	144.83	775.8
60	147.56	808.5
61	148.73	819.5
62	148.94	822.3
63	149.15	827.2
64	149.35	825.4
65	149.46	836.1
66	149.51	837.2
67	149.81	840.6
68	150.19	829.6

TABLE 4.3

STREAMFLOWS USED BY SUB-REACH,
UPPER SUSITNA

Cross-Sections		(Factor	Corresponding to Watana Gage Flows (cfs)					
From	To	Used)	8,100	17,200	26,700	30,700	42,200	46,400
URX-121	URX-117	(1.079)	8,740	18,560	28,810	33,120	45,530	50,060
URX-116	URX-112	(1.038)	8,410	17,850	27,710	31,870	43,800	48,160
URX-111	URX-102	(1.000)	8,100	17,200	26,700	30,700	42,200	46,400
URX-101	URX-101	(0.969)	7,850	16,670	25,870	29,750	40,890	44,960

TABLE 4.4

STREAMFLOWS USED BY SUB-REACH,
MIDDLE SUSITNA

Cross-Sections		(Factor	Corresponding to Gold Creek Flows (cfs)					
From	To	Used)	9,700	13,400	17,000	23,400	34,500	52,000
LRX-3	LRX-23	(1.030)	9,990	13,800	17,510	24,100	35,540	53,560
LRX-24	LRX-50	(1.000)	9,700	13,400	17,000	23,400	34,500	52,000
LRX-51	LRX-61	(0.983)	9,540	13,170	16,710	23,000	33,910	51,120
LRX-62	LRX-68	(0.942)	9,140	12,620	16,010	22,040	32,500	48,980

TABLE 4.5

VARIATION IN WATER SURFACE ELEVATION BETWEEN CHANNELS
(Flow Less Than 10,000 cfs)

Station Number	Date of Survey	Flow (cfs)	Water Surface Elevation (ft.) Main Channel	Side Channel(s)	Comments
LRX-4	10/4/80	9800	350.4	348.2, 350.9	
LRX-7	10/6/80	9380	364.6	365.7	
LRX-16	10/10/80	9695	455.2	455.5	
LRX-29	11/6/80	4950	568.4	?	
LRX-31	11/18/80	2400	594.1	592.6, 593.7	
LRX-36	10/30/80	5525	619.0	618.5	Frazil ice accum.; 10' wide shore ice.
LRX-39	10/28/80	5400	645.6	644.7, 642.9	Shore ice; ice floes.
LRX-42	10/20/80	7230	668.7	666.8 (slough) 667.8	Variation of 0.4' in water surface across main channel
LRX-43	10/17/80	7350	670.9	673.7	Frazil ice
LRX-44	10/17/80	7350		680.8	
	10/20/80	7230	679.9		
LRX-47	10/15/80	7440	688.5		Ponded water in side channel
LRX-48	10/14/80	7290	691.7	689.7 (ponded)	
LRX-52	10/24/80	6420	713.8	716.3	
LRX-53	10/24/80	6420	722.2	724.0	Sm. side channel w/flowing water
LRX-54	10/24/80	6420	731.8	733.5	
LRX-55	10/23/80	6270	742.6	739.9	

HEC-2 assumes a uniform water surface elevation across the entire X-section. However, this is not the case in the field, due to the complexity of the river system. The variation in the water surface elevation is illustrated in the above table, which shows elevation differences of up to 2.8 feet (LRX-43) in the natural system. Therefore, some care should be taken in assuming an absolute water surface elevation in the sloughs for a given flow.

TABLE 4.6

VARIATION IN WATER SURFACE ELEVATION BETWEEN CHANNELS
(Flow Greater Than 21,000 cfs)

Station Number	Date of Survey	Flow (cfs)	Water Surface Elevation (ft.) Main Channel	Side Channel(s)	Comments
LRX-3	8/31/81	22300	343.7(L)		L - left channel
LRX-4	8/31/81	22300	351.4(M)	351.5(L), 352.6(R)	M - middle channel
LRX-7	8/31/81	22300	367.6(L)	368.0(R)	R - right channel
LRX-9	8/31/81	22300	381.0(M)		SL - slough
LRX-16	8/31/81	22300	457.4(L)	457.6(R), 455.9(ctr.SL) 457.3(RSL)	
LRX-19	8/31/81	22300	489.7(M)		
LRX-24	8/31/81	22300	523.8(M)		
LRX-28	8/31/81	22300	557.7(M)	556.4(L), 557.2(R)	
LRX-29	8/31/81	22300	572.4(R)	574.0(LSL)	ponded water in left slough
LRX-31	8/31/81	22300	598.2(R)	594.8(ctr.SL), 593.0(LSL)	
LRX-35	8/31/81	22300	619.6(M)		
LRX-36	9/1/81	21100	622.4(L)	621.6(R)	
LRX-39	9/1/81	21100	648.5(R)	647.0(L), 646.1(LSL)	
LRX-40	9/1/81	21100	657.4(M)		
LRX-42	9/1/81	21100	672.2(R)	669.5(LSL)	Flowing water in left slough
LRX-43	9/1/81	21100	673.5(R)	673.5(ctr SL), 674.8(LSL)	
LRX-44	9/1/81	21100	683.8(R)	681.8(ctr SL) 682.8(L.SL)	
LRX-45	9/1/81	21100	686.4(M)		
LRX-47	9/1/81	21100	693.7(M)	691.1(LSL	
LRX-48	9/1/81	21100	695.3(R)	692.7(LSL)	
LRX-51	9/1/81	21100	709.6(M)		
LRX-53	9/1/81	21100	725.4(R)	725.1(LSL)	
LRX-55	9/1/81	21100	743.6@LB 744.9@RB	743.1(LSL)	
LRX-59	9/1/81	21100	788.3(M)		
LRX-62	9/1/81	21100	838.3(M)		
LRX-68	9/1/81	21100	853.8(M)		

TABLE 4.7

MIDDLE SUSITNA RIVER WATER LEVEL OBSERVATION SITES

Location Name	Cross-Section Number	River Mile (from Mouth)	Type of Site
Susitna-Chulitna Confluence	LRX-4	99.5	R&M Crest Gage
Chase	LRX-9	103.3	R&M Crest Gage
Curry	LRX-24	120.7	R&M Crest Gage
Section 25*	LRX-28	124.4	R&M Crest Gage
Sherman	LRX-35	130.9	R&M Crest Gage
Gold Creek	LRX-45	136.2	USGS Stage Recorder
Portage Creek	LRX-62	148.9	R&M Crest Gage
Devil Canyon Staff Gage**	LRX-68	150.2	R&M Staff Gage

* The name Section 25 is derived from the location of this crest gage within Section 25 of T30N, R4W, Seward Meridian.

** The staff gage at Devil Canyon was installed in April 1981.

TABLE 4.8

UPPER SUSITNA RIVER WATER LEVEL OBSERVATION SITES

Location Name	Cross-Section Number	River Mile (from Mouth)	Type of Site
Devil Creek	URX-121	162.1	R&M Crest Gage
Watana Streamgage	URX-111	182.1	R&M Streamgage
Watana Damsite	URX-106.3	184.4	R&M Crest Gage
Deadman Creek	URX-101	186.8	R&M Crest Gage

TABLE 4.9

HYDRAULIC PARAMETERS AND MANNING'S N VALUES COMPUTED AT LRX-35 (SHERMAN) FOR OBSERVED FLOWS

Date	Q (cfs)	W.S. Elevation (ft)	Area (ft^2)	Wetted Perim. (ft)	Hydr. Rad. (ft)	Manning's n**
-	50,000	623.0*	4839.5	419.7	11.53	.028
7/31/80	34,500	621.34	4128.2	397.4	10.39	.033
-	15,000	618.40*	3007.6	378.6	7.94	.046
9/6/80	9,700	617.29	2605.3	358.4	7.27	.057
10/14/80	7,290	616.32	2258.5	338.3	6.68	.063
10/30/80	5,525	615.73	2069.8	327.3	6.32	.073
11/11/80	2,984	614.71	1742.5	314.0	5.55	.104

* No observation was made at given flow, so this elevation is estimated.

** n values computed from Manning equation:

$$n = \frac{1.49\ AR^{2/3}\ S^{\frac{1}{2}}}{Q}$$

where: A = Area, ft^2

R = Hydraulic Radius, ft

S = Slope, ft/ft = $\frac{5.1 \text{ ft.}}{3480 \text{ ft.}}$ = .000147 (bed slope on thalweg)

Q = streamflow, cfs

TABLE 4.10

CRITERIA FOR SELECTION OF MANNING'S N FOR OVERBANK AREAS, MIDDLE SUSITNA RIVER

Variable	Description	Value	Explanation
n_0	Basic value for straight, uniform, smooth channel in natural materials	.045	This is a minimum for natural channels, based on past experience
n_1	Degree of surface irregularity	.005	Moderate
n_2	Effect of variations in size and shape of cross-section	.000 - .010	Negligible (gradual) to moderate +
n_3	Effect of obstructions and debris	.000 - .005	Negligible to minor (mostly below Chase)
n_4	Effect of vegetation	.005 - .015 .015 - .025	Willow areas Mature trees
m_5	Degree of meandering	1.000	Minor

Resultant $n = (n_0 + n_1 + n_2 + n_3 + n_4)\, m_5$ (after Chow, 1959)

Range for Susitna overbanks:

Minimum = .055 for light willow areas

Maximum = .090 for dense tree areas

TABLE 4.11

BED MATERIAL DISTRIBUTION ANALYSIS,
MIDDLE SUSITNA RIVER CROSS SECTIONS (LRX'S)

LRX Number[1]	D_{16} (mm.)	D_{50} (mm.)	D_{84} (mm.)
4	13	25	46
5	12	21	39
6	20	47	112
8	19	45	112
9	14	32	72
10	58	94	152
11	18	43	100
14	20	36	66
16	8	26	92
18	12	36	110
19	47	80	132
20	16	38	92
21	26	49	95
22	8	21	58
23	22	48	108
26	25	54	113
27	19	43	100
28	13	31	68
29	32	59	110
30	33	64	122
31	28	49	84
32	19	43	100
40	20	46	110
42	15	38	94
43	19	44	94
44	14	35	88
46	29	53	100
48	21	56	155
49	26	53	112
50	18	53	160
51	44	88	170
53	86	125	188
54	18	43	105
55	178	220	265
56	29	73	183
57	20	47	110
58	62	112	200
59	26	66	170

1 All cross-sections are not listed because bed material photographs were not satisfactory for analysis in some cases.

misc9/x2

TABLE 4.12

MANNING'S N VALUES COMPUTED FROM BED PARTICLE SIZES

		d_w''		River Discharge									
				5,000 cfs		9,700 cfs		17,000 cfs		34,500 cfs		50,000 cfs	
Site Name	X-Section	(mm)	(ft)	R (ft)	n	R (ft)	n	R (ft)	n	R (ft)	n	R (ft)	n
Su-Chu Confluence	LRX-4	36	.12	1.2	.033	2.8	.030	2.8	.030	4.3	.029	4.5	.029
Chase	LRX-9	64	.21	6.6	.033	7.5	.032	7.6	.032	9.5	.032	10.1	.032
Curry	LRX-24	81	.27	6.2	.035	6.3	.035	6.5	.035	8.8	.034	10.5	.034
Section 25	LRX-28	51	.17	1.7	.035	2.4	.034	2.7	.033	4.6	.032	5.2	.032
Sherman	LRX-35	75	.25	6.3	.034	7.3	.034	8.2	.033	10.4	.033	11.5	.033
Gold Creek	LRX-45	65	.21	5.2	.033	6.2	.033	7.8	.032	8.9	.032	9.5	.032
Portage Creek	LRX-62	135	.44	4.7	.041	5.3	.040	9.8	.038	14.1	.037	18.2	.036

1. $n = \frac{.0926R^{1/6}}{.90 + 2.0 \log (R/d_w'')}$, where $d_w'' = .6d_{84} + .3d_{50} + .1d_{16}$

2. Method after Limerinos (1970).

TABLE 4.13

ASSUMED MANNING'S n VALUES AT MIDDLE SUSITNA CROSS-SECTIONS (For Flow at Gold Creek of 9,700 cfs)

LRX	Manning's n	LRX	Manning's n	LRX	Manning's n
3	.040	25	.030	47	.040
4	.040	26	.035	48	.040
5	.040	27	.035	49	.040
6	.040	28	.035	50	.045
7	.040	29	.035	51	.050
8	.050	30	.038	52	.050
9	.055	31	.038	53	.050
10	.055	32	.038	54	.055
11	.055	33	.0361	55	.055
12	.055	34	.0361	56	.055
13	.055	35	.0361	57	.050
14	.055	36	.0361	58	.050
15	.045	37	.0361	59	.050
16	.040	38	.0361	60	.055
17	.040	39	.0361	61	.055
18	.040	40	.038	62	.055
19	.040	41	.038	63	.055
20	.040	42	.038	64	.055
21	.040	43	.040	65	.055
22	.030	44	.040	66	.055
23	.030	45	.040	67	.055
24	.030	46	.045	68	.055

Note: Adjustment factors for n values at flows other than 9,700 cfs:

$$n_{3,000} = (1.20)\ n_{9,700}$$
$$n_{13,400} = (0.95)\ n_{9,700}$$
$$n_{17,000} = (0.90)\ n_{9,700}$$
$$n_{23,400} = (0.90)\ n_{9,700}$$
$$n_{34,500} = (0.81)\ n_{9,700}$$
$$n_{52,000} = (0.81)\ n_{9,700}$$

TABLE 4.14

ASSUMED MANNING'S n VALUES AT UPPER SUSITNA CROSS-SECTIONS
(For Flow at Watana Streamgage of 8,100 cfs)

URX	Manning's n	URX	Manning's n
121	.045	109	.045
120	.045	208	.045
119	.045	108	.040
118	.047	207	.040
117	.047	107	.045
116	.045	106.3	.045
115	.048	105	.045
114	.050	104	.060
113	.045	103	.060
112	.040	102	.045
111	.040	101	.055
110	.045		

Note: Adjustment factors for n values at flows other than 8,100 cfs:

$$n_{17,200} = (0.90)\ n_{8,100}$$
$$n_{26,700} = (0.81)\ n_{8,100}$$
$$n_{30,700} = (0.81)\ n_{8,100}$$
$$n_{42,200} = (0.729)\ n_{8,100}$$
$$n_{46,400} = (0.693)\ n_{8,100}$$

TABLE 4.15

COMPARISON OF OBSERVED AND COMPUTED WATER SURFACE ELEVATIONS, UPPER SUSITNA STUDY REACH

Susitna Discharge, cfs (Watana Gage)	URX-121 Comp.	URX-121 [Obs.]	URX-111 Comp.	URX-111 [Obs.]	URX-106.3 Comp.	URX-106.3 [Obs.]	URX-101 Comp.	URX-101 [Obs.]
8,100	1211.2	[1211.2][1]	1435.3	[1435.8]	1456.2	[1455.9]	1510.1	[1510.7]
17,200	1213.5	[1213.5]	1437.8	[1437.8]	1459.3	[1458.2]	1513.0	[1512.9]
26,700	1215.7	[1215.7][1]	1439.8	[1439.6]	1461.3	[1461.2]	1515.0	[1515.0]
30,700	1216.5	[1216.5][1]	1440.7	[1440.2]	1462.3	[1461.8]	1515.9	[1515.8][1,2]
42,200	1218.4	[1218.4]	1442.4	[1441.6]	1464.0	[1464.3]	1517.8	[1517.8]
46,400	1219.3	[1219.3][1,2]	1442.8	[1442.0]	1464.4	[1465.0][1,3]	1518.2	[1518.5][1,3]

Note: Water surface elevations are referenced to mean sea level (msl).

1 These "observed" water surface elevations were determined from the sites' rating curves.

2 Actual "observed" water level at URX-101 was 1517.0 but was considerably above the rating curve and believed invalid.

3 Actual "observed" water levels were 1218.6 at URX-121, 1464.0 at URX-106.3, and 1517.7 at URX-101. These were crest gage readings, however, and believed unreliable, so the rating curve values were used instead.

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ERROR CORR - 01,02,03,04
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

UPPER SUSITNA RIVER

SUMMARY PRINTOUT Table 4.16

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
121.000	8740.00	1211.20	7.69	5.50	0.00	45.00	1136.61	297.46	1025.45	1322.91
121.000	18563.76	1213.50	9.95	7.80	0.00	40.50	1865.77	336.59	1007.16	1343.75
121.000	28809.66	1215.70	10.95	10.00	0.00	36.45	2632.33	351.71	999.71	1351.43
120.000	8740.00	1276.25	3.44	6.85	2.59	45.00	2540.37	491.89	1091.61	1583.50
120.000	18563.76	1278.66	4.95	9.26	2.59	40.50	3752.54	518.37	1077.05	1595.43
120.000	28809.66	1279.87	6.56	10.47	2.59	36.45	4390.55	532.20	1069.21	1601.41
119.000	8740.00	1330.80	4.48	6.30	1.78	45.00	1949.14	473.36	2050.32	2523.68
119.000	18563.76	1333.00	6.15	8.50	1.78	40.50	3016.45	493.04	2037.26	2530.30
119.000	28809.66	1334.90	7.26	10.40	1.78	36.45	3967.97	509.14	2026.86	2536.00
118.000	8740.00	1340.04	3.90	8.04	1.71	47.00	2240.96	416.88	1165.45	1582.33
118.000	18563.76	1342.84	5.07	10.64	1.71	42.30	3662.46	615.08	1140.50	1966.95
118.000	28809.66	1344.24	6.30	12.24	1.71	38.07	4575.45	692.19	1133.14	1974.69
117.000	8740.00	1363.91	4.57	6.31	2.42	47.00	1914.24	487.95	2033.07	2636.02
117.000	18563.76	1366.48	5.51	8.88	2.42	42.30	3369.10	627.00	2018.13	2645.13
117.000	28809.66	1367.87	6.78	10.27	2.42	38.07	4251.07	632.46	2013.71	2646.17
116.000	8410.00	1370.78	3.85	9.08	1.11	45.00	2186.85	337.59	2395.41	2733.00
116.000	17862.84	1373.51	5.63	11.81	1.11	40.50	3172.14	387.14	2358.54	2745.68
116.000	27721.88	1375.14	7.25	13.44	1.11	36.45	3825.41	418.52	2334.72	2753.24
115.000	8410.00	1391.62	4.61	6.52	2.03	48.00	1825.09	448.18	1054.42	1502.60
115.000	17862.84	1394.34	5.76	9.24	2.03	43.20	3099.20	484.17	1039.29	1523.46
115.000	27721.88	1396.26	6.85	11.16	2.03	38.88	4047.39	507.20	1030.61	1537.81
114.000	8410.00	1410.57	3.30	6.17	2.92	50.00	2560.08	790.84	1052.93	3303.86
114.000	17862.84	1412.06	4.65	7.66	2.92	45.00	3946.00	1037.68	1033.12	4255.51
114.000	27721.88	1412.94	5.89	8.54	2.92	40.50	4865.86	1098.27	1029.42	4269.06

SECNO	G	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
113.000	8410.00	1414.37	3.94	7.07	1.49	45.00	2135.81	423.31	1005.96	1429.26
113.000	17862.84	1416.54	5.77	9.24	1.49	40.50	3094.56	449.74	1002.40	1452.14
113.000	27721.88	1417.78	7.59	10.48	1.49	36.45	3653.45	456.12	1000.37	1456.49
112.000	8410.00	1428.84	6.71	9.44	1.81	40.00	1252.57	212.45	1005.25	1217.70
112.000	17862.84	1431.99	9.04	12.59	1.81	36.00	1976.85	249.09	1000.84	1249.93
112.000	27721.88	1434.18	10.84	14.78	1.81	32.40	2556.82	283.30	999.29	1282.59
111.000	8100.00	1435.28	4.98	5.18	5.27	40.00	1624.88	412.52	1060.58	1473.09
111.000	17204.40	1437.85	6.30	7.75	5.27	36.00	2729.59	447.81	1039.34	1487.15
111.000	26700.03	1439.84	7.28	9.74	5.27	32.40	3666.94	488.37	1016.84	1505.21
110.000	8100.00	1440.71	4.14	5.51	3.00	45.00	1956.67	614.38	1038.04	2365.56
110.000	17204.40	1442.43	5.55	7.23	3.00	40.50	3100.85	726.98	1029.04	2372.45
110.000	26700.03	1443.83	6.35	8.63	3.00	36.45	4206.61	868.77	1021.60	2375.21
109.000	8100.00	1443.69	3.27	6.39	1.54	45.00	2478.16	587.84	1072.90	1660.74
109.000	17204.40	1445.57	4.79	8.27	1.54	40.50	3592.11	601.17	1062.88	1664.05
109.000	26700.03	1446.82	6.13	9.52	1.54	36.45	4354.87	610.09	1055.63	1665.63
208.000	8100.00	1449.80	3.82	6.80	1.34	45.00	2119.06	401.26	1038.59	1439.85
208.000	17204.40	1452.20	5.54	9.20	1.34	40.50	3107.89	420.81	1031.61	1452.42
208.000	26700.03	1453.75	7.08	10.75	1.34	36.45	3770.46	431.23	1027.09	1458.31
108.000	8100.00	1451.55	4.49	8.15	.32	40.00	1803.55	311.93	1054.98	1366.91
108.000	17204.40	1454.13	6.45	10.73	.32	36.00	2667.49	355.41	1045.22	1400.63
108.000	26700.03	1455.76	8.17	12.36	.32	32.40	3267.71	377.24	1040.25	1417.49
207.000	8100.00	1453.46	4.50	9.56	.38	40.00	1800.09	317.58	1050.91	1368.50
207.000	17204.40	1456.30	6.20	12.40	.38	36.00	2774.54	362.89	1047.81	1410.79
207.000	26700.03	1458.07	7.78	14.17	.38	32.40	3432.37	376.99	1045.87	1422.86
107.000	8100.00	1454.59	4.07	9.49	1.38	45.00	1990.86	261.98	1110.94	1372.92
107.000	17204.40	1457.54	6.20	12.44	1.38	40.50	2775.54	271.04	1103.15	1374.19
107.000	26700.03	1459.35	8.16	14.25	1.38	36.45	3273.04	276.64	1098.34	1374.98
106.300	8100.00	1456.19	5.14	8.09	3.00	45.00	1575.65	350.47	954.33	1304.80
106.300	17204.40	1459.29	6.12	11.19	3.00	40.50	2812.83	443.27	938.93	1382.20
106.300	26700.03	1461.32	7.13	13.22	3.00	36.45	3750.72	468.07	937.23	1405.30
105.000	8100.00	1462.86	5.23	11.86	1.12	45.00	1549.90	236.64	1229.73	1466.37
105.000	17204.40	1465.93	7.12	14.93	1.12	40.50	2415.26	348.64	1071.68	1472.27
105.000	26700.03	1467.43	8.96	16.43	1.12	36.45	2979.12	403.63	1063.60	1475.14
104.000	8100.00	1472.97	5.00	5.87	5.96	60.00	1618.47	502.69	1020.83	1523.52
104.000	17204.40	1475.78	5.43	8.68	5.96	54.00	3165.57	604.17	1010.75	1614.92
104.000	26700.03	1477.43	6.41	10.33	5.96	48.60	4167.91	614.22	1004.89	1619.11
103.000	8100.00	1497.31	2.85	6.11	6.36	60.00	2840.49	1336.49	1082.90	2419.39
103.000	17204.40	1497.87	4.78	6.67	6.36	54.00	3596.93	1355.56	1067.10	2422.66
103.000	26700.03	1498.26	6.47	7.06	6.36	48.60	4123.65	1368.58	1056.33	2424.91

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
102.000	8100.00	1505.30	5.84	13.60	.19	45.00	1386.96	183.38	1023.98	1207.36
102.000	17204.40	1509.00	7.63	17.30	.19	40.50	2255.26	274.26	1016.80	1291.06
102.000	26700.03	1510.86	9.58	19.16	.19	36.45	2787.82	298.76	1014.78	1313.54
101.000	7850.00	1510.10	4.01	6.10	9.11	55.00	1955.59	711.78	1130.60	2203.47
101.000	16673.40	1512.96	4.02	8.96	9.11	49.50	4147.79	890.65	1090.04	2216.81
101.000	25875.96	1514.95	4.48	10.95	9.11	44.55	5780.98	849.46	1084.73	2219.69

1 Column Heading Descriptions:

SECNO Identifying cross-section number.

Q Total flow in the cross-section.

CWSEL Computed water surface elevation.

VCH Mean velocity in the channel.

DEPTH Maximum depth of flow at the cross-section.

K*CHSL Channel slope from current cross-section to next-downstream cross-section in feet/foot (times 1,000).

K*XNCH Manning's n value used for the channel portion of the cross-section (times 1,000).

AREA Cross-section area (area of flow).

TOPWID Cross-section width at the calculated water surface elevation. Equal to sum of individual channel top widths.

SSTA Starting survey station where the water surface intersects the ground on the left side.

ENDST Ending survey station where the water surface intersects the ground on the right side. The difference between ENDST and SSTA gives the total distance from the left edge to the right edge of water.

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*********************************************
HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CORR - 01,02,03,04
MODIFICATION - 50,51,52,53,54
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

UPPER SUSITNA RIVER

SUMMARY PRINTOUT Table 4.17

SECNO	Q	CWSEL	VCH	DEPTH	*K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
121.000	33125.47	1216.50	11.37	10.80	0.00	36.45	2913.87	352.13	999.54	1351.67
121.000	45534.53	1218.40	12.72	12.70	0.00	32.81	3583.86	353.13	999.12	1352.25
121.000	50066.22	1219.30	12.85	13.60	0.00	31.17	3901.89	353.60	998.93	1352.52
120.000	33125.47	1280.55	6.97	11.15	2.59	36.45	4752.95	537.71	1067.05	1604.76
120.000	45534.53	1281.37	8.77	11.97	2.59	32.81	5194.99	541.55	1064.43	1605.99
120.000	50066.22	1281.25	9.76	11.85	2.59	31.17	5127.48	540.99	1064.83	1605.83
119.000	33125.47	1335.69	7.58	11.19	1.78	36.45	4370.35	514.31	2023.49	2537.80
119.000	45534.53	1337.26	8.77	12.76	1.78	32.81	5193.85	524.74	2016.70	2541.44
119.000	50066.22	1337.88	9.08	13.38	1.78	31.17	5514.47	528.75	2014.09	2542.84
118.000	33125.47	1344.95	6.52	12.95	1.71	38.07	5082.86	731.70	1130.14	1978.57
118.000	45534.53	1345.98	7.78	13.98	1.71	34.26	5915.37	872.77	1125.77	2406.16
118.000	50066.22	1346.16	8.36	14.16	1.71	32.55	6072.29	884.81	1125.01	2409.66
117.000	33125.47	1368.49	7.14	10.89	2.42	38.07	4642.59	634.87	2011.76	2646.63
117.000	45534.53	1369.48	8.63	11.88	2.42	34.26	5277.10	638.76	2008.61	2647.37
117.000	50066.22	1369.75	9.21	12.15	2.42	32.55	5436.51	639.73	2007.82	2647.55
116.000	31874.74	1375.91	7.67	14.21	1.11	36.45	4156.56	433.56	2323.30	2756.86
116.000	43815.26	1377.29	9.16	15.59	1.11	32.81	4784.00	479.56	2281.99	2761.55
116.000	48175.84	1377.57	9.79	15.87	1.11	31.17	4922.71	486.79	2273.08	2761.87
115.000	31874.74	1397.16	7.07	12.06	2.03	38.88	4510.17	520.77	1027.42	1548.20
115.000	43815.26	1398.83	8.10	13.73	2.03	34.99	5409.99	561.66	1021.52	1583.18
115.000	48175.84	1399.19	8.58	14.09	2.03	33.24	5617.63	571.24	1020.22	1591.47
114.000	31874.74	1413.40	6.17	9.00	2.92	40.50	5387.80	1125.20	1027.52	4271.82
114.000	43815.26	1414.22	7.27	9.82	2.92	36.45	6354.94	1255.48	1024.05	4276.85
114.000	48175.84	1414.55	7.52	10.15	2.92	34.63	6613.04	1451.00	1022.62	4278.83

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
113.000	31874.74	1418.34	8.15	11.04	1.49	36.45	3912.02	458.61	999.88	1458.49
113.000	43815.26	1419.19	10.19	11.89	1.49	32.81	4301.64	461.90	999.58	1461.47
113.000	48175.84	1419.43	10.92	12.13	1.49	31.17	4411.94	462.82	999.49	1462.32
112.000	31874.74	1435.13	11.26	15.73	1.81	32.40	2834.77	302.74	998.85	1301.59
112.000	43815.26	1436.57	13.46	17.17	1.81	29.16	3303.36	371.76	998.20	1369.95
112.000	48175.84	1436.81	14.46	17.41	1.81	27.70	3399.62	375.59	998.08	1373.67
111.000	30699.81	1440.72	7.48	10.62	5.27	32.40	4105.39	504.27	1011.46	1515.73
111.000	42200.19	1442.37	8.51	12.27	5.27	29.16	4958.01	525.06	1001.40	1526.45
111.000	46400.04	1442.83	8.92	12.73	5.27	27.70	5201.49	528.94	999.22	1528.17
110.000	30699.81	1444.49	6.41	9.29	3.00	36.45	4791.07	908.82	1019.21	2375.99
110.000	42200.19	1445.69	7.14	10.49	3.00	32.81	5913.17	960.28	1017.39	2377.43
110.000	46400.04	1446.00	7.46	10.80	3.00	31.17	6221.30	972.03	1016.90	2377.82
109.000	30699.81	1447.36	6.55	10.06	1.54	36.45	4686.98	613.77	1052.34	1666.11
109.000	42200.19	1448.27	8.05	10.97	1.54	32.81	5247.27	620.07	1046.84	1666.91
109.000	46400.04	1448.46	8.65	11.16	1.54	31.17	5365.35	621.39	1045.69	1667.07
208.000	30699.81	1454.50	7.49	11.50	1.34	36.45	4096.45	436.26	1024.90	1461.16
208.000	42200.19	1455.72	9.12	12.72	1.34	32.81	4625.93	440.41	1022.47	1462.88
208.000	46400.04	1455.97	9.79	12.97	1.34	31.17	4740.36	441.14	1022.05	1463.20
108.000	30699.81	1456.54	8.61	13.14	.32	32.40	3564.18	385.21	1037.88	1423.09
108.000	42200.19	1457.76	10.44	14.36	.32	29.16	4040.99	396.04	1034.17	1430.21
108.000	46400.04	1457.99	11.22	14.59	.32	27.70	4134.65	396.96	1033.45	1430.41
207.000	30699.81	1458.90	8.19	15.00	.38	32.40	3746.73	385.13	1043.38	1428.51
207.000	42200.19	1460.29	9.84	16.39	.38	29.16	4289.60	400.41	1037.55	1437.96
207.000	46400.04	1460.60	10.51	16.70	.38	27.70	4414.01	403.83	1036.25	1440.06
107.000	30699.81	1460.20	8.75	15.10	1.38	36.45	3508.25	279.22	1096.10	1375.32
107.000	42200.19	1461.55	10.85	16.45	1.38	32.81	3889.65	282.93	1092.67	1375.60
107.000	46400.04	1461.83	11.70	16.73	1.38	31.17	3966.85	283.61	1092.05	1375.66
106.300	30699.81	1462.27	7.34	14.17	3.00	36.45	4196.46	472.65	936.44	1409.09
106.300	42200.19	1463.98	8.49	15.88	3.00	32.81	5011.14	480.91	935.02	1415.92
106.300	46400.04	1464.42	8.97	16.32	3.00	31.17	5222.45	483.03	934.65	1417.68
105.000	30699.81	1468.08	9.46	17.08	1.12	36.45	3245.90	416.26	1060.12	1476.38
105.000	42200.19	1469.05	11.55	18.05	1.12	32.81	3654.20	421.00	1056.07	1477.07
105.000	46400.04	1469.23	12.45	18.23	1.12	31.17	3728.65	421.75	1055.34	1477.09
104.000	30699.81	1478.14	6.67	11.04	5.96	48.60	4604.60	618.10	1002.37	1620.46
104.000	42200.19	1479.39	7.85	12.29	5.96	43.74	5385.17	623.12	999.74	1622.86
104.000	46400.04	1479.74	8.30	12.64	5.96	41.56	5602.86	623.94	999.59	1623.53
103.000	30699.81	1498.51	6.87	7.31	6.36	48.60	4466.31	1376.99	1049.37	2426.36
* 103.000	42200.19	1498.28	10.18	7.08	6.36	43.74	4144.13	1369.09	1055.91	2425.00
* 103.000	46400.04	1498.96	9.12	7.76	6.36	41.56	5087.14	1392.09	1036.88	2428.97

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
102.000	30699.81	1511.63	10.15	19.93	.19	36.45	3023.23	308.98	1013.93	1322.91
102.000	42200.19	1513.47	11.70	21.77	.19	32.81	3606.29	321.16	1011.93	1333.08
102.000	46400.04	1513.09	13.32	21.39	.19	31.17	3482.79	320.05	1012.35	1332.40
101.000	29752.29	1515.90	4.50	11.90	9.11	44.55	6616.92	915.36	1062.61	2221.00
101.000	40697.72	1517.79	4.89	13.79	9.11	40.10	8367.83	937.04	1058.90	2223.61
101.000	44967.94	1516.24	5.11	14.24	9.11	38.69	8794.23	942.25	1058.01	2224.23

[1] Column Heading Descriptions:

SECNO	Identifying cross-section number.
Q	Total flow in the cross-section.
CWSEL	Computed water surface elevation.
VCH	Mean velocity in the channel.
DEPTH	Maximum depth of flow at the cross-section.
K*CHSL	Channel slope from current cross-section to next-downstream cross-section in feet/foot (times 1,000).
K*XNCH	Manning's n value used for the channel portion of the cross-section (times 1,000).
AREA	Cross-section area (area of flow).
TOPWID	Cross-section width at the calculated water surface elevation. Equal to sum of individual channel top widths.
SSTA	Starting survey station where the water surface intersects the ground on the left side.
ENDST	Ending survey station where the water surface intersects the ground on the right side. The difference between ENDST and SSTA gives the total distance from the left edge to the right edge of water.

misc9/x5

TABLE 4.18

COMPARISON OF OBSERVED AND COMPUTED WATER SURFACE ELEVATIONS, MIDDLE SUSITNA STUDY REACH

Susitna Discharge, (cfs) (Gold Creek)	Cross-Section Number LRX-4 Comp. [Obs.]	LRX-9 Comp. [Obs.]	LRX-24 Comp. [Obs.]	LRX-28 Comp. [Obs.]	LRX-35 Comp. [Obs.]	LRX-45 Comp. [Obs.]	LRX-62 Comp. [Obs.]	LRX-68 Comp. [Obs.]
9,700	348.6 [348.1]	378.1 [378.4]	521.7 [521.3]	555.0 [553.8]	617.7 [617.3]	684.0 [684.1]	835.1 [835.4]	850.6 [851.4]*
13,400	350.0 [349.5]	379.4 [379.0]	522.6 [522.0]	555.7 [555.3]*	618.7 [617.9]	685.1 [685.2]	836.4 [835.9]	851.8 [852.2]*
17,000	350.8 [350.5]	380.3 [379.8]	523.2 [522.9]	556.2 [556.0]	619.4 [619.0]	685.8 [685.9]	837.5 [837.5]	852.8 [852.9]
23,400	352.2 [352.0]	381.8 [381.6]	524.3 [523.8]*	557.0 [557.0]	620.3 [620.0]	687.0 [687.0]	838.0 [838.3]*	854.0 [854.1]
34,500	353.1 [352.9]	383.4 [383.1]	525.4 [525.4]	558.1 [558.2]	621.6 [621.3]	688.1 [688.4]	840.8 [840.7]*	855.8 [856.0]*
52,000	355.1 [354.6]	386.2 [385.4]*	527.2 [527.5]	560.1 [559.8]	623.3 [623.3]	689.9 [690.0]	844.2 [843.9]*	858.7 [859.0]*

Note: Water surface elevations are referenced to mean sea level (msl).

* "Observed" water surface elevations at these locations were determined from the sites' rating curves.

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HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CORR - 01,02,03,04
MODIFICATION - 50,51,52,53,54
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

MIDDLE SUSITNA RIVER--

SUMMARY PRINTOUT Table 4.19

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
3.000	9990.00	344.00	2.39	11.40	0.00	40.00	4180.72	662.62	4021.55	5578.00
3.000	13800.19	344.50	3.04	11.90	0.00	38.00	4542.03	767.73	4020.94	5654.37
3.000	17508.47	345.50	3.26	12.90	0.00	36.00	5365.70	901.34	4019.71	5658.07
4.000	9990.00	348.63	5.27	4.63	2.16	40.00	1894.93	778.10	3113.19	5784.76
4.000	13800.19	350.05	4.34	6.05	2.16	38.00	3179.21	1034.50	3106.95	5790.24
4.000	17508.47	350.82	4.32	6.82	2.16	36.00	4056.67	1249.28	3103.53	5792.48
5.000	9990.00	359.21	2.56	6.61	1.85	40.00	3902.94	1316.03	6047.13	7363.16
5.000	13800.19	359.44	3.28	6.84	1.85	38.00	4205.12	1316.56	6046.94	7363.50
5.000	17508.47	359.74	3.81	7.14	1.85	36.00	4598.01	1317.23	6046.71	7363.94
6.000	9990.00	362.70	2.78	5.60	1.41	40.00	3589.17	1041.29	6639.40	7680.69
6.000	13800.19	363.37	3.21	6.27	1.41	38.00	4296.41	1044.28	6637.73	7682.01
6.000	17508.47	363.84	3.66	6.74	1.41	36.00	4779.35	1046.31	6636.59	7682.90
7.000	9990.00	366.56	3.15	7.16	.79	40.00	3174.39	1073.52	1104.78	2412.14
7.000	13800.19	367.19	3.49	7.79	.79	38.00	3957.28	1281.50	1103.86	2434.01
7.000	17508.47	367.64	3.86	8.24	.79	36.00	4534.82	1327.76	1103.23	2449.08
8.000	9990.00	373.04	3.34	8.94	1.02	50.00	2991.65	511.84	3120.59	3632.43
8.000	13800.19	373.92	3.67	9.82	1.02	47.50	4246.36	844.36	3117.98	3962.34
8.000	17508.47	374.48	4.24	10.38	1.02	45.00	4719.36	848.11	3116.32	3964.43
9.000	9990.00	378.09	3.11	11.49	.51	55.00	3216.07	424.43	2184.75	2609.18
9.000	13800.19	379.36	3.64	12.76	.51	52.25	3789.02	474.00	2147.80	2621.80
9.000	17508.47	380.33	4.11	13.73	.51	49.50	4263.71	511.45	2119.89	2631.34
10.000	9990.00	391.48	4.07	5.28	2.60	55.00	2451.95	810.45	1156.23	2941.13
10.000	13800.19	392.49	4.18	6.29	2.60	52.25	3301.68	856.98	1144.30	2947.66
10.000	17508.47	393.24	4.44	7.04	2.60	49.50	3945.46	885.44	1138.62	2952.41

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
11.000	9990.00	409.92	2.53	8.92	1.45	55.00	3944.11	712.23	2043.29	2755.53
11.000	13800.19	410.64	3.09	9.64	1.45	52.25	4462.21	725.23	2033.51	2758.74
11.000	17508.47	411.21	3.60	10.21	1.45	49.50	4868.02	732.60	2028.61	2761.21
12.000	9990.00	421.58	3.57	7.18	1.47	55.00	2800.95	550.14	1094.84	1644.99
12.000	13800.19	422.75	4.00	8.35	1.47	52.25	3453.95	561.59	1089.35	1650.95
12.000	17508.47	423.63	4.44	9.23	1.47	49.50	3944.29	569.09	1086.26	1655.36
13.000	9990.00	437.61	3.33	11.11	1.18	55.00	2997.13	458.19	1068.81	2755.35
13.000	13800.19	438.78	3.88	12.28	1.18	52.25	3560.68	507.94	1066.71	2779.18
13.000	17508.47	439.60	4.39	13.10	1.18	49.50	3985.59	528.73	1065.23	2782.52
14.000	9990.00	443.77	3.83	6.57	3.79	55.00	2607.45	888.94	1097.63	2562.85
14.000	13800.19	444.69	4.00	7.49	3.79	52.25	3450.30	939.83	1096.65	2567.27
14.000	17508.47	445.37	4.27	8.17	3.79	49.50	4104.72	988.28	1095.92	2569.78
15.000	9990.00	452.52	2.70	6.42	1.79	45.00	3706.66	816.22	1061.80	2292.25
15.000	13800.19	453.21	3.22	7.11	1.79	42.75	4289.21	853.75	1060.68	2303.00
15.000	17508.47	453.77	3.68	7.67	1.79	40.50	4762.63	880.35	1059.81	2311.41
16.000	9990.00	455.73	3.52	6.03	1.33	40.00	2839.30	827.57	1059.00	2938.09
16.000	13800.19	456.60	3.80	6.90	1.33	38.00	3629.93	981.24	1056.06	2953.99
16.000	17508.47	457.21	4.10	7.51	1.33	36.00	4270.27	1083.07	1053.99	2957.07
17.000	9990.00	459.41	3.76	6.01	2.03	40.00	2657.03	897.00	1068.47	2204.97
17.000	13800.19	460.06	4.23	6.66	2.03	38.00	3264.70	951.47	1062.82	2208.52
17.000	17508.47	460.54	4.69	7.14	2.03	36.00	3735.47	991.61	1058.65	2211.13
18.000	9990.00	461.32	2.91	8.42	-.29	40.00	3432.61	584.14	1079.84	1663.98
18.000	13800.19	462.10	3.55	9.20	-.29	38.00	3888.71	590.65	1077.28	1667.93
18.000	17508.47	462.68	4.14	9.78	-.29	36.00	4231.73	595.51	1075.37	1670.88
19.000	9990.00	485.60	6.32	3.90	1.60	40.00	1579.70	501.53	1635.14	2136.66
19.000	13800.19	486.63	6.54	4.93	1.60	38.00	2109.34	518.98	1624.93	2143.91
19.000	17508.47	487.43	6.93	5.73	1.60	36.00	2526.23	532.31	1617.14	2149.45
20.000	9990.00	495.51	3.15	12.21	.39	40.00	3173.03	819.43	1325.70	3678.42
20.000	13800.19	496.16	3.70	12.86	.39	38.00	3731.91	897.51	1324.62	3683.84
20.000	17508.47	496.70	4.13	13.40	.39	36.00	4237.54	983.70	1323.72	3688.36
21.000	9990.00	510.04	4.42	9.14	1.72	40.00	2259.90	469.18	1566.70	2035.88
21.000	13800.19	511.19	4.89	10.29	1.72	38.00	2819.78	514.26	1537.41	2051.67
21.000	17508.47	512.01	5.38	11.11	1.72	36.00	3256.27	546.77	1516.25	2063.02
22.000	9990.00	511.60	4.82	8.20	2.78	30.00	2074.73	595.03	1139.41	2302.35
22.000	13800.19	512.53	5.23	9.13	2.78	28.50	2636.55	613.52	1137.55	2303.99
22.000	17508.47	513.25	5.67	9.85	2.78	27.00	3088.61	632.41	1136.09	2309.67
23.000	9990.00	519.95	4.25	4.45	2.46	30.00	2348.11	738.54	1362.06	2612.63
23.000	13800.19	520.44	5.08	4.94	2.46	28.50	2717.46	774.55	1359.72	2614.44
23.000	17508.47	520.81	5.82	5.31	2.46	27.00	3009.72	788.51	1357.93	2615.84

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
24.000	9700.00	521.71	3.80	14.11	-3.66	30.00	2551.02	375.37	1197.28	1572.65
24.000	13399.58	522.58	4.63	14.58	-3.66	28.50	2891.07	410.80	1132.44	1575.07
24.000	17000.22	523.25	5.34	15.65	-3.66	27.00	3181.27	450.31	1126.63	1576.94
24.500	9700.00	524.59	6.36	6.59	3.25	30.00	1526.32	472.59	2786.94	4177.46
24.500	13399.58	525.87	5.94	7.87	3.25	28.50	2257.15	664.79	2758.41	4181.74
24.500	17000.22	526.75	5.88	8.75	3.25	27.00	2889.14	793.41	2739.15	4183.48
25.000	9700.00	530.60	5.73	4.40	4.39	30.00	1691.68	761.68	1662.03	4212.31
* 25.000	13399.58	530.89	6.98	4.69	4.39	28.50	1919.76	805.29	1661.60	4213.26
25.000	17000.22	531.11	8.09	4.91	4.39	27.00	2100.51	875.28	1661.27	4213.97
26.000	9700.00	538.46	3.65	6.36	1.18	35.00	2656.46	558.36	2528.87	3087.23
26.000	13399.58	539.38	4.22	7.28	1.18	33.25	3173.26	570.38	2525.17	3095.55
26.000	17000.22	539.91	4.89	7.81	1.18	31.50	3475.08	577.28	2523.05	3100.33
27.000	9700.00	542.86	4.56	9.06	.44	35.00	2127.09	450.89	2354.40	2805.29
27.000	13399.58	543.71	5.32	9.91	.44	33.25	2519.65	461.20	2348.83	2810.03
27.000	17000.22	544.40	5.98	10.60	.44	31.50	2844.08	468.59	2345.28	2813.87
28.000	9700.00	555.15	4.91	7.15	2.44	35.00	1977.25	699.46	1492.99	2726.08
28.000	13399.58	555.76	5.54	7.76	2.44	33.25	2417.03	731.98	1491.23	2726.38
28.000	17000.22	556.25	6.12	8.25	2.44	31.50	2778.63	774.53	1489.85	2726.63
29.000	9700.00	570.97	3.79	7.67	1.71	35.00	2561.69	566.96	3494.17	4061.13
29.000	13399.58	571.73	4.47	8.43	1.71	33.25	2998.15	580.71	3483.08	4063.79
29.000	17000.22	572.33	5.07	9.03	1.71	31.50	3350.07	591.56	3474.34	4065.90
30.000	9700.00	585.28	4.37	6.88	2.06	38.00	2221.15	1070.82	1187.23	4442.21
30.000	13399.58	585.92	4.43	7.52	2.06	36.10	3023.62	1384.94	1185.83	4456.25
30.000	17000.22	586.39	4.51	7.99	2.06	34.20	3768.98	1708.61	1184.79	4456.52
31.000	9700.00	594.98	3.60	8.18	1.37	38.00	2694.64	445.05	3458.32	3903.37
31.000	13399.58	595.87	4.33	9.07	1.37	36.10	3094.75	454.65	3453.83	3908.48
31.000	17000.22	596.53	5.00	9.73	1.37	34.20	3396.90	461.77	3450.50	3912.27
32.000	9700.00	605.18	7.74	3.23	2.84	38.00	1252.75	561.62	3891.94	4679.44
32.000	13399.58	606.04	7.59	4.09	2.84	36.10	1765.33	626.87	3883.40	4689.13
32.000	17000.22	606.71	7.68	4.76	2.84	34.20	2214.89	698.68	3876.74	4696.69
33.000	9700.00	612.93	3.28	6.43	1.91	36.10	2957.01	863.73	2875.33	4050.63
33.000	13399.58	613.66	3.67	7.16	1.91	34.30	3653.37	1090.63	2874.44	4058.57
33.000	17000.22	614.06	4.12	7.56	1.91	32.49	4128.10	1173.46	2873.92	4063.07
34.000	9700.00	616.04	4.40	7.14	1.13	36.10	2206.57	567.92	1899.72	2467.63
34.000	13399.58	616.87	5.00	7.97	1.13	34.30	2681.83	577.59	1896.81	2474.40
34.000	17000.22	617.38	5.70	8.48	1.13	32.49	2980.39	583.58	1895.01	2478.59
35.000	9700.00	617.72	3.52	12.22	-1.88	36.10	2753.43	363.73	1403.74	1767.48
35.000	13399.58	618.69	4.30	13.19	-1.88	34.30	3114.37	378.68	1394.60	1773.48
35.000	17000.22	619.38	5.04	13.88	-1.88	32.49	3376.22	385.63	1392.09	1777.72

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
36.000	9700.00	619.47	5.63	5.47	5.09	36.10	1724.30	692.71	1484.81	2814.50
36.000	13399.58	620.54	5.28	6.54	5.09	34.30	2536.00	806.35	1478.15	2849.16
36.000	17000.22	621.29	5.40	7.29	5.09	32.49	3148.89	862.61	1473.58	2857.49
37.000	9700.00	627.06	4.03	8.26	1.47	36.10	2405.16	505.27	1057.52	1562.79
37.000	13399.58	627.56	5.04	8.76	1.47	34.30	2660.06	512.77	1056.47	1569.24
37.000	17000.22	627.96	5.94	9.16	1.47	32.49	2861.76	518.63	1055.65	1574.28
38.000	9700.00	638.97	5.58	4.27	2.75	36.10	1737.65	601.39	1280.88	2652.16
38.000	13399.58	639.90	5.78	5.20	2.75	34.30	2318.88	653.59	1263.83	2674.42
38.000	17000.22	640.57	6.13	5.87	2.75	32.49	2773.75	692.41	1251.42	2694.46
39.000	9700.00	645.84	3.79	4.84	2.78	36.10	2558.66	874.93	1806.91	2899.17
39.000	13399.58	646.27	4.54	5.27	2.78	34.30	2950.09	903.90	1791.39	2900.66
39.000	17000.22	646.64	5.18	5.64	2.78	32.49	3280.53	927.66	1778.67	2901.89
40.000	9700.00	655.11	4.10	5.11	1.80	38.00	2368.10	584.84	1090.55	1675.39
40.000	13399.58	655.89	4.74	5.89	1.80	36.10	2825.78	590.38	1088.43	1678.82
40.000	17000.22	656.46	5.37	6.46	1.80	34.20	3165.84	594.47	1086.87	1681.35
41.000	9700.00	659.87	4.56	9.47	.17	38.00	2402.91	596.39	1165.69	3016.48
41.000	13399.58	660.61	5.46	10.21	.17	36.10	2868.62	670.15	1162.31	3020.59
41.000	17000.22	661.21	6.27	10.81	.17	34.20	3287.46	797.20	1159.68	3023.65
42.000	9700.00	668.85	3.68	4.95	4.01	38.00	2948.42	1439.29	1253.59	3004.96
42.000	13399.58	669.37	4.09	5.47	4.01	36.10	3703.98	1494.17	1251.54	3006.49
42.000	17000.22	669.77	4.48	5.87	4.01	34.20	4322.91	1529.43	1249.90	3007.71
43.000	9700.00	671.18	3.80	13.58	-3.32	40.00	2554.71	324.51	2890.42	3214.94
43.000	13399.58	672.07	4.69	14.47	-3.32	38.00	2857.78	359.12	2860.23	3219.35
43.000	17000.22	672.68	5.51	15.08	-3.32	36.00	3088.03	382.44	2839.10	3221.54
43.500	9700.00	672.77	7.02	8.27	4.93	40.00	1381.47	255.05	3141.25	3396.31
43.500	13399.58	674.11	7.58	9.61	4.93	38.00	1767.23	321.85	3083.52	3405.37
43.500	17000.22	675.05	8.11	10.55	4.93	36.00	2095.37	376.89	3034.12	3411.02
44.000	9700.00	681.16	5.52	6.56	4.59	40.00	1756.96	446.98	2962.74	3409.72
44.000	13399.58	682.21	5.92	7.61	4.59	38.00	2265.26	514.70	2900.53	3415.24
44.000	17000.22	682.99	6.34	8.39	4.59	36.00	2680.32	567.15	2852.10	3419.24
45.000	9700.00	684.02	4.28	10.52	-.75	40.00	2264.56	343.31	1227.62	1570.92
45.000	13399.58	685.06	5.10	11.56	-.75	38.00	2628.22	354.37	1226.81	1581.18
45.000	17000.22	685.83	5.86	12.33	-.75	36.00	2903.01	362.51	1226.21	1588.72
46.000	9700.00	687.13	6.81	5.73	5.27	45.00	1424.17	386.83	1666.69	2053.52
46.000	13399.58	688.16	7.34	6.76	5.27	42.75	1825.37	398.10	1659.24	2057.35
46.000	17000.22	688.93	7.96	7.53	5.27	40.50	2136.04	406.28	1653.96	2060.24
47.000	9700.00	690.64	4.77	8.74	.49	40.00	2031.47	356.09	2168.68	2524.77
47.000	13399.58	691.56	5.66	9.66	.49	38.00	2367.59	371.63	2157.01	2528.65
47.000	17000.22	692.28	6.44	10.38	.49	36.00	2641.76	383.85	2147.85	2531.69

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
48.000	9700.00	693.09	4.60	7.79	2.57	40.00	2107.44	468.76	1690.37	2159.13
48.000	13399.58	694.09	5.18	8.79	2.57	38.00	2588.51	488.98	1676.99	2167.96
48.000	17000.22	694.86	5.72	9.56	2.57	36.00	2972.15	504.53	1670.23	2174.76
49.000	9700.00	701.97	4.28	7.77	2.06	40.00	2268.50	552.06	1227.16	2027.51
49.000	13399.58	702.90	4.72	8.70	2.06	38.00	2840.60	676.29	1218.69	2051.78
49.000	17000.22	703.56	5.13	9.36	2.06	36.00	3310.89	763.42	1212.75	2068.80
50.000	9700.00	703.68	3.17	10.18	-.52	45.00	3061.25	466.44	1015.25	1481.69
50.000	13399.58	704.72	3.78	11.22	-.52	42.75	3547.42	472.08	1011.87	1483.95
50.000	17000.22	705.45	4.37	11.95	-.52	40.50	3890.78	476.02	1009.50	1485.52
51.000	9540.00	707.24	5.35	5.34	3.93	50.00	1783.71	638.30	1019.41	1657.71
51.000	13178.56	708.14	5.59	6.24	3.93	47.50	2357.90	643.92	1016.86	1660.78
51.000	16719.80	708.85	5.94	6.95	3.93	45.00	2813.70	648.36	1014.85	1663.20
52.000	9540.00	716.81	2.65	9.61	1.82	50.00	3602.22	1111.26	1026.63	2361.09
52.000	13178.56	717.36	3.10	10.16	1.82	47.50	4247.13	1231.61	1025.77	2362.06
52.000	16719.80	717.78	3.51	10.58	1.82	45.00	4758.30	1311.66	1025.14	2362.77
53.000	9540.00	723.59	3.83	6.39	2.63	50.00	2488.24	502.18	1902.92	2405.09
53.000	13178.56	724.54	4.43	7.34	2.63	47.50	2973.93	515.97	1899.36	2415.33
53.000	16719.80	725.24	5.01	8.04	2.63	45.00	3336.01	526.02	1896.77	2422.78
54.000	9540.00	733.17	4.53	6.87	2.53	55.00	2108.08	476.59	1635.86	2112.45
54.000	13178.56	734.07	5.16	7.77	2.53	52.25	2553.50	515.72	1601.89	2117.61
54.000	16719.80	734.77	5.72	8.47	2.53	49.50	2924.45	543.71	1577.92	2121.62
55.000	9540.00	744.00	3.55	8.80	2.55	55.00	2686.93	626.11	1655.97	2282.08
55.000	13178.56	744.82	4.12	9.62	2.55	52.25	3200.02	632.05	1652.83	2284.89
55.000	16719.80	745.44	4.66	10.24	2.55	49.50	3591.28	636.55	1650.46	2287.01
56.000	9540.00	752.24	3.97	7.84	2.76	55.00	2401.48	472.33	1804.44	2276.77
56.000	13178.56	753.17	4.62	8.77	2.76	52.25	2651.02	502.62	1625.13	2280.88
56.000	16719.80	753.94	5.13	9.54	2.76	49.50	3259.08	551.35	1616.52	2284.32
57.000	9540.00	754.38	3.08	8.88	.95	50.00	3095.42	637.66	1118.84	1756.49
57.000	13178.56	755.34	3.55	9.84	.95	47.50	3713.41	646.38	1115.98	1762.36
57.000	16719.80	756.13	3.96	10.63	.95	45.00	4223.89	653.23	1113.91	1767.15
58.000	9540.00	763.89	5.09	6.99	2.57	50.00	1874.66	447.12	1394.65	1841.77
58.000	13178.56	764.65	5.93	7.75	2.57	47.50	2223.70	469.72	1389.25	1856.97
58.000	16719.80	765.19	6.72	8.29	2.57	45.00	2487.38	486.10	1385.34	1871.44
59.000	9540.00	786.01	3.89	10.21	2.18	50.00	2449.66	422.64	1148.32	1570.96
59.000	13178.56	787.14	4.48	11.34	2.18	47.50	2941.76	443.40	1132.93	1576.34
59.000	16719.80	787.99	5.04	12.19	2.18	45.00	3320.68	452.54	1127.81	1580.35
60.000	9540.00	818.79	4.97	10.29	2.27	55.00	1921.27	337.89	1175.69	1513.58
60.000	13178.56	819.86	5.75	11.36	2.27	52.25	2291.22	349.29	1167.08	1516.37
60.000	16719.80	820.67	6.49	12.17	2.27	49.50	2574.42	357.78	1160.67	1516.44

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
61.000	9540.00	832.94	4.25	13.44	1.78	55.00	2243.59	288.55	999.77	1288.33
61.000	13178.56	834.29	5.00	14.79	1.78	52.25	2638.25	293.25	999.10	1292.35
61.000	16719.80	835.34	5.67	15.84	1.78	49.50	2948.81	296.89	998.57	1295.47
62.000	9140.00	835.09	4.58	12.79	2.50	55.00	1997.04	304.71	999.41	1304.12
62.000	12626.00	836.43	5.24	14.13	2.50	52.25	2411.09	310.07	998.74	1308.80
62.000	16018.76	837.47	5.86	15.17	2.50	49.50	2735.66	314.20	998.22	1312.42
63.000	9140.00	837.51	4.46	10.31	4.41	55.00	2048.97	284.11	1002.31	1286.42
63.000	12626.00	838.79	5.23	11.59	4.41	52.25	2415.83	288.69	1000.45	1289.14
63.000	16018.76	839.79	5.92	12.59	4.41	49.50	2706.74	291.82	999.93	1291.75
64.000	9140.00	839.55	4.23	14.15	-1.73	55.00	2158.39	309.50	1001.44	1310.95
64.000	12626.00	840.86	4.92	15.46	-1.73	52.25	2568.27	315.23	999.98	1315.21
64.000	16018.76	841.87	5.54	16.47	-1.73	49.50	2890.23	317.64	999.88	1317.53
65.000	9140.00	841.47	7.60	5.37	19.11	55.00	1201.91	374.58	1005.39	1652.29
65.000	12626.00	842.59	7.70	6.49	19.11	52.25	1639.97	408.61	1000.86	1662.93
65.000	16018.76	843.46	8.00	7.36	19.11	49.50	2003.55	422.60	999.93	1665.52
66.000	9140.00	844.28	4.48	7.08	3.79	55.00	2040.85	496.00	999.89	1648.25
66.000	12626.00	845.10	5.11	7.90	3.79	52.25	2471.10	548.55	999.81	1649.98
66.000	16018.76	845.77	5.63	8.57	3.79	49.50	2847.18	589.46	999.74	1651.27
67.000	9140.00	848.37	3.68	7.77	2.10	55.00	2485.65	395.85	999.97	1395.82
67.000	12626.00	849.39	4.37	8.79	2.10	52.25	2891.55	397.68	999.87	1397.55
67.000	16018.76	850.14	5.02	9.54	2.10	49.50	3193.65	398.95	999.80	1398.74
68.000	9140.00	850.58	3.24	20.68	-5.35	55.00	2824.64	312.47	1030.10	1342.57
68.000	12626.00	851.85	3.91	21.95	-5.35	52.25	3228.06	322.16	1026.87	1349.03
68.000	16018.76	852.78	4.54	22.88	-5.35	49.50	3528.27	324.81	1024.40	1349.22

[1] Column Heading Descriptions:

SECNO	Identifying cross-section number.
Q	Total flow in the cross-section.
CWSEL	Computed water surface elevation.
VCH	Mean velocity in the channel.
DEPTH	Maximum depth of flow at the cross-section.
K*CHSL	Channel slope from current cross-section to next-downstream cross-section in
K*XNCH	Manning's n value used for the channel portion of the cross-section (times 1,000).
AREA	Cross-section area (area of flow).
TOPWID	Cross-section width at the calculated water surface elevation. Equal to sum of individual channel top widths.
SSTA	Starting survey station where the water surface intersects the ground on the left side.
ENDST	Ending survey station where the water surface intersects the ground on the right side. The difference between ENDST and SSTA gives the total distance from the left edge to the right edge of water.

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HEC2 RELEASE DATED NOV 76 UPDATED APRI 1980
ERROR CORR - 01,02,03,04
MODIFICATION - 50,51,52,53,54
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

LOWER SUSITNA RIVER--

SUMMARY PRINTOUT Table 4.20

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
3.000	35540.00	348.00	3.73	15.40	0.00	32.40	13046.19	3669.60	1610.11	5667.33
3.000	53565.89	348.50	4.98	15.90	0.00	32.40	14993.78	4022.57	1609.29	5669.19
3.000	24106.78	346.50	3.79	13.90	0.00	36.00	6352.64	1109.86	4000.00	5661.78
4.000	35540.00	353.06	4.78	9.06	2.16	32.40	7434.87	1760.93	3093.63	5795.81
4.000	53565.89	355.14	4.47	11.14	2.16	32.40	11989.02	2787.42	3090.33	5890.62
4.000	24106.78	352.25	3.95	8.25	2.16	36.00	6101.48	1573.96	3097.24	5794.59
5.000	35540.00	360.74	5.03	8.14	1.85	32.40	8322.29	1878.87	5106.53	7463.20
5.000	53565.89	362.01	5.88	9.41	1.85	32.40	10780.34	2062.18	5101.99	7466.16
5.000	24106.78	359.89	4.11	7.29	1.85	36.00	6747.72	1830.61	5108.22	7461.21
6.000	35540.00	365.26	4.79	8.16	1.41	32.40	7420.86	1411.74	6112.57	7685.65
6.000	53565.89	366.79	5.53	9.69	1.41	32.40	9679.82	1578.60	6110.02	7688.62
6.000	24106.78	364.46	3.83	7.36	1.41	36.00	6293.08	1403.00	6113.91	7684.10
7.000	35540.00	369.22	5.31	9.82	.79	32.40	6731.90	1391.34	1069.54	2460.89
7.000	53565.89	370.75	6.09	11.35	.79	32.40	8869.67	1398.96	1065.34	2464.24
7.000	24106.78	368.42	4.31	9.02	.79	36.00	5598.53	1357.04	1102.11	2459.15
8.000	35540.00	376.66	6.35	12.56	1.02	40.50	6579.15	862.19	3111.92	3974.11
8.000	53565.89	378.42	7.82	14.32	1.02	40.50	8114.27	873.44	3110.12	3983.56
8.000	24106.78	375.56	4.94	11.46	1.02	45.00	5633.41	855.32	3113.13	3968.46
9.000	35540.00	383.44	5.91	16.84	.51	40.50	6011.98	593.90	2052.76	2646.66
9.000	53565.89	386.22	6.89	19.62	.51	40.50	7773.55	649.79	2006.55	2656.34
9.000	24106.78	381.77	4.79	15.17	.51	45.00	5036.12	560.34	2080.35	2640.69
10.000	35540.00	395.45	5.92	9.25	2.60	40.50	6002.42	950.79	1124.24	2966.72
10.000	53565.89	397.84	6.45	11.64	2.60	40.50	8302.84	990.51	1120.29	2969.56
10.000	24106.78	394.15	5.05	7.95	2.60	45.00	4771.09	920.65	1131.59	2958.29

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
11.000	35540.00	413.14	5.64	12.14	1.45	40.50	6298.75	745.16	2019.61	2764.77
11.000	53565.89	415.10	6.89	14.10	1.45	40.50	7774.64	756.57	2010.47	2767.04
11.000	24106.78	412.01	4.41	11.01	1.45	45.00	5461.14	738.60	2024.86	2763.47
12.000	35540.00	426.37	6.41	11.97	1.47	40.50	5544.72	592.92	1076.44	1669.36
12.000	53565.89	429.16	7.42	14.76	1.47	40.50	7220.99	607.94	1069.05	1676.98
12.000	24106.78	424.75	5.25	10.35	1.47	45.00	4589.85	578.82	1082.25	1661.07
13.000	35540.00	442.56	6.27	16.06	1.18	40.50	5666.70	635.90	1059.88	2789.15
13.000	53565.89	445.87	6.43	19.37	1.18	40.50	8340.95	948.73	1053.90	2792.99
13.000	24106.78	440.76	5.22	14.26	1.18	45.00	4616.20	560.03	1063.13	2787.07
14.000	35540.00	447.77	5.27	10.57	3.79	40.50	6741.35	1165.10	1093.35	2578.21
14.000	53565.89	450.59	5.14	13.39	3.79	40.50	10416.54	1486.42	1090.33	2581.61
14.000	24106.78	446.34	4.72	9.14	3.79	45.00	5109.84	1082.90	1094.88	2573.36
15.000	35540.00	455.74	5.41	9.64	1.79	36.45	6573.93	939.44	1056.65	2326.70
15.000	53565.89	458.02	6.06	11.92	1.79	36.45	8842.68	1209.62	1053.02	2342.65
15.000	24106.78	454.78	4.25	8.68	1.79	40.50	5676.89	916.72	1058.19	2319.41
16.000	35540.00	459.37	5.24	9.67	1.33	32.40	6783.89	1223.96	1048.01	2966.26
16.000	53565.89	461.63	5.53	11.93	1.33	32.40	9682.96	1380.38	1044.66	2972.93
16.000	24106.78	458.31	4.38	8.61	1.33	36.00	5506.18	1182.10	1050.32	2962.54
17.000	35540.00	462.33	6.31	8.93	2.03	32.40	5629.66	1131.38	1051.16	2220.74
17.000	53565.89	464.02	7.04	10.62	2.03	32.40	7612.04	1178.38	1048.39	2226.77
17.000	24106.78	461.44	5.18	8.04	2.03	36.00	4657.30	1064.18	1052.61	2215.96
18.000	35540.00	464.85	6.42	11.95	-.29	32.40	5536.99	609.07	1070.94	1680.01
18.000	53565.89	466.61	8.10	13.71	-.29	32.40	6619.26	617.83	1068.42	1686.24
18.000	24106.78	463.78	4.93	10.88	-.29	36.00	4885.96	603.12	1072.47	1675.59
19.000	35540.00	490.71	8.14	9.01	1.60	32.40	4364.92	587.52	1584.87	2172.39
19.000	53565.89	493.53	8.86	11.83	1.60	32.40	6053.26	608.86	1488.81	2184.79
19.000	24106.78	489.04	7.08	7.34	1.60	36.00	3487.32	559.45	1601.28	2160.72
20.000	35540.00	498.95	5.13	15.65	.39	32.40	6922.30	1436.76	1320.02	3704.07
20.000	53565.89	501.12	4.86	17.82	.39	32.40	11031.41	2398.05	1316.43	3714.48
20.000	24106.78	497.82	4.45	14.52	.39	36.00	5421.20	1204.59	1321.88	3697.68
21.000	35540.00	514.92	5.94	14.02	1.72	32.40	6002.20	1027.89	1046.89	2074.79
21.000	53565.89	516.54	7.00	15.64	1.72	32.40	7691.19	1037.80	1043.60	2081.40
21.000	24106.78	513.37	5.22	12.47	1.72	36.00	4618.36	774.94	1050.61	2068.53
22.000	35540.00	515.91	7.22	12.51	2.78	24.30	4920.64	728.70	1130.78	2375.98
22.000	53565.89	517.50	8.79	14.10	2.78	24.30	6093.98	741.65	1127.59	2379.05
22.000	24106.78	514.47	6.18	11.07	2.78	27.00	3900.68	690.11	1133.64	2347.00
23.000	35540.00	522.63	7.88	7.13	2.46	24.30	4510.70	852.63	1349.16	2707.96
23.000	53565.89	524.51	8.66	9.01	2.46	24.30	6182.55	927.75	1343.86	2729.40
23.000	24106.78	521.75	6.39	6.25	2.46	27.00	3775.18	824.56	1353.39	2619.36

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
24.000	34500.00	525.41	8.25	17.81	-3.66	24.30	4180.41	469.65	1113.31	1582.97
24.000	51998.40	527.21	10.34	19.61	-3.66	24.30	5028.30	474.92	1111.58	1586.50
24.000	23401.35	524.33	6.37	16.73	-3.66	27.00	3674.19	462.70	1117.24	1579.95
24.500	34500.00	529.47	6.24	11.47	3.25	24.30	5526.63	1124.93	2661.37	4188.93
24.500	51998.40	531.91	5.86	13.91	3.25	24.30	8868.36	1615.48	2563.73	4194.77
24.500	23401.35	528.09	5.72	10.09	3.25	27.00	4089.73	968.96	2709.11	4186.18
25.000	34500.00	533.36	8.39	7.16	4.39	24.30	5033.87	1646.35	1657.86	4221.40
25.000	51998.40	534.80	9.04	8.60	4.39	24.30	7555.55	1846.89	1546.17	4226.10
25.000	23401.35	532.74	6.76	6.54	4.39	27.00	4040.52	1475.15	1658.82	4219.32
26.000	34500.00	542.76	6.67	10.66	1.18	26.35	5172.87	605.85	2512.60	3118.45
26.000	51998.40	544.55	8.31	12.45	1.18	26.35	6258.30	608.72	2510.61	3119.33
26.000	23401.35	541.54	5.27	9.44	1.18	31.50	4440.28	598.82	2516.44	3115.25
27.000	34500.00	547.06	8.37	13.26	.44	26.35	4120.75	496.59	2331.85	2828.45
27.000	51998.40	549.40	9.80	15.60	.44	26.35	5307.85	510.81	2322.54	2833.34
27.000	23401.35	545.70	6.77	11.90	.44	31.50	3456.47	482.23	2338.74	2820.97
28.000	34500.00	558.15	6.81	10.15	2.44	28.35	5853.44	1304.41	1169.31	2727.57
28.000	51998.40	560.05	7.03	12.05	2.44	28.35	8538.75	1520.29	1012.39	2728.53
28.000	23401.35	557.06	5.86	9.06	2.44	31.50	4531.72	1148.20	1174.13	2727.03
29.000	34500.00	574.24	7.67	10.94	1.71	28.35	4500.10	607.69	3462.73	4070.42
29.000	51998.40	575.84	9.50	12.54	1.71	28.35	5476.10	612.52	3458.81	4071.33
29.000	23401.35	573.26	5.99	9.96	1.71	31.50	3906.58	604.02	3465.13	4069.15
30.000	34500.00	588.05	4.89	9.65	2.06	30.78	7068.45	2266.04	1016.86	4457.47
30.000	51998.40	589.41	5.01	11.01	2.06	30.78	10431.14	2566.44	1000.00	4458.25
30.000	23401.35	587.25	4.37	8.85	2.06	34.20	5358.32	2034.62	1182.91	4457.02
31.000	34500.00	598.35	6.38	11.55	1.37	30.78	5405.41	786.60	2082.38	3922.71
31.000	51998.40	599.67	8.03	12.87	1.37	30.78	6478.76	850.14	2078.76	3927.68
31.000	23401.35	597.55	4.90	10.75	1.37	34.20	4778.71	774.46	2084.58	3918.10
32.000	34500.00	608.93	7.65	6.98	2.84	30.78	5462.69	1259.28	3428.80	4721.15
32.000	51998.40	610.84	8.06	8.89	2.84	30.78	7979.08	1358.80	3252.88	4730.55
32.000	23401.35	607.77	6.85	5.82	2.84	34.20	4065.85	1147.38	3436.47	4708.45
33.000	34500.00	614.95	5.69	8.45	1.91	29.24	7816.14	1964.43	1077.53	4412.61
33.000	51998.40	616.09	6.75	9.59	1.91	29.24	10320.81	2418.24	1000.96	4420.54
33.000	23401.35	614.24	4.51	7.74	1.91	32.49	6497.99	1818.19	1079.03	4407.68
34.000	34500.00	619.02	6.91	10.12	1.13	29.24	4995.74	993.46	1168.12	2491.94
34.000	51998.40	620.39	8.08	11.49	1.13	29.24	6437.04	1078.06	1162.53	2503.05
34.000	23401.35	618.01	5.71	9.11	1.13	32.49	4097.94	828.88	1172.23	2483.76
35.000	34500.00	621.57	8.12	16.07	-1.88	29.24	4247.79	407.27	1384.05	1791.32
35.000	51998.40	623.34	10.44	17.84	-1.88	29.24	4980.84	417.44	1379.82	1797.27
35.000	23401.35	620.27	6.28	14.77	-1.88	32.49	3726.20	394.46	1388.81	1783.27

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
36.000	34500.00	624.19	5.35	10.19	5.09	29.24	6448.95	1255.04	1459.51	2866.53
36.000	51998.40	626.55	5.52	12.55	5.09	29.24	9461.90	1332.49	1455.59	2911.47
36.000	23401.35	622.74	5.04	8.74	5.09	32.49	4644.64	1199.23	1464.46	2863.02
37.000	34500.00	629.39	9.41	10.59	1.47	29.24	3969.96	947.82	1052.64	2312.17
37.000	51998.40	630.44	12.02	11.64	1.47	29.24	5085.93	1170.73	1050.43	2313.10
37.000	23401.35	628.94	6.86	10.14	1.47	32.49	3577.02	756.77	1053.58	2172.48
38.000	34500.00	643.35	6.82	8.65	2.75	29.24	5055.17	952.10	1204.68	2837.64
38.000	51998.40	645.60	6.98	10.90	2.75	29.24	7452.71	1166.44	1201.74	2843.07
38.000	23401.35	641.79	6.36	7.09	2.75	32.49	3679.71	800.91	1229.07	2833.90
39.000	34500.00	648.22	7.18	7.22	2.78	29.24	4805.09	988.53	1764.56	2907.26
39.000	51998.40	649.74	8.21	8.74	2.78	29.24	6337.27	1032.75	1762.78	2912.40
39.000	23401.35	647.46	5.77	6.46	2.78	32.49	4053.59	965.73	1765.47	2904.65
40.000	34500.00	658.64	7.67	8.64	1.80	30.78	4495.66	623.64	1080.96	1704.60
40.000	51998.40	660.40	9.29	10.40	1.80	30.78	5599.58	629.75	1076.17	1705.92
40.000	23401.35	657.53	6.14	7.53	1.80	34.20	3809.52	611.33	1083.97	1703.77
41.000	34500.00	663.56	5.95	13.16	.17	30.78	5801.03	1284.48	1154.75	3031.59
41.000	51998.40	665.67	5.71	15.27	.17	30.78	9110.71	1883.67	1152.01	3035.67
41.000	23401.35	662.28	5.45	11.88	.17	34.20	4292.82	988.90	1156.38	3029.15
42.000	34500.00	671.11	6.19	7.21	4.01	30.78	6464.38	1659.22	1240.99	3011.68
42.000	51998.40	672.38	6.95	8.48	4.01	30.78	8683.62	1776.03	1239.42	3015.45
42.000	23401.35	670.38	5.07	6.48	4.01	34.20	5281.64	1587.95	1241.89	3009.54
43.000	34500.00	675.42	7.77	17.82	-3.32	32.40	4440.13	656.52	2437.62	3226.66
43.000	51998.40	677.08	9.14	19.48	-3.32	32.40	5692.48	793.40	2434.38	3227.79
43.000	23401.35	674.10	6.34	16.50	-3.32	36.00	3691.97	499.12	2444.23	3224.18
43.500	34500.00	678.96	8.77	14.46	4.93	32.40	3932.58	614.20	2812.66	3426.86
43.500	51998.40	681.26	9.41	16.76	4.93	32.40	5525.87	788.70	2639.87	3428.56
43.500	23401.35	677.04	7.96	12.54	4.93	36.00	2941.70	465.37	2953.70	3419.08
44.000	34500.00	685.32	7.13	10.72	4.59	32.40	4836.06	841.73	2350.04	3431.44
44.000	51998.40	687.27	7.99	12.67	4.59	32.40	6504.32	868.93	2342.46	3436.38
44.000	23401.35	684.09	6.13	9.49	4.59	36.00	3820.12	820.18	2354.79	3425.06
45.000	34500.00	688.10	9.13	14.60	-.75	32.40	3909.87	437.41	1173.57	1610.97
45.000	51998.40	689.90	11.53	16.40	-.75	32.40	4710.72	449.60	1169.56	1619.16
45.000	23401.35	687.01	6.97	13.51	-.75	36.00	3442.46	424.32	1175.98	1600.30
46.000	34500.00	692.04	8.90	10.64	5.27	36.45	5135.80	838.51	1127.58	2066.95
46.000	51998.40	694.86	9.28	13.46	5.27	36.45	7685.18	953.01	399.95	2069.95
46.000	23401.35	690.47	7.71	9.07	5.27	40.50	3844.72	808.08	1140.38	2065.29
47.000	34500.00	694.57	8.61	12.67	.49	32.40	5138.20	795.05	1214.79	2541.06
47.000	51998.40	696.96	9.69	15.06	.49	32.40	7196.65	1139.17	715.23	2543.09
47.000	23401.35	693.24	7.00	11.34	.49	36.00	4123.66	728.45	1219.04	2535.72

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
48.000	34500.00	697.18	6.95	11.88	2.57	32.40	6676.48	1214.96	1042.95	2439.31
48.000	51998.40	699.51	7.66	14.21	2.57	32.40	9751.40	1382.31	554.55	2448.91
48.000	23401.35	695.74	5.86	10.44	2.57	36.00	5072.34	1013.62	1054.16	2433.37
49.000	34500.00	705.37	7.08	11.17	2.06	32.40	4871.41	904.58	1204.59	2109.17
49.000	51998.40	706.90	8.31	12.70	2.06	32.40	6264.75	907.57	1202.56	2110.13
49.000	23401.35	704.45	5.80	10.25	2.06	36.00	4037.85	880.24	1205.81	2091.83
50.000	34500.00	707.79	6.87	14.29	-.52	36.45	5022.11	493.58	1004.96	1498.54
50.000	51998.40	709.72	8.63	16.22	-.52	36.45	6122.84	844.58	1001.86	1936.50
50.000	23401.35	706.66	5.23	13.16	-.52	40.50	4475.59	481.40	1006.78	1488.18
51.000	33910.00	711.69	7.24	9.79	3.93	40.50	4681.94	665.70	1006.74	1672.44
51.000	51109.15	714.32	7.93	12.42	3.93	40.50	6444.44	675.10	1003.59	1678.69
51.000	23001.15	710.25	6.17	8.35	3.93	45.00	3727.63	657.15	1010.85	1668.00
52.000	33910.00	719.12	4.65	11.92	1.82	40.50	8354.80	1884.81	1023.09	3173.62
52.000	51109.15	720.75	5.14	13.55	1.82	40.50	11449.52	1943.58	1020.71	3177.78
52.000	23001.15	718.30	3.81	11.10	1.82	45.00	6814.46	1879.27	1024.31	3171.53
53.000	33910.00	727.30	7.62	10.10	2.63	40.50	4447.33	555.72	1889.11	2444.83
53.000	51109.15	728.89	9.56	11.69	2.63	40.50	5345.44	574.34	1884.49	2458.83
53.000	23001.15	726.27	5.92	9.07	2.63	45.00	3867.86	540.97	1892.91	2433.88
54.000	33910.00	737.41	6.93	11.11	2.53	44.55	5798.12	913.34	1146.52	2131.93
54.000	51109.15	739.86	7.63	13.56	2.53	44.55	8083.56	978.26	1140.54	2134.19
54.000	23001.15	736.00	5.87	9.70	2.53	49.50	4516.07	901.03	1150.33	2128.72
55.000	33910.00	747.20	6.63	12.00	2.55	44.55	5835.09	976.99	998.37	2291.53
55.000	51109.15	748.95	7.77	13.75	2.55	44.55	7923.62	1295.52	997.52	2293.03
55.000	23001.15	746.19	5.31	10.99	2.55	49.50	4847.53	950.91	998.88	2289.58
56.000	33910.00	756.74	6.74	12.34	2.76	44.55	5029.01	692.01	1601.70	2293.71
56.000	51109.15	758.74	7.95	14.34	2.76	44.55	6427.98	707.25	1588.16	2295.40
56.000	23001.15	755.40	5.58	11.00	2.76	49.50	4125.73	637.85	1605.37	2290.77
57.000	33910.00	759.03	5.52	13.53	.95	40.50	6144.61	666.86	1111.80	1778.67
57.000	51109.15	761.25	6.70	15.75	.95	40.50	7632.32	669.80	1110.18	1779.99
57.000	23001.15	757.60	4.43	12.10	.95	45.00	5192.30	663.27	1112.84	1776.12
58.000	33910.00	767.53	8.40	10.63	2.57	40.50	4502.29	755.21	998.93	1924.15
58.000	51109.15	769.88	9.03	12.98	2.57	40.50	6401.05	874.39	997.56	1935.28
58.000	23001.15	766.24	7.05	9.34	2.57	45.00	3562.06	705.79	999.68	1895.06
59.000	33910.00	790.92	7.23	15.12	2.18	40.50	4690.44	476.55	1113.91	1590.46
59.000	51109.15	793.25	8.79	17.45	2.18	40.50	5811.50	484.02	1110.79	1594.81
59.000	23001.15	789.41	5.79	13.61	2.18	45.00	3975.73	467.92	1119.18	1587.10
60.000	33910.00	823.84	9.01	15.34	2.27	40.50	3762.24	389.15	1136.66	1525.81
60.000	51109.15	827.04	10.17	18.54	2.27	40.50	5034.33	405.89	1123.99	1529.88
60.000	23001.15	822.09	7.43	13.59	2.27	45.00	3094.36	372.85	1149.28	1522.13

SECNO	Q	CWSEL	VCH	DEPTH	K*CHSL	K*XNCH	AREA	TOPWID	SSTA	ENDST
61.000	33910.00	838.57	8.64	19.07	1.78	40.50	3923.10	308.05	996.97	1305.02
61.000	51109.15	841.69	10.45	22.19	1.78	40.50	4895.63	312.75	995.40	1308.15
61.000	23001.15	836.61	6.91	17.11	1.78	45.00	3327.74	301.28	997.94	1299.22
62.000	32500.00	840.85	8.51	18.55	2.50	40.50	3817.62	324.69	996.54	1321.23
62.000	48984.00	844.23	9.94	21.93	2.50	40.50	4929.16	331.85	994.85	1326.70
62.000	22044.75	838.82	6.97	16.52	2.50	45.00	3161.08	319.15	997.55	1316.70
63.000	32500.00	843.12	8.80	15.92	4.41	40.50	3695.20	301.94	999.60	1301.54
63.000	48984.00	846.52	10.35	19.32	4.41	40.50	4734.35	308.91	999.26	1308.17
63.000	22044.75	841.14	7.11	13.94	4.41	45.00	3100.68	295.90	999.80	1295.69
64.000	32500.00	845.33	8.12	19.93	-1.73	40.50	4001.40	324.81	999.54	1324.35
64.000	48984.00	848.88	9.48	23.48	-1.73	40.50	5164.58	330.89	999.18	1330.07
64.000	22044.75	843.27	6.61	17.87	-1.73	45.00	3336.77	320.54	999.74	1320.29
65.000	32500.00	846.87	8.66	10.77	19.11	40.50	3752.32	665.40	999.59	1672.35
65.000	48984.00	850.53	7.87	14.43	19.11	40.50	6222.44	680.43	999.23	1679.65
65.000	22044.75	844.74	8.59	8.64	19.11	45.00	2567.18	471.49	999.81	1668.09
66.000	32500.00	848.43	7.13	11.23	3.79	40.50	4557.75	657.01	999.48	1656.49
66.000	48984.00	851.26	7.62	14.06	3.79	40.50	6424.76	662.83	999.19	1662.02
66.000	22044.75	846.82	6.28	9.62	3.79	45.00	3508.95	653.72	999.64	1653.35
67.000	32500.00	852.36	7.97	11.76	2.10	40.50	4080.10	402.64	999.57	1402.21
67.000	48984.00	854.63	9.80	14.03	2.10	40.50	4998.21	405.22	999.35	1404.57
67.000	22044.75	851.12	6.15	10.52	2.10	45.00	3582.29	400.57	999.70	1400.27
68.000	32500.00	855.76	7.21	25.86	-5.35	40.50	4508.03	333.56	1016.26	1349.81
68.000	48984.00	858.74	8.89	28.84	-5.35	40.50	5513.79	342.30	1008.11	1350.41
68.000	22044.75	854.03	5.60	24.13	-5.35	45.00	3934.75	328.47	1021.00	1349.47

[1] Column Heading Descriptions:

SECNO	Identifying cross-section number.	K*XNCH	Manning's n value used for the channel portion of the cross-section (times 1,000).
Q	Total flow in the cross-section.	AREA	Cross-section area (area of flow).
CWSEL	Computed water surface elevation.	TOPWID	Cross-section width at the calculated water surface elevation. Equal to sum of individual channel top widths.
VCH	Mean velocity in the channel.	SSTA	Starting survey station where the water surface intersects the ground on the left side.
DEPTH	Maximum depth of flow at the cross-section.	ENDST	Ending survey station where the water surface intersects the ground on the right side. The difference between ENDST and SSTA gives the total distance from the left edge to the right edge of water.
K*CHSL	Channel slope from current cross-section		

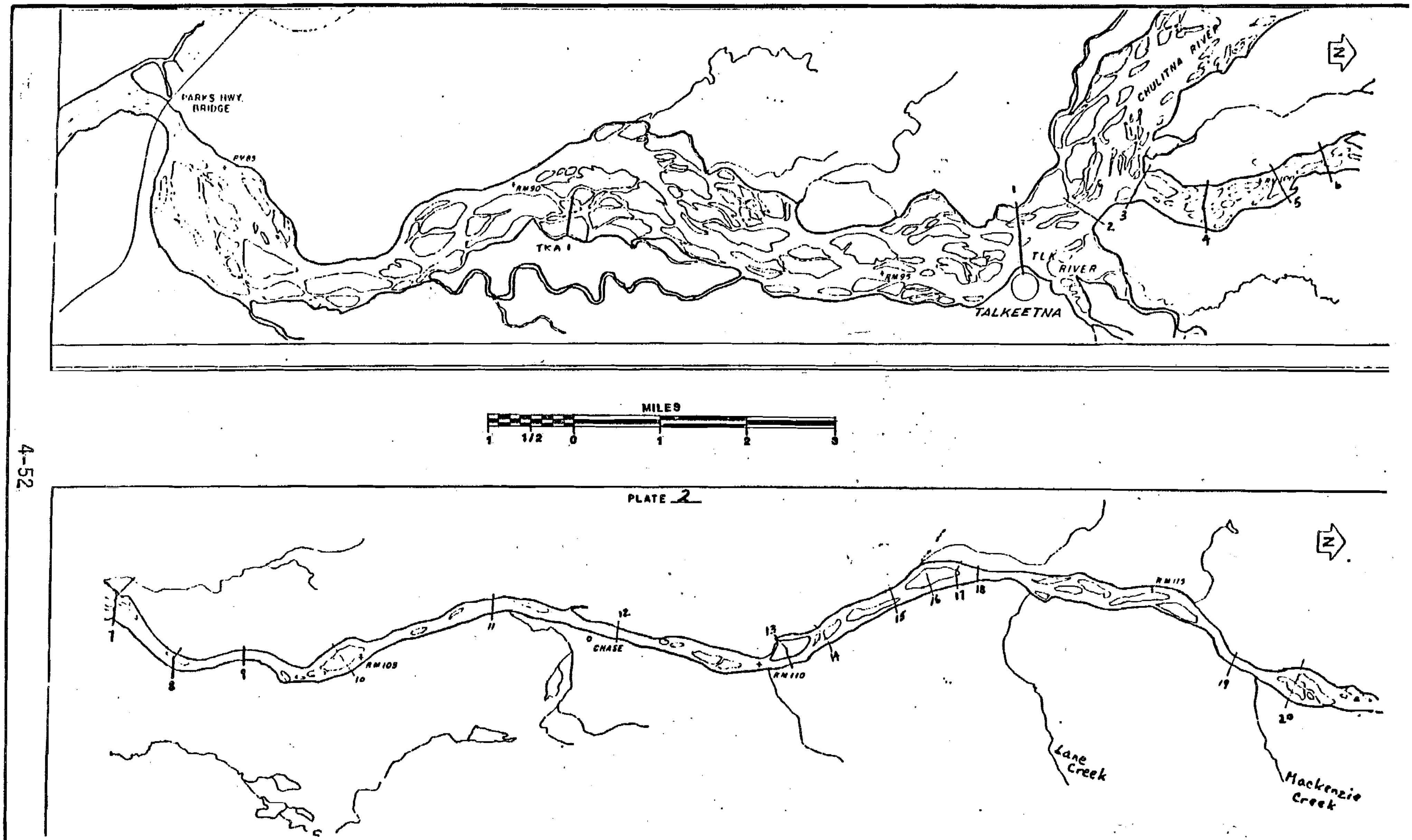

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FIGURE 4.1 RIVER CROSS-SECTION LOCATIONS

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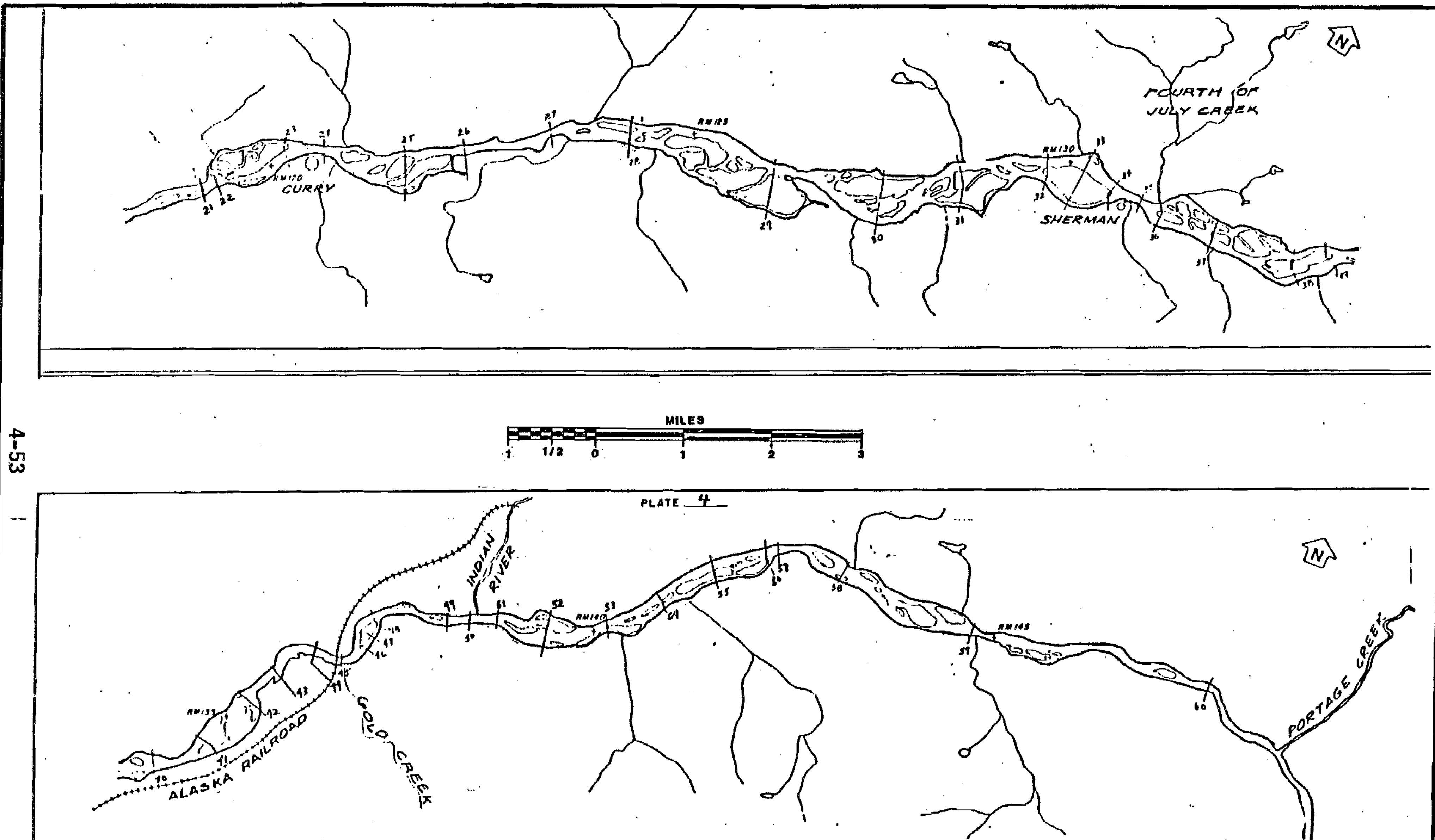

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FIGURE 4.1 CONTINUED

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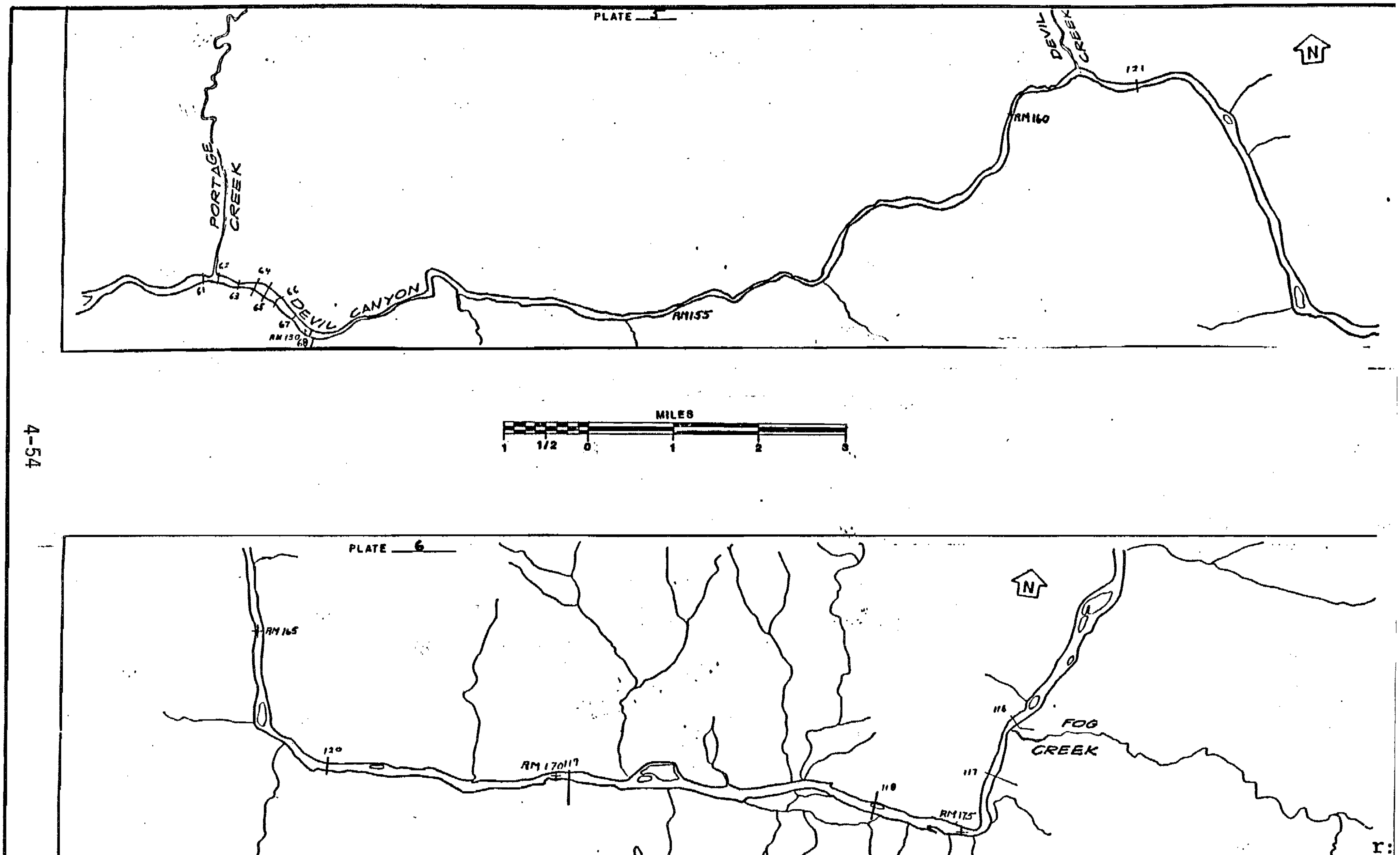

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FIGURE 4.1 CONTINUED

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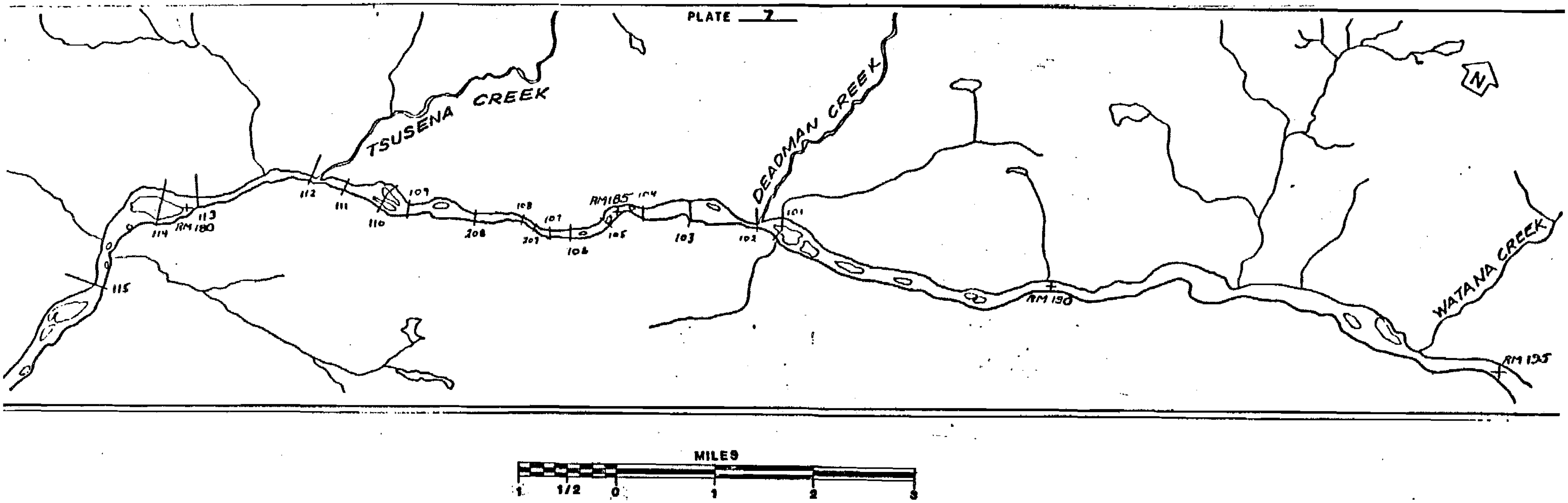

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FIGURE 4.1 CONTINUED

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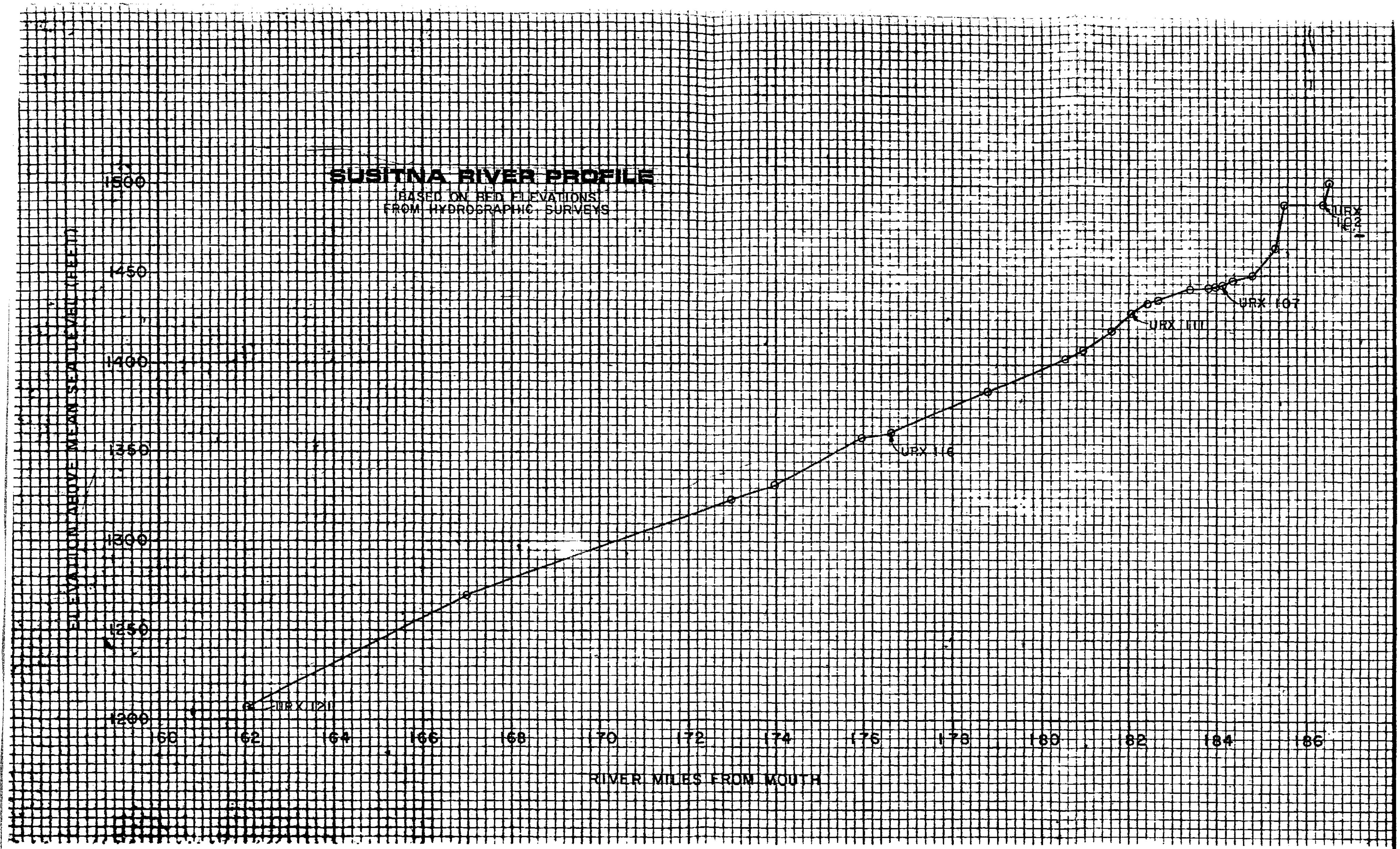

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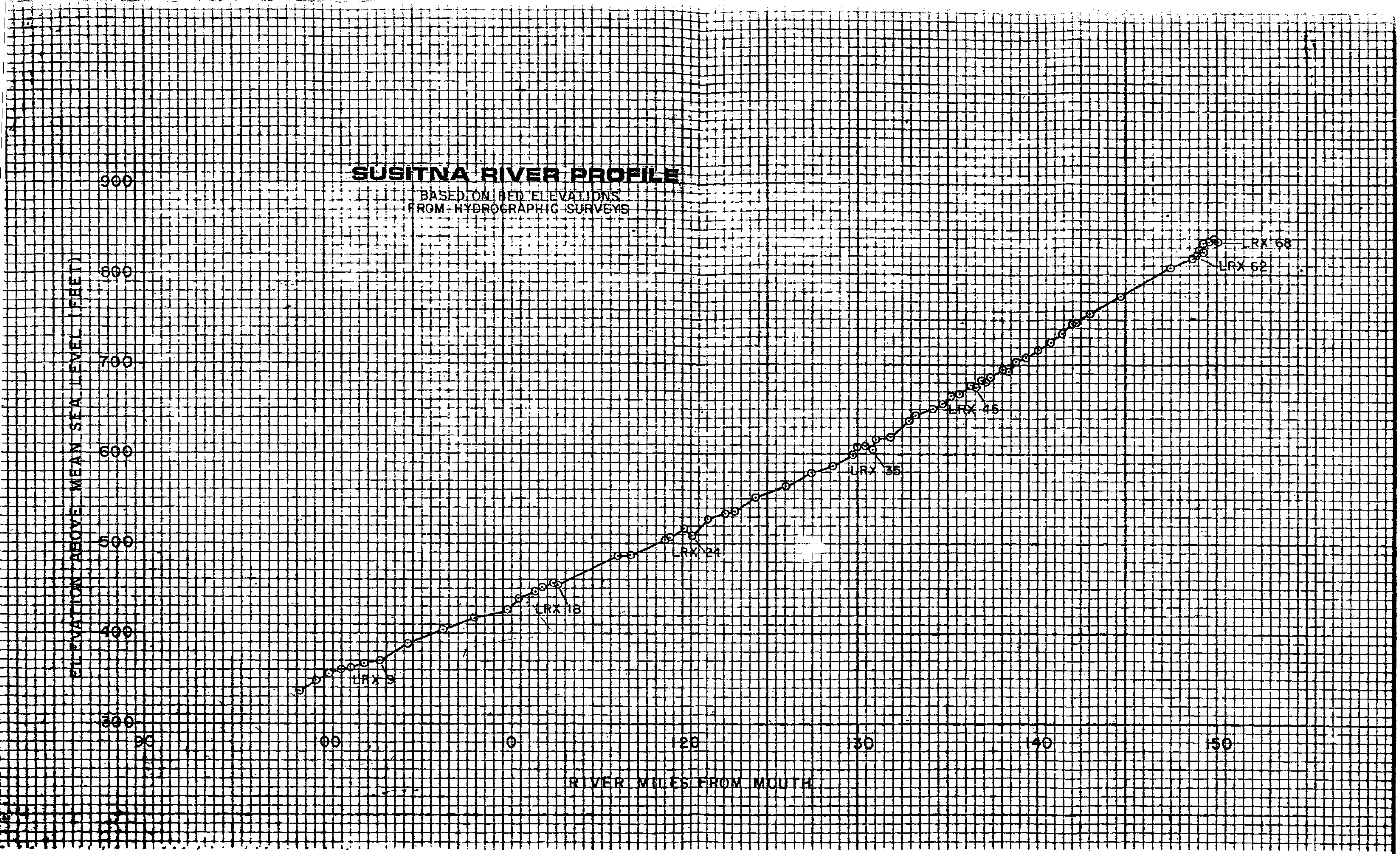
LONGITUDINAL RIVER PROFILE FROM DEADMAN CREEK TO DEVIL CREEK

FIG. 4.2



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LONGITUDINAL RIVER PROFILE FROM DEVIL CANYON TO TALKEETNA

PREPARED FOR:

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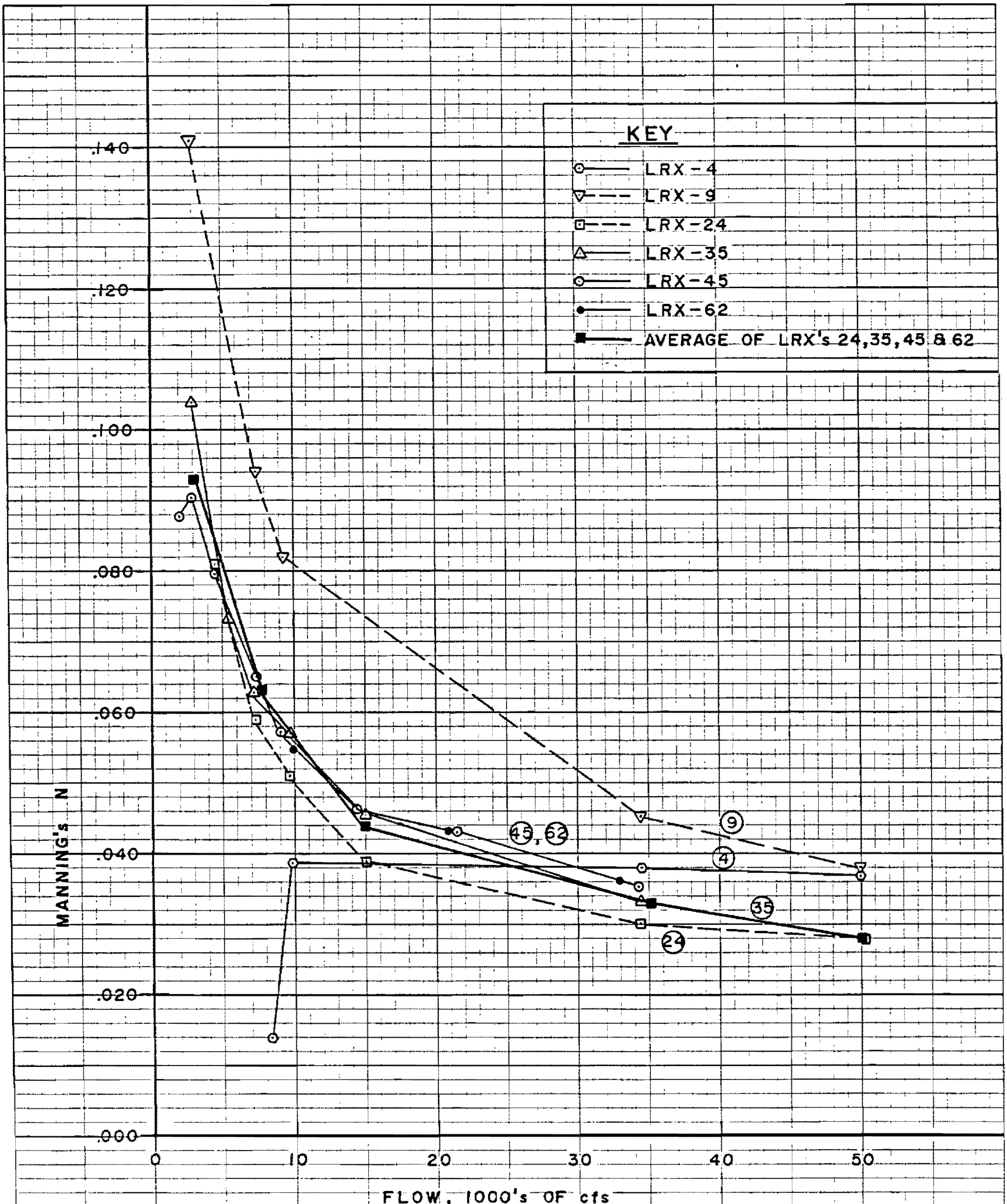
FIG. 4.3



MANNING's N AS A FUNCTION OF DISCHARGE, MIDDLE SUSITNA RIVER

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 4.4

ACRES

5 - ICE PROCESS ANALYSES

Geographically, the Susitna River upstream from Talkeetna can be divided into three major segments. The upper segment above the Oshetna confluence, the middle segment reaching to just below Devil Canyon, and the lower segment from near Indian River to Talkeetna.

The upper segment flows southward from its various glacial origins near latitude 63°30'N for some 90 miles to latitude 62°40'N. The elevation in this segment decreases from about 2,600 feet at the toes of the glaciers (which rise to above 10,000 feet) to 2,150 feet. This is a fall of sime 450 feet at an average slope of about 5 ft/mile. No notable concentration of fall occurs in this segment.

The middle segment flows westward with a slight northward trend for about 90 miles from the Oshetna River confluence near longitude 147°25'W to the downstream end of Devil Canyon (Indian River confluence) at 140°25'W and 62°50'N. The fall in this segment is about 1,350 feet to elevation 800 feet, providing an average slope of 15 ft/mile. Concentrations of the fall in the middle segment occur in four reaches: at the Oshetna River, at Vee Canyon, just below Devil Creek, and in particular, at Devil Canyon.

The lower segment flows in a south-southwesterly direction for about 40 miles from Indian River to near the town of Talkeetna at 150°05'W and 62°20'N. The fall in this segment is about 450 feet to elevation 350 feet at an average slope of about 11 ft/mile. No notable concentration of fall occurs in this segment.

Downstream to Talkeetna where the Susitna flow conjoins with those of the Chulitna and Talkeetna Rivers, the Susitna's course is southward for 75 miles to sea level at Cook inlet at 61°20'N with an average slope of 5 ft/mile. No concentration of fall occurs in this southern segment of the river.

5.1 - Field Observations

The geographic orientation of the river on the south slope of the Alaska Range results in air temperatures increasing along its course from the headwaters to the lower reaches. Whereas this temperature gradient may be due in part to the 2-degree latitudinal span of the river, it is probably due primarily to the 3,300-foot altitudinal difference from the lower to the upper reaches, as well as to the proximity of climate-moderating ocean waters to the lower reaches. In any case, the gradient gives rise to a period of time in the early stages of freezeup (late October-early November) in which the lower basin temperatures are above the freezing point while the upper basin is at subfreezing temperatures. This was the situation observed on October 17, 1980, with late afternoon temperatures (4:30 p.m. ADT) above Watana being 30°F or lower while the temperature at Talkeetna was at about 39°F. Presumably, a similar springtime period occurs with temperatures straddling the freezing point at some intermediate point in the basin. This point would move in an upstream direction with upward trending temperatures (i.e. springtime) and downstream with downward trending temperatures (i.e. autumn). In both cases, this pattern of temperature affects the sequence and timing of ice cover events.

As noted, on October 16 and 17, 1980, the foregoing autumn temperature situation was seen to prevail. Glacial melt from the headwaters cooled enough in its course through the relatively mild slope of the upper segment of the river to produce notable quantities of frazil flock and slush pans (15-25 percent surface coverage) under post-dawn air temperatures of 18°F to 14°F. In the fast-flowing rapids of the middle segment, relatively large quantities of frazil were being produced, which augmented the inflow of ice from upstream loading, to surface coverage of the river as high as 75-85 percent. As inflows from major tributaries along the source of the upper and middle segments had little, if any, ice content, the near-freezing temperature of the glacial melt is judged to be a significant determinant of the origin of ice from which a cover will develop and, therefore, of the timing of that development. Thus, the summer collection and storage of heat in the proposed reservoirs in the upper reaches of the river will produce significant changes in the autumn temperature regime in the downstream reaches and, therefore, in the timing and rate of cover development.

Details of the observations made during the river freeze-up (1980) and breakup (1981) may be found in the Ice Observations report (R&M, 1981b).

5.2 - Modeling of Ice Processes

(a) Description of the Computer Models

Acres' in-house computer models HEATSIM and ICESIM were used to simulate the ice processes in the river reach above Talkeetna. HEATSIM simulates a daily heat balance in the river reach to determine water temperature progressively downstream. Details of the model and its calibration to simulate Susitna river reaches are presented in Appendix A4 to the main Feasibility Report. The model is used to predict water temperature in the river and to determine the approximate location and time when water temperature reaches 32°F. This location is used as input to the ICESIM model which simulates the formation and progression of an ice cover and the water levels associated with the processes. The following paragraphs describe the ICESIM model in some detail.

ICESIM Model Input

Input data to the ICESIM model include streamflow, river cross-sectional details, and an estimate of ice flow into the study reach. Physical coefficients such as ice density, cohesion, and ice cover friction (Manning's n) are also input to the program. Standard values available in the literature are used in the model. Aspects of flow characteristics such as ice erosion velocity and critical Froude number for ice cover progression should also be defined. Based on the literature and field observations made in 1980-81, values were estimated for these parameters and are listed in Table 5.1.

Model Backwater Calculations

The ICESIM model includes a subroutine which calculates backwater profiles in the river reach to assess water levels at different cross-sections. The routine is similar to the HEC-2 model described in Section 4 but is less sophisticated with respect to hydraulic computations in order to accommodate the complexities of the ice process simulation. Effectively, this simplicity translates to less precise water level calculations (±1 to 2 feet), as compared to HEC-2 modeling accuracy which is to better than ±1', but it is considered adequate to provide representative results. This model was calibrated against the HEC-2 model results for a single river discharge as discussed below.

Historically, freezeup has started at a river discharge of around 4,000 cfs at Gold Creek in the end of October and progressed above Talkeetna until late November/ early December when the discharge dropped below 3,000 cfs. Calibrating the backwater routine with observed water levels for a river discharge of around 3,000 cfs at Gold Creek proved exceedingly difficult due to critical or near-critical flow conditions encountered in the river reach analyzed. Post-project winter discharges will be considerably higher (around 10,000 cfs) as discussed in Appendix A1 to the main Feasibility Report. It was therefore decided that the backwater routine should be calibrated against the HEC-2 model results for a discharge close to the 10,000 cfs. Field measurements of water levels in the river reach had been made for a natural streamflow of 9,700 cfs (at Gold Creek) and have been used in the calibration of the HEC-2 model (Section 4). It was considered appropriate to use this discharge to calibrate the backwater routine of the ICESIM model as well. A comparison of the HEC-2 and ICESIM routine calculations is presented in Table 5.2 which indicates a reasonable agreement between the two model results.

Modeling of Ice Cover Formation and Progression

The model simulates the formation and progression upstream of the ice cover given the location of the leading edge of ice cover and the time of its occurrence. The model checks the stability of ice cover and adjusts its thickness consistent with ice supply, river goemetry, and hydraulics of the flow. The ice thickness is adjusted either by telescoping of the cover or by thickening, and the model proceeds to the next section upstream. Except for occasional minor bridging, the steep river slope in the reach does not permit ice progression by bridging. This is also generally confirmed by the river observations in 1980-81.

Model Calibration

An attempt was made to calibrate the ice process simulation model with the field data collected during the 1980 river freezeup period. It became apparent that the model could not simulate numerous critical or near-critical flows that occur in the river, due to the relatively large lengths of subreaches modeled. Several intermediate river cross-sections were synthesized between surveyed sections to reduce these subreach lengths. Nevertheless, the model has been used to simulate ice formation and progression at average post-project winter flows. Several qualitative checks have been made to assess the accuracy of this simulation. These include general heat balance of the river waters, river hydraulic characteristics as observed in the field, and comparisons with similar studies elsewhere in the northern climate.

It must be emphasized that precision of predicted water levels in the river under post-project ice conditions is rather limited (±1 to 2 feet). However, the width of the uncertainty band in the modeling does not have a significant impact on the simulation of the ice regime of the river above the Talkeetna confluence, due to limited progression (see Section 5.3).

5.3 - Results of Simulation Studies

Studies were conducted for the following stages of project developments:

- During construction of the Watana dam.
- Only Watana development operational.
- Both Watana and Devil Canyon developments operational.

(a) Watana Construction Stage

During this stage, no significant change in the river regime is expected since natural flows in the river below the damsite will be maintained with the proposed diversion facilities. No simulation of this condition was carried out.

(b) Operation with Watana Development Only

Heat balance analyses were made using the HEATSIM model in the 35-mile river stretch between Watana and Devil Canyon damsites. The analyses indicated that the temperature of the power flow from Watana would reach close to 32°F below Devil Canyon by about the third week of November under average climatic conditions. This is about a month later than under natural conditions and would delay the ice progression above Talkeetna by a similar interval. It was determined that an ice cover will be formed above the Chulitna confluence around the end of November with ice generated from the reach below Watana damsite. Ice simulation studies indicated that the ice front progressed upstream at roughly 0.3 miles/day, a rate less than one-eighth of that observed in 1980 (Table 5.3). The front reached some 15 miles upstream by the end of January, after which a thermal decay of the ice cover is expected due to increased air temperature and reduced cooling of the power flow from Watana. The ice cover formed in the reach above Talkeetna is expected to melt in place by the end of March, and the decay will proceed further downstream thereafter. It is unlikely that any ice jam of significance will occur above the Chulitna confluence.

Below the confluence, it is speculated that ice cover formation will be delayed by one to three weeks due to lower and delayed supply of ice from the Susitna, but progression of the ice front would not significantly differ from that under natural conditions. However, the decay of the ice cover is expected to start earlier, by the end of March, due to warmer waters from the power development. Significant increase in water temperature from that under natural conditions is not expected near the river mouth.

(c) Operation with Watana and Devil Canyon

When both developments are operational, the temperature of power outflows from Devil Canyon is expected to be close to 39°F during the winter months (see Appendix A4 to the main Feasibility Report). As it progresses downstream, water becomes cooler from heat exchange with the atmosphere. By early January, it is expected that this water will cool to about 32°F near Talkeenta (see Figure 5.1). It is expected that very little ice cover will be formed in the river reach above Talkeetna under average weather conditions.

Due to the warmer water temperatures above the confluence, ice cover formation and progress in the lower river will also be delayed. It is expected that ice contribution from the Chulitna, Talkeetna, and Yentna Rivers will cause an ice cover to be formed in the lower river, but this cannot be quantified at this time without field data on such ice contributions and further observations of river freezeup phenomena.

(d) River Water Levels Under Ice Cover Conditions

Under natural conditions, significant staging occurs at several points in the river during ice cover formation. Table 5.4 presents staging observations made during the 1980 freezeup period for selected locations in the river. With increased flows in the winter under post-project conditions, a significant rise in water level during ice cover formation can be expected near Talkeetna. Table 5.5 presents estimated water levels under pre- and post-project conditions. Below the confluence, the rise in water levels during ice cover formation under post-project conditions will progressively decrease downstream. More detailed river cross-section surveys and river freezeup observations will be necessary to confirm these estimates and speculations.

5.4 - Reservoir Ice Cover

Ice cover formation and growth in the Watana and Devil Canyon reservoirs will be substantially different from that in the corresponding river reach under natural conditions. An assessment of the formation, growth, bank-ice deposition, and eventual decay of the reservoir ice is presented below.

The initial ice cover on the reservoirs is expected to be formed with some 100 freezing degree-days (°F) after the surface water reaches 32°F. Based on available climatic data and the reservoir thermal modeling (see Appendix A4 to the main Feasibility Report), the initial ice cover will be formed toward the end of October under average weather conditions. Once a stable cover is formed, its growth is accomplished chiefly by conductive heat loss to the atmosphere. Figure 5.2 presents estimated ice cover growth in the Watana reservoir over an average winter season. Devil Canyon reservoir ice cover would progress similarly. The only difference would be that several miles of this reservoir immediately below Watana dam may have open water year-round due to outflow temperatures from Watana of 39°F or higher. Near the power intakes at each development, open water stretches will be present because of larger velocities, as well as significant mixing with warmer (39°F) waters in the lower layers.

Under normal operation, the Watana and Devil Canyon reservoirs will be drawn down by about 90 and 50 feet, respectively, toward the end of winter. Thus, the ice cover formed on the surface would be deposited on the banks as blocks, with sizes varying from a few inches to about three feet. The deposits will be generally irregular and cracked due to irregular bank slopes and drawdown rates. Most of this bank ice is unlikely to melt until about the end of June, or earlier if the reservoir level is raised with spring floods.

The ice cover in the reservoir itself will essentially melt in place. By late February or early March, the ice cover will slowly start to disintegrate with higher air temperatures and increased solar radiation on the surface. Operation of the power intakes may slightly alter the disintegration of ice cover close to the intake with convection mixing underneath the cover. It is expected that the ice cover in the reservoirs will completely dissipate by the end of May or early June, with warmer inflow waters and the onset of spring. During the period between March and May, the ice cover may become structurally weak due to the disintegration process, though its thickness may still be two to three feet.

TABLE 5.1

CALIBRATION COEFFICIENTS USED IN ICESIM

Manning's 'n' of Ice	0.050
Critical Froude No. at Ice Front	0.120
Erosion Velocity	6.5 ft/sec
Density of Ice	47.0 lb/ft^3
Cohesion of Ice	0.145 psi

TABLE 5.2

COMPARISON OF HEC-2 AND ICESIM
BACKWATER ROUTINE RESULTS

Cross-Section No.	Computed Water Surface Elevation (ft, msl)*	
	HEC-2	ICESIM
LRX - 3	344.0	--
LRX - 9	378.1	379.0
LRX - 15	452.5	453.5
LRX - 21	510.0	511.7
LRX - 27	542.9	544.4
LRX - 34	616.0	615.8
LRX - 41	659.9	659.8
LRX - 47	690.6	690.3
LRX - 54	733.2	733.8
LRX - 61	832.9	834.2
LRX - 68	850.6	--

* For Gold Creek discharge of 9700 cfs.

TABLE 5.3

ESTIMATED ICE COVER PROGRESSION ABOVE TALKEETNA
Post-Project Conditions - Average Year

Date	Location of Leading Edge* Rivermiles	Section
December 1	No Ice Cover	
December 15	102	LRX-7
December 25	105	LRX-10
January 10	109	LRX-12
January 20	112	LRX-15

* With Watana only operational.

TABLE 5.4

OBSERVED RIVER STAGING DURING
ICE COVER FORMATION - 1980

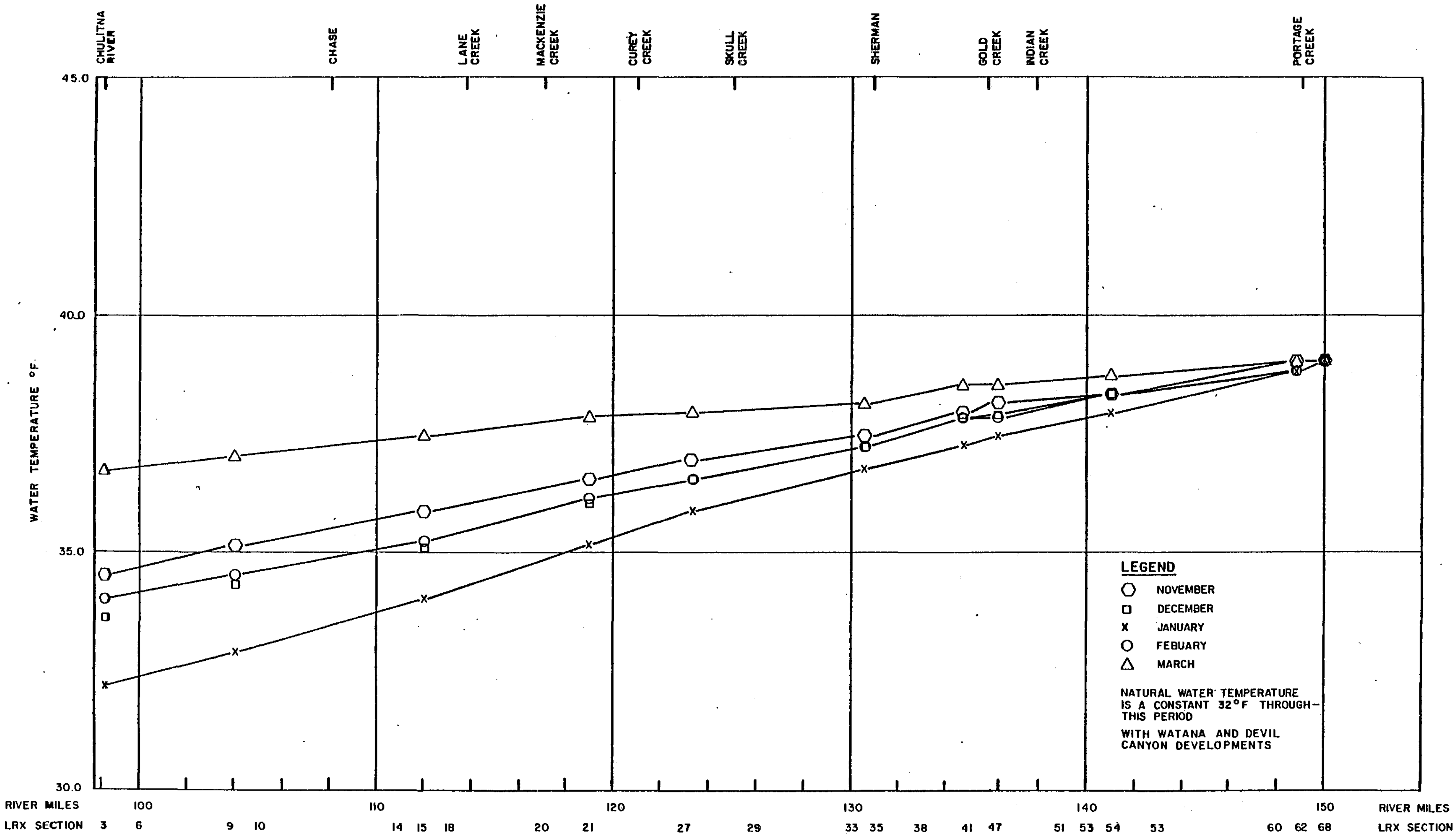
Location	Approximate Maximum Observed Staging Above 10/17/80 Open Water Level
Talkeetna (LRX-3)	3 - 4 ft.
Gold Creek	5 - 6 ft.
Downstream end of Devil Canyon	12 - 15 ft.
Devil Canyon Dam Site (Devil's Elbow)	10 - 12 ft.
Immediately upstream of Devil's Elbow	3 - 15 ft.

TABLE 5.5

ESTIMATED WATER LEVELS AT SELECTED RIVER SECTIONS

River Cross-Section Number	Water Surface Elevations (feet)		
	Natural Ice-Cover Condition[1]	Post Project Conditions[2]	
		Open Water[3]	With Ice Cover[4]
LRX - 3	349.0	345.0	352.7
LRX - 5	N/A	358.0	362.4
LRX - 6	N/A	362.9	366.5
LRX - 7	N/A	366.9	370.8
LRX - 8	N/A	373.8	378.1
LRX - 9	381.0	379.0	389.8
LRX - 10	395.0	391.6	405.4
LRX - 12	421.0	421.9	430.4
LRX - 13	437.0	437.4	445.4
LRX - 15	450.0	453.5	455.8
LRX - 16	457.0	456.1	457.2
LRX - 19	N/A	486.9	no ice

1 1980 Freeze-up data.
2 Average discharge 9,700 cfs at Gold Creek.
3 With Watana and Devil Canyon both operational.
4 With Watana only operational.
N/A Not Available.



LONGITUDINAL THERMAL PROFILES

POST PROJECT AND NATURAL CONDITIONS

FIGURE 5.1

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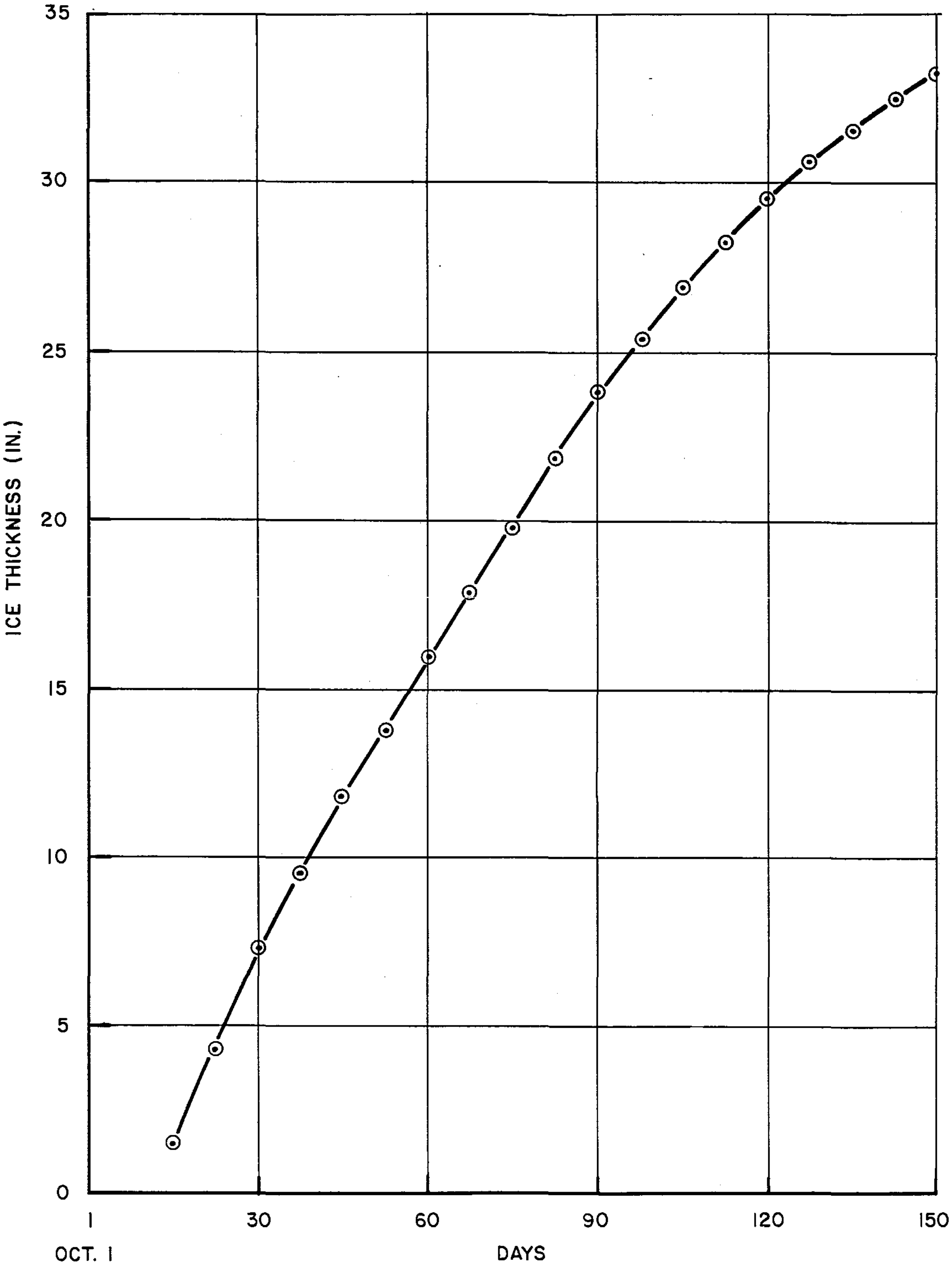

ESTIMATED ICE COVER DEVELOPMENT IN
WATANA RESERVOIR

FIGURE 5.2

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ATTACHMENT A

STAGE-DISCHARGE RATING CURVES, STUDY REACH OBSERVATION SITES

NOTES ON RATING CURVES

1. Rating curves are provided for the following water level observation sites:

URX-101	Susitna River near Deadman Creek CSR*
URX-106.3	Susitna River at Watana Damsite CSR
URX-111	Susitna River near Watana Damsite Streamgage
URX-121	Susitna River near Devil Creek CSR
LRX-68	Susitna River at Devil Canyon Staff Gage
LRX-62	Susitna River at Portage Creek CSR
LRX-45	Susitna River at Gold Creek Streamgage
LRX-35	Susitna River at Sherman CSR
LRX-28	Susitna River at Section 25 CSR
LRX-24	Susitna River at Curry CSR
LRX-9	Susitna River at Chase CSR
LRX-4	Susitna River at Chulitna River Confluence CSR

2. The sites are in order by upstream-to-downstream sequence, with a space separating the Upper Susitna Study Reach from the Middle Susitna Study Reach.

3. Streamflows plotted on the curves were determined by adjusting the recorded flow at the nearest streamgage by a factor based on drainage area. The two streamgages used were the USGS gage at Gold Creek and the R&M gage near the Watana Damsite. Adjustment factors are given on each rating curve.

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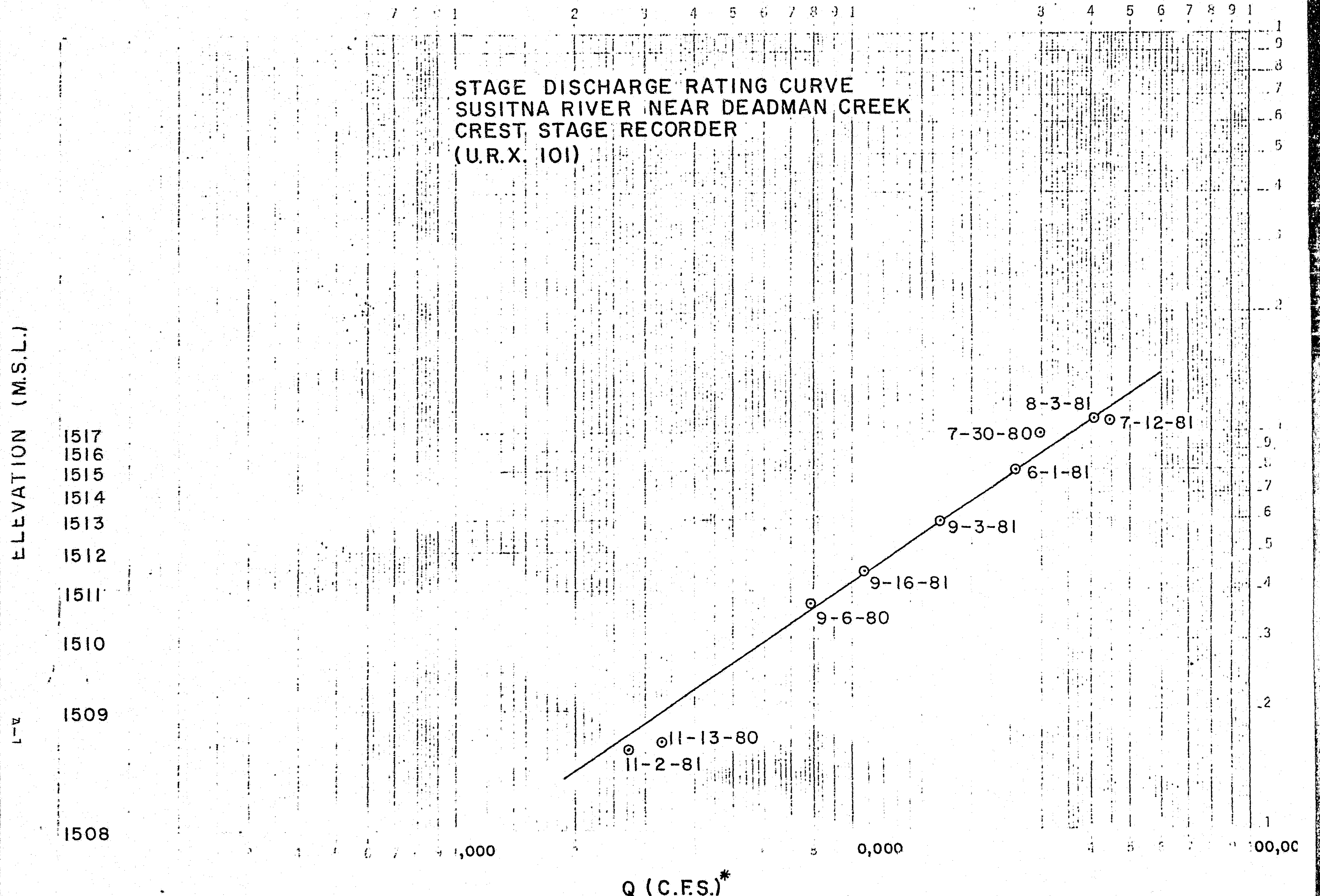
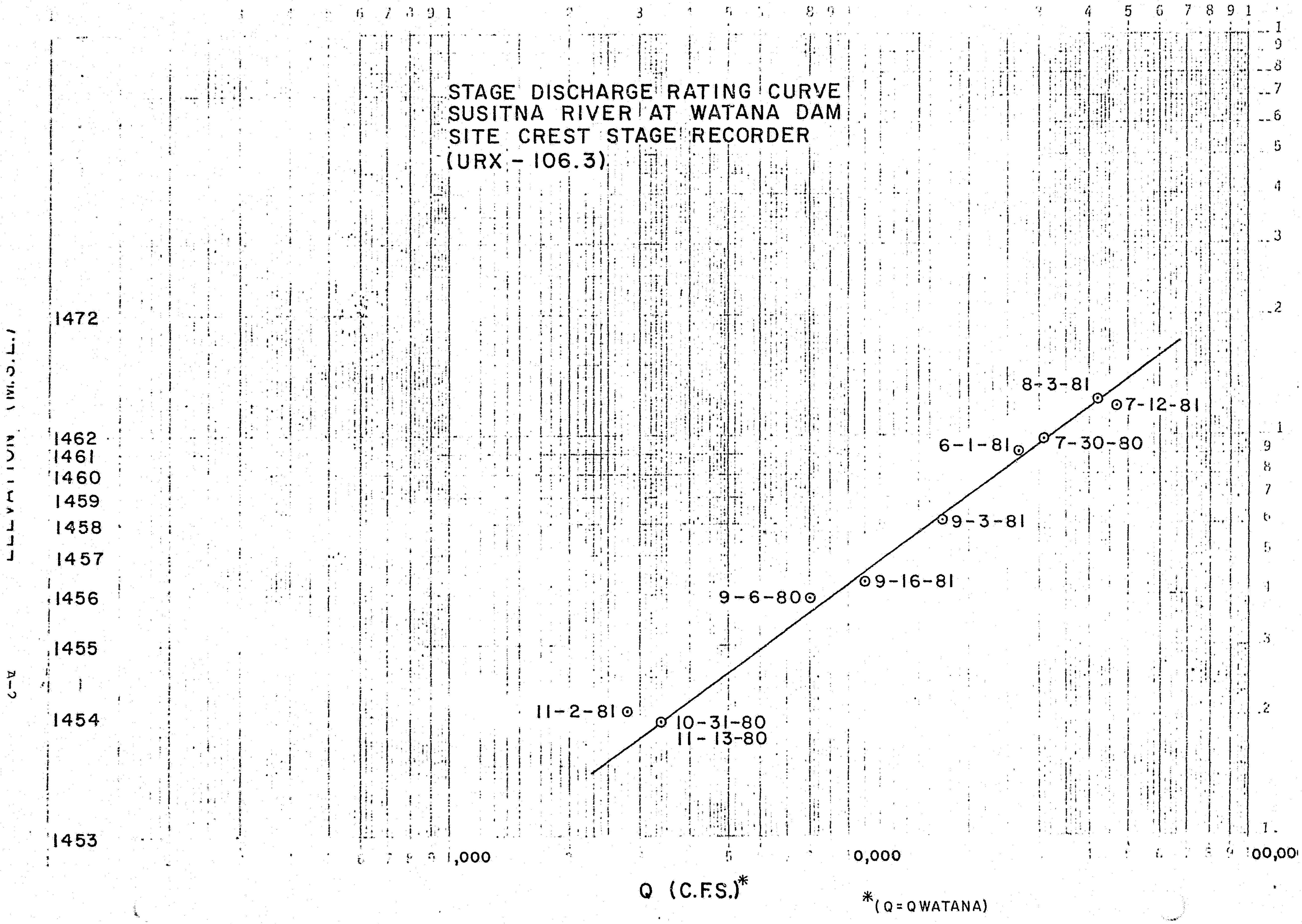
* "CSR" = crest-stage recorder.



* Q = (QWATANA)(0.969)


STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT WATANA DAM
SITE CREST STAGE RECORDER
(URX - 106.3)
ELEVATION (M.S.L.)
1472
1462
1461
1460
1459
1458
1457
1456
1455
1454
1453
1,000
10,000
100,000
Q (C.F.S.)*
*(Q = Q WATANA)
8-3-81
7-12-81
6-1-81
7-30-80
9-3-81
9-16-81
9-6-80
11-2-81
10-31-80
11-13-80

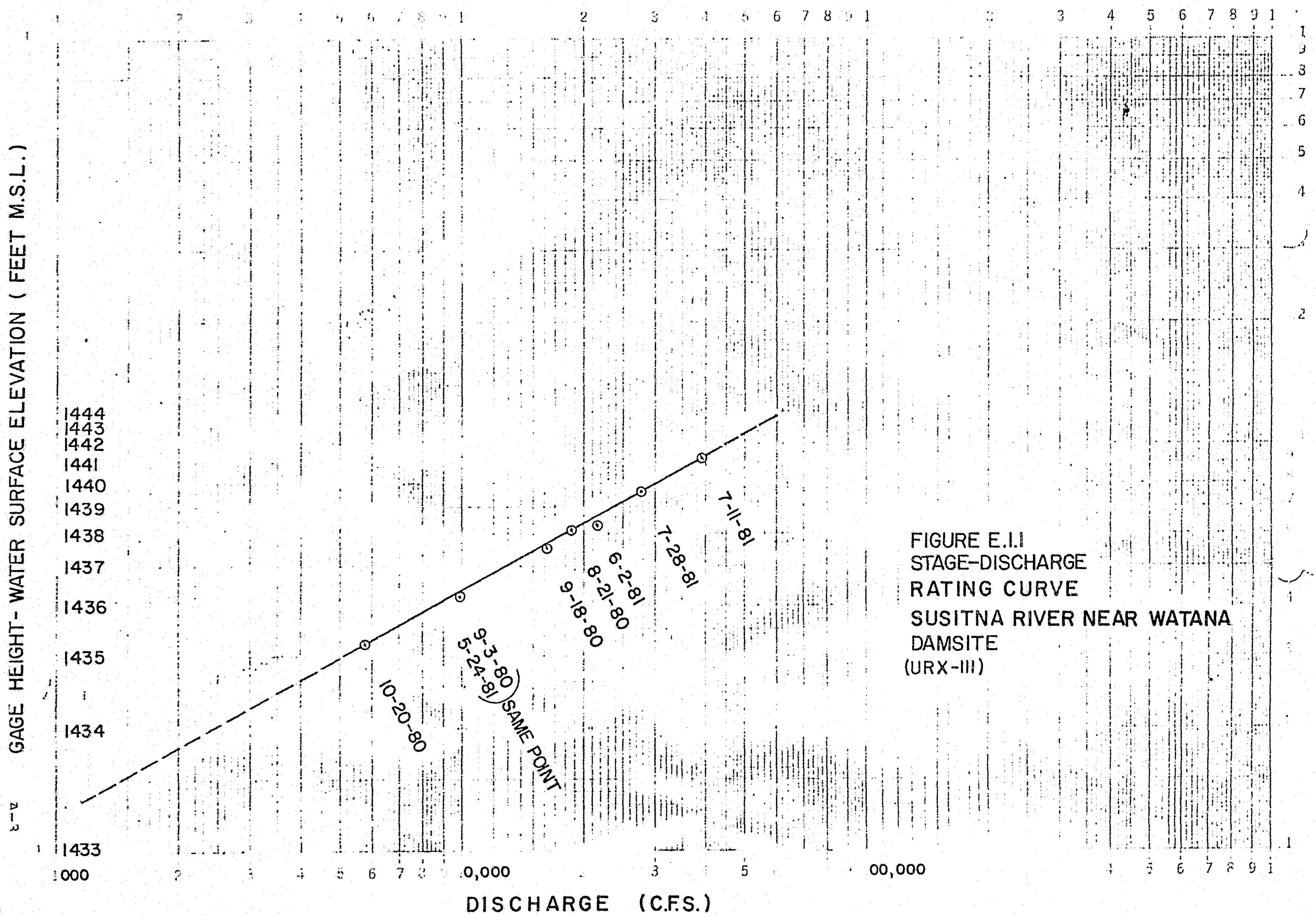
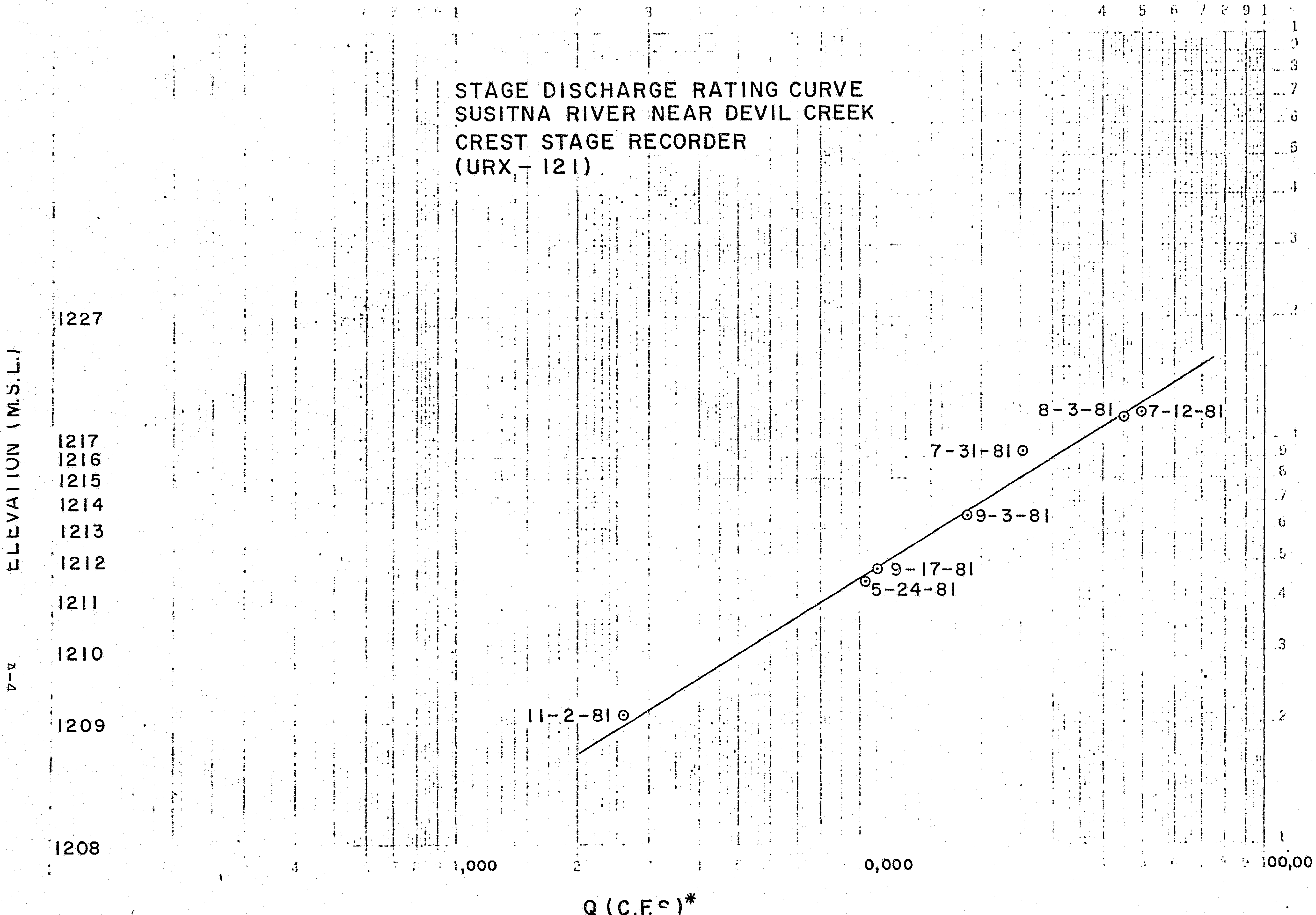
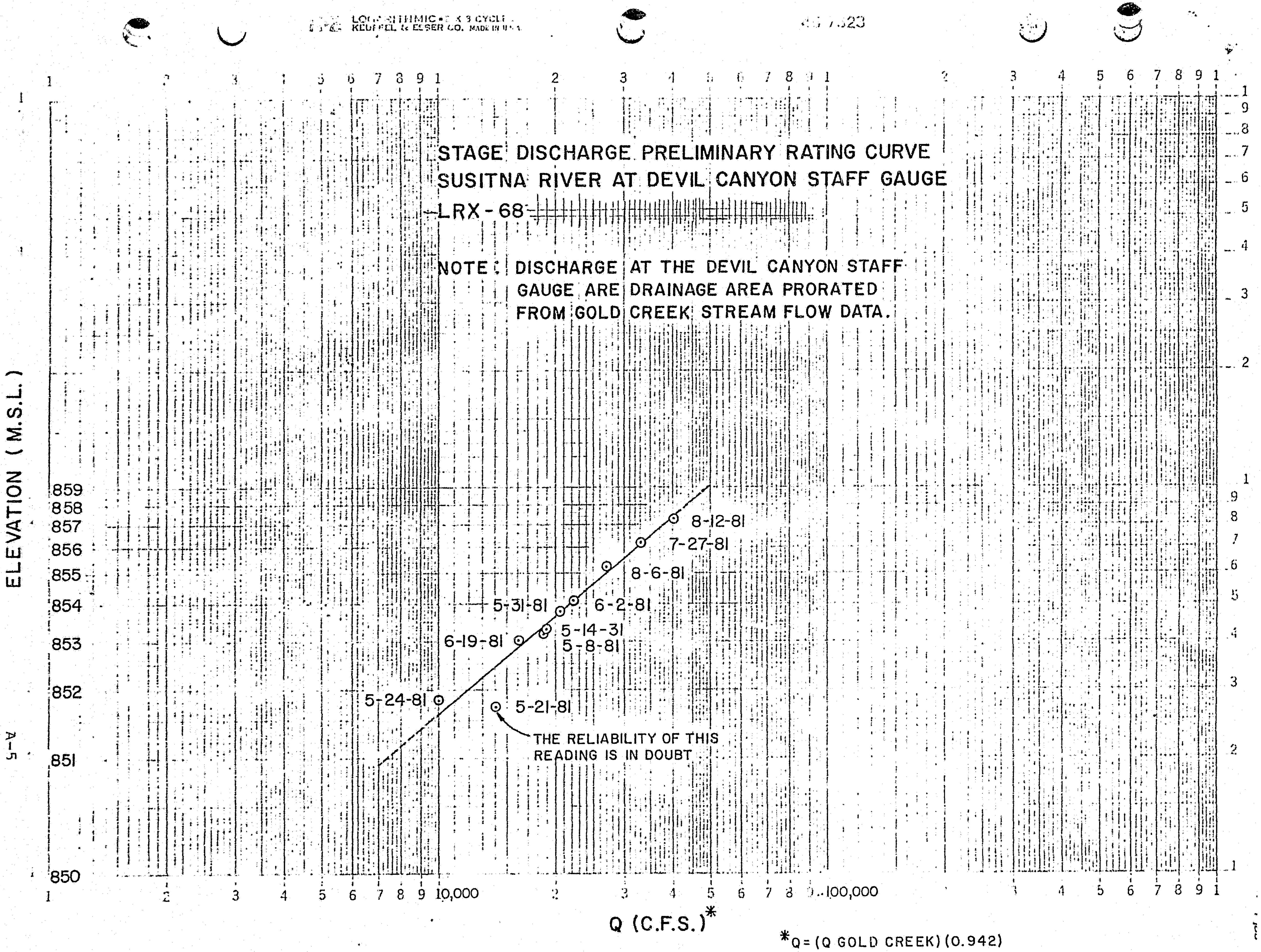
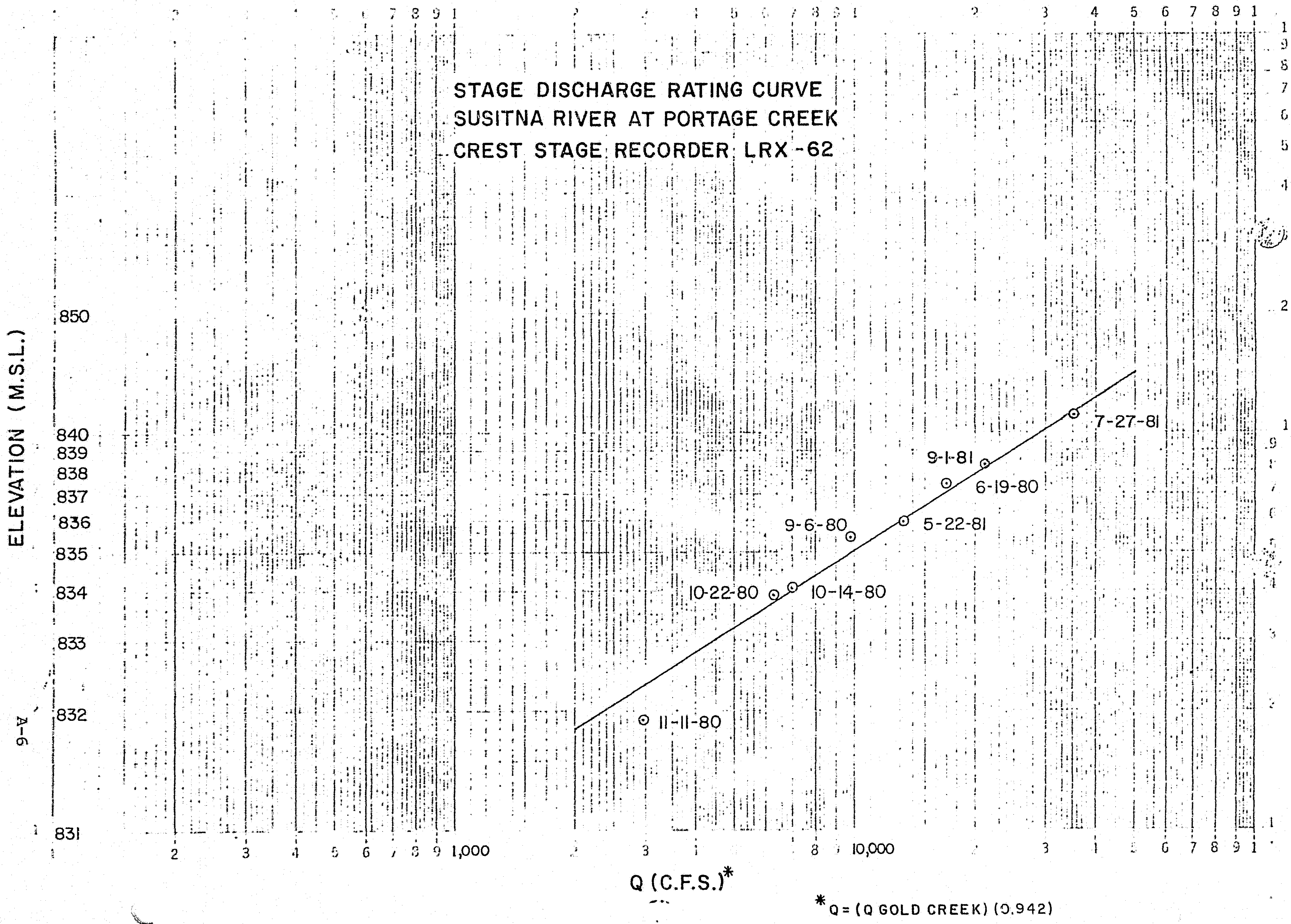


FIGURE E.1.1
STAGE-DISCHARGE
RATING CURVE
SUSITNA RIVER NEAR WATANA
DAMSITE
(URX-III)



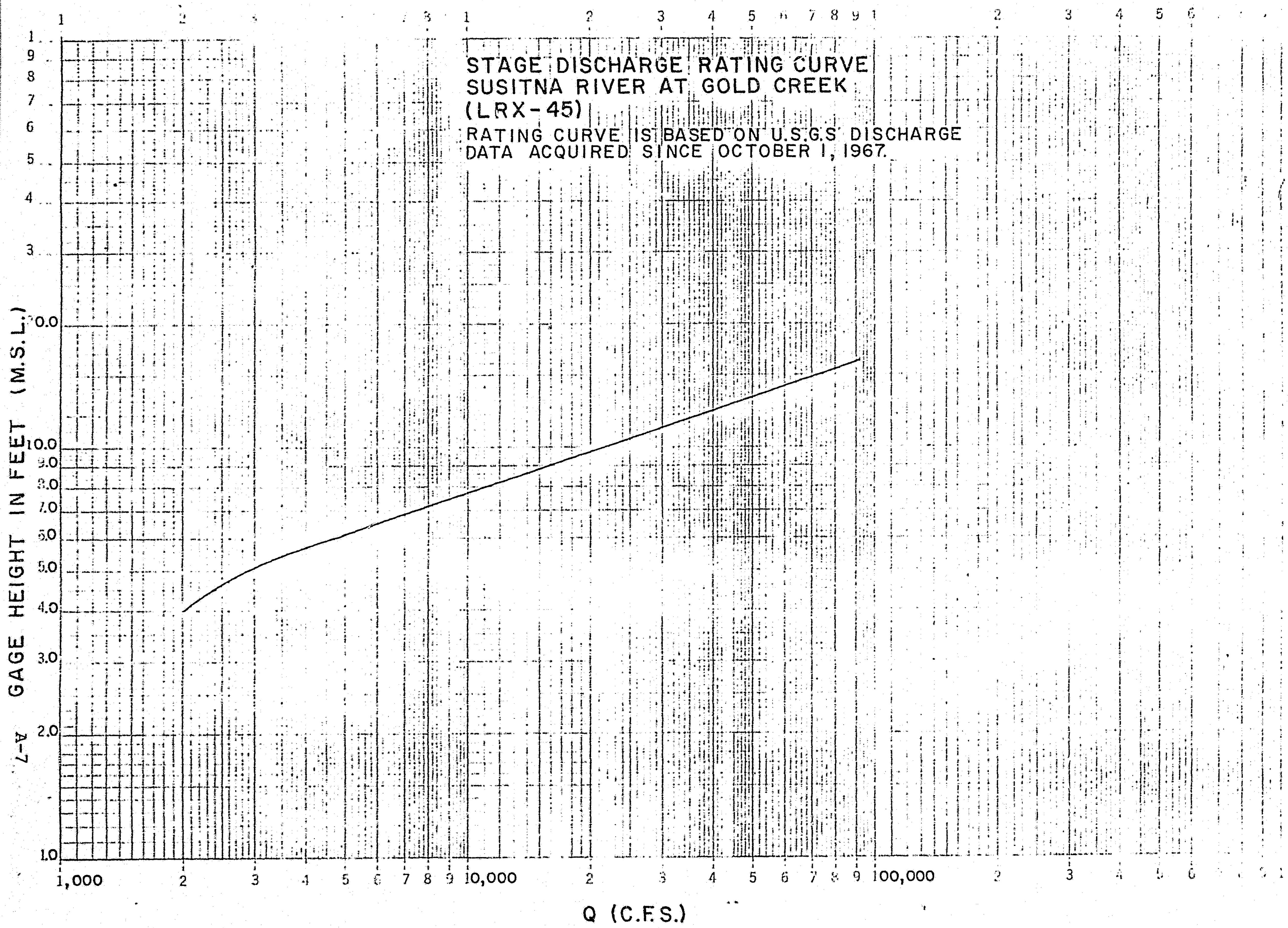
* Q = (QWATANA) (1.079)

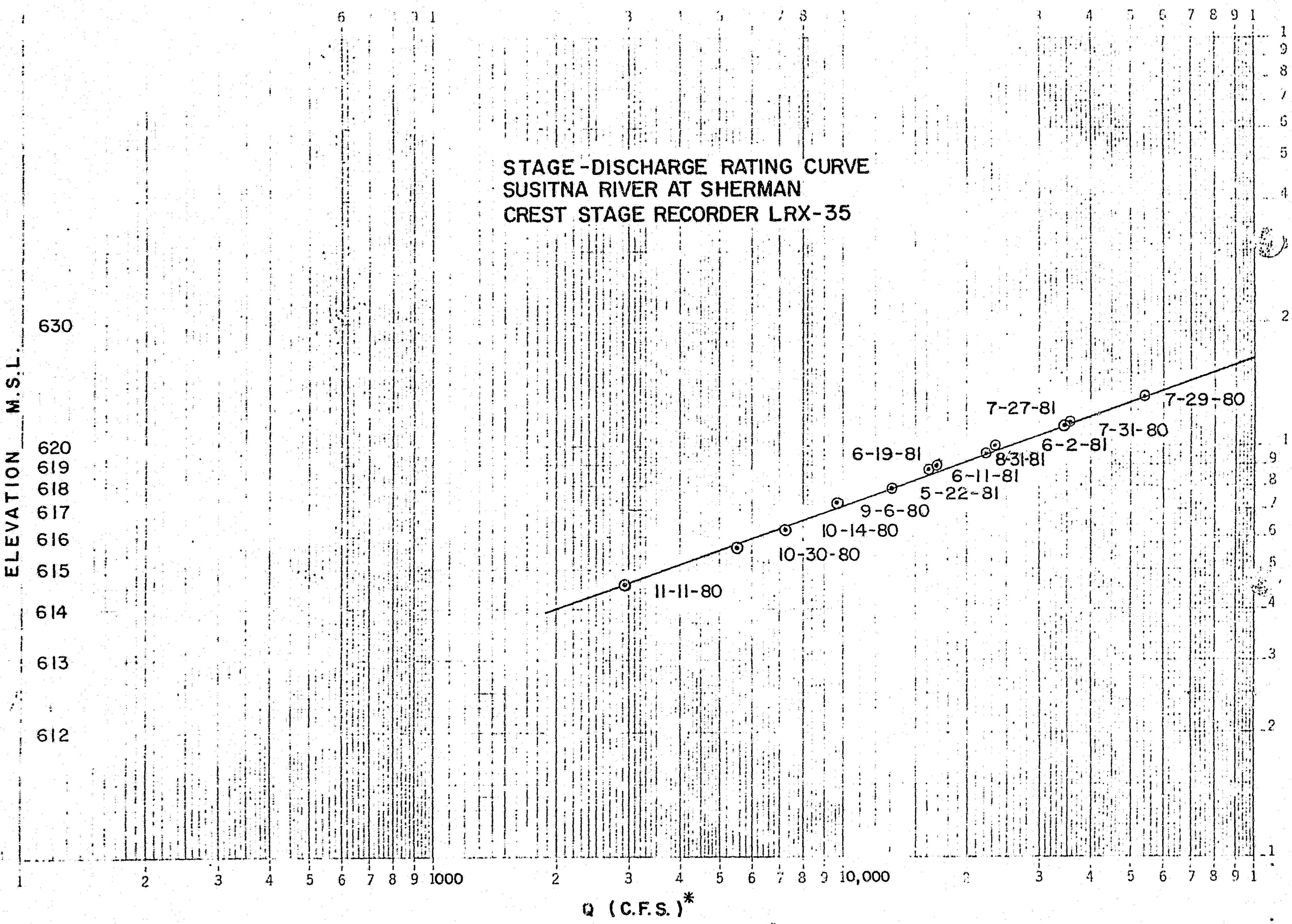

STAGE DISCHARGE PRELIMINARY RATING CURVE
SUSITNA RIVER AT DEVIL CANYON STAFF GAUGE
LRX - 68
NOTE: DISCHARGE AT THE DEVIL CANYON STAFF GAUGE ARE DRAINAGE AREA PRORATED FROM GOLD CREEK STREAM FLOW DATA.
ELEVATION (M.S.L.)
850
851
852
853
854
855
856
857
858
859
10,000
100,000
Q (C.F.S.)*
8-12-81
7-27-81
8-6-81
6-2-81
5-31-81
5-14-31
5-8-81
6-19-81
5-24-81
5-21-81
THE RELIABILITY OF THIS READING IS IN DOUBT
*Q = (Q GOLD CREEK) (0.942)


STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT PORTAGE CREEK
CREST STAGE RECORDER LRX-62
ELEVATION (M.S.L.)
850
840
839
838
837
836
835
834
833
832
831
Q (C.F.S.)*
1,000
10,000
7-27-81
9-1-81
6-19-80
5-22-81
9-6-80
10-22-80
10-14-80
11-11-80
*Q = (Q GOLD CREEK) (0.942)

A-6

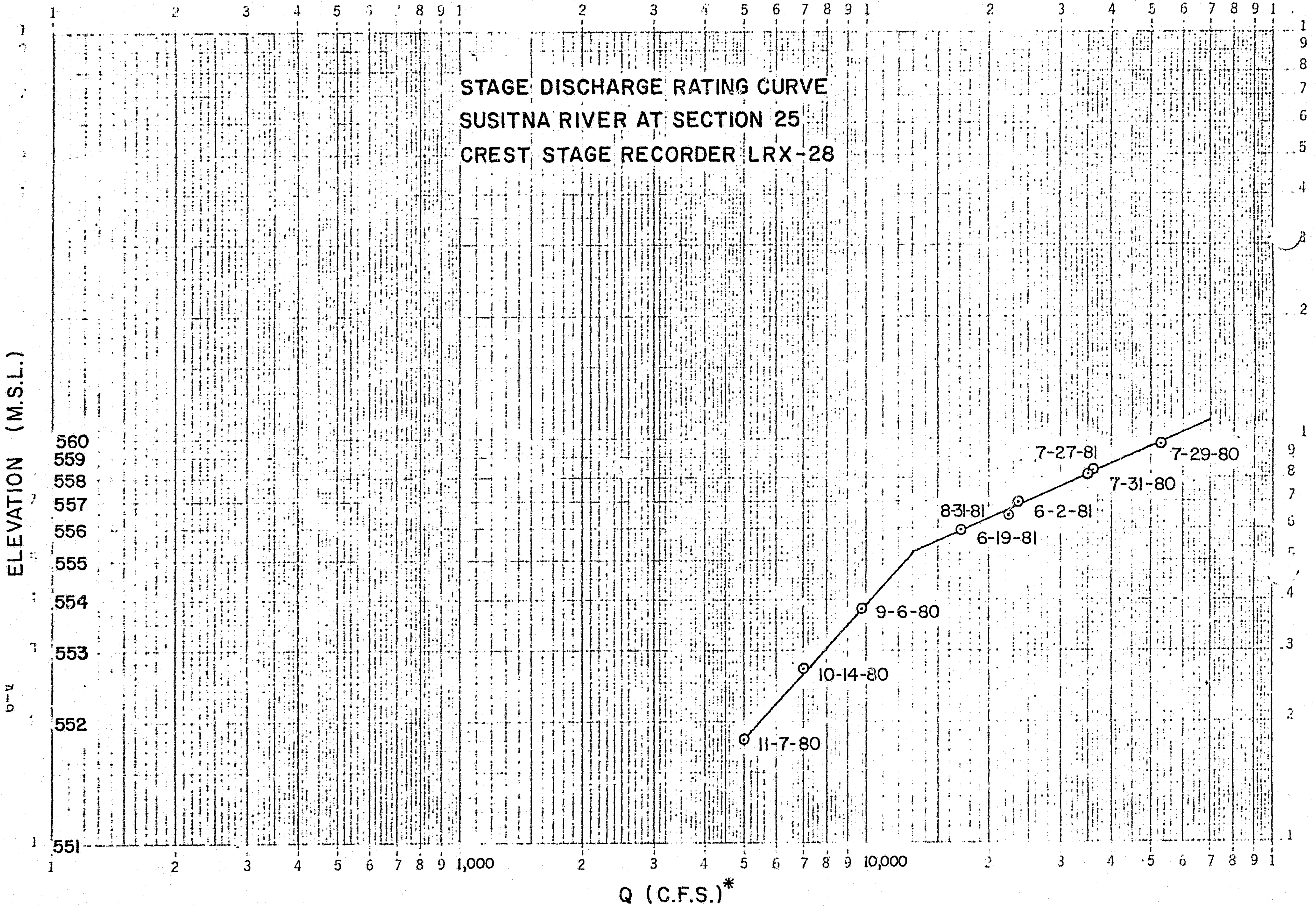
46 7323


STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT GOLD CREEK
(LRX-45)
RATING CURVE IS BASED ON U.S.G.S DISCHARGE
DATA ACQUIRED SINCE OCTOBER 1, 1967.
GAGE HEIGHT IN FEET (M.S.L.)
Q (C.F.S.)
1,000
10,000
100,000
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0



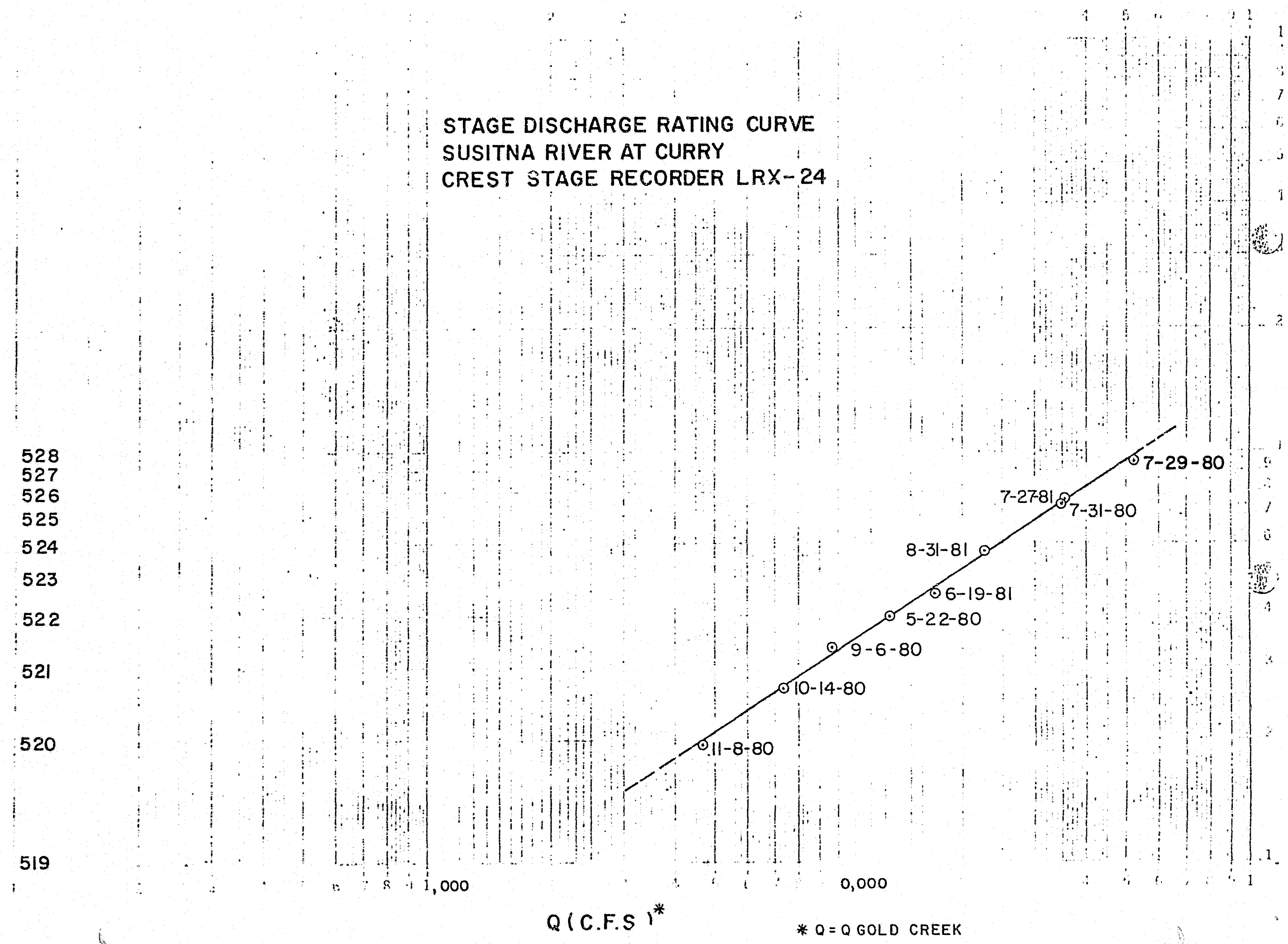
*Q= Q GOLD CREEK

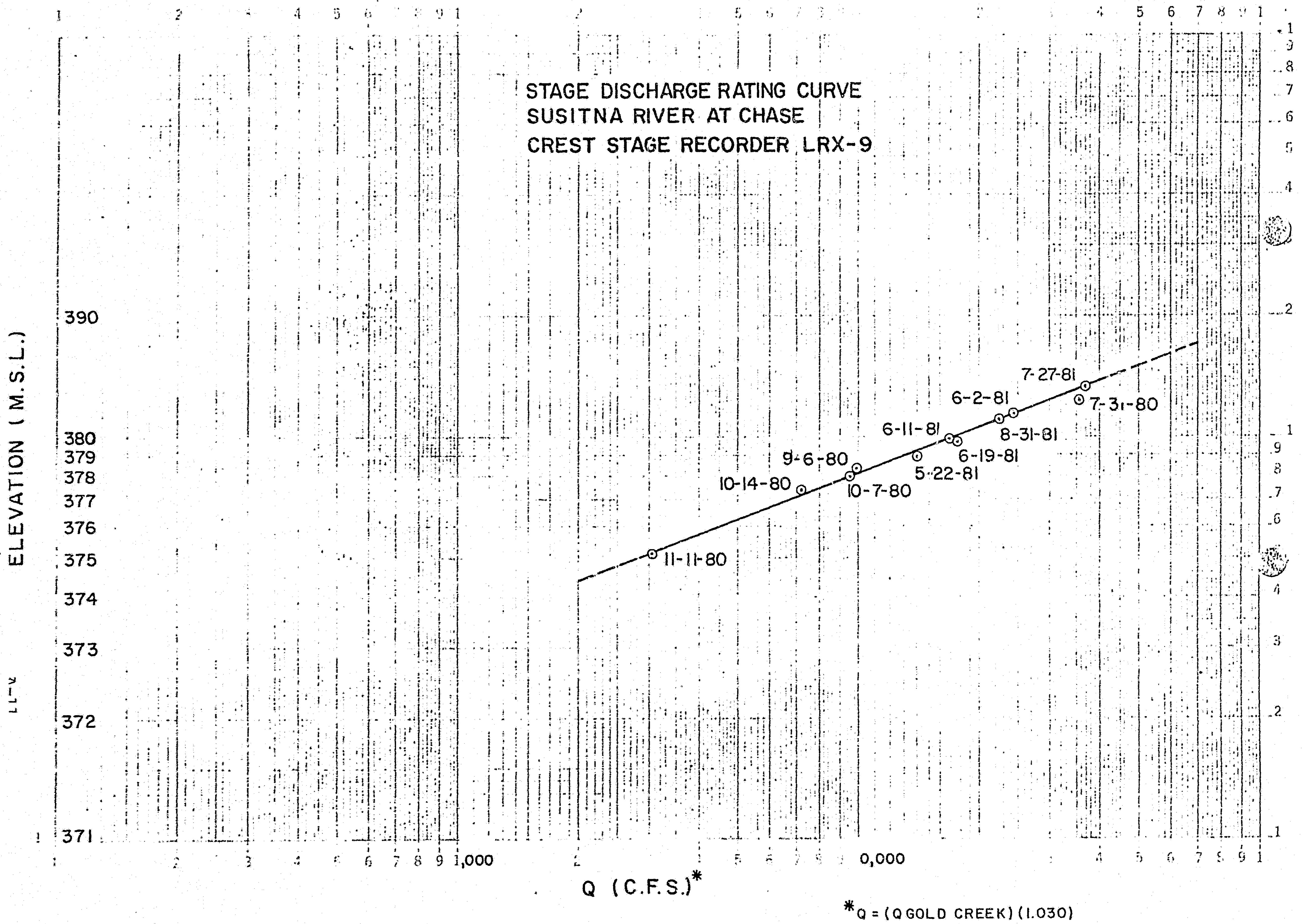
STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT SECTION 25
CREST STAGE RECORDER LRX-28

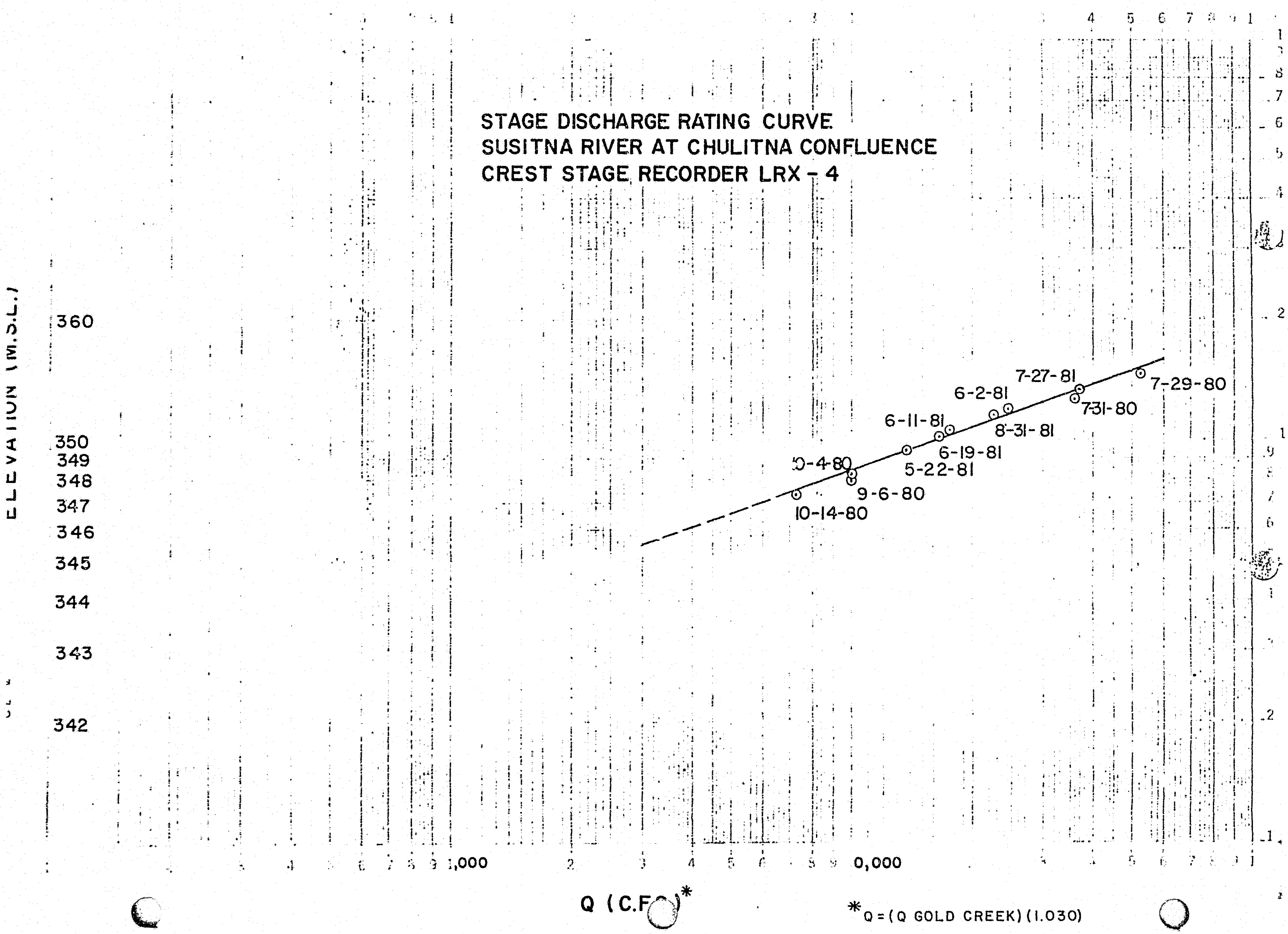


*Q = Q GOLD CREEK

A-9


STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT CURRY
CREST STAGE RECORDER LRX-24
528
527
526
525
524
523
522
521
520
519
7-29-80
7-27-81
7-31-80
8-31-81
6-19-81
5-22-80
9-6-80
10-14-80
11-8-80
1,000
0,000
Q (C.F.S)*
* Q = Q GOLD CREEK


STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT CHASE
CREST STAGE RECORDER LRX-9
ELEVATION (M.S.L.)
390
380
379
378
377
376
375
374
373
372
371
Q (C.F.S.)*
1,000
0,000
7-27-81
7-31-80
6-2-81
8-31-81
6-11-81
6-19-81
9-6-80
5-22-81
10-14-80
10-7-80
11-11-80
*Q = (Q GOLD CREEK)(1.030)



STAGE DISCHARGE RATING CURVE
SUSITNA RIVER AT CHULITNA CONFLUENCE
CREST STAGE RECORDER LRX - 4
ELEVATION (M.S.L.)
360
350
349
348
347
346
345
344
343
342
1,000
2
3
4
5
6
0,000
4
5
6
7
Q (C.F.S.)*
10-4-80
10-14-80
9-6-80
5-22-81
6-11-81
6-19-81
6-2-81
8-31-81
7-27-81
7-31-80
7-29-80
*Q = (Q GOLD CREEK) (1.030)

ATTACHMENT B

COMPUTED WATER SURFACE ELEVATIONS PLOTTED ON UPPER SUSITNA CROSS-SECTIONS

NOTES ON CROSS-SECTION PLOTS - UPPER SUSITNA

1. Cross-sections are in sequence from the upstream to the downstream end of the reach. Number 101 is the most-upstream cross-section, and Number 121 is the most-downstream. Numbering is sequential except that Number 207 follows 107 and Number 208 follows 108.

2. Plotting scales used vary somewhat from cross-section to cross-section. All are plotted with 10 feet to the inch vertically, but the horizontal scale used is either 100, 200, or 500 feet per inch.

3. All cross-sections are plotted looking <u>downstream</u>.

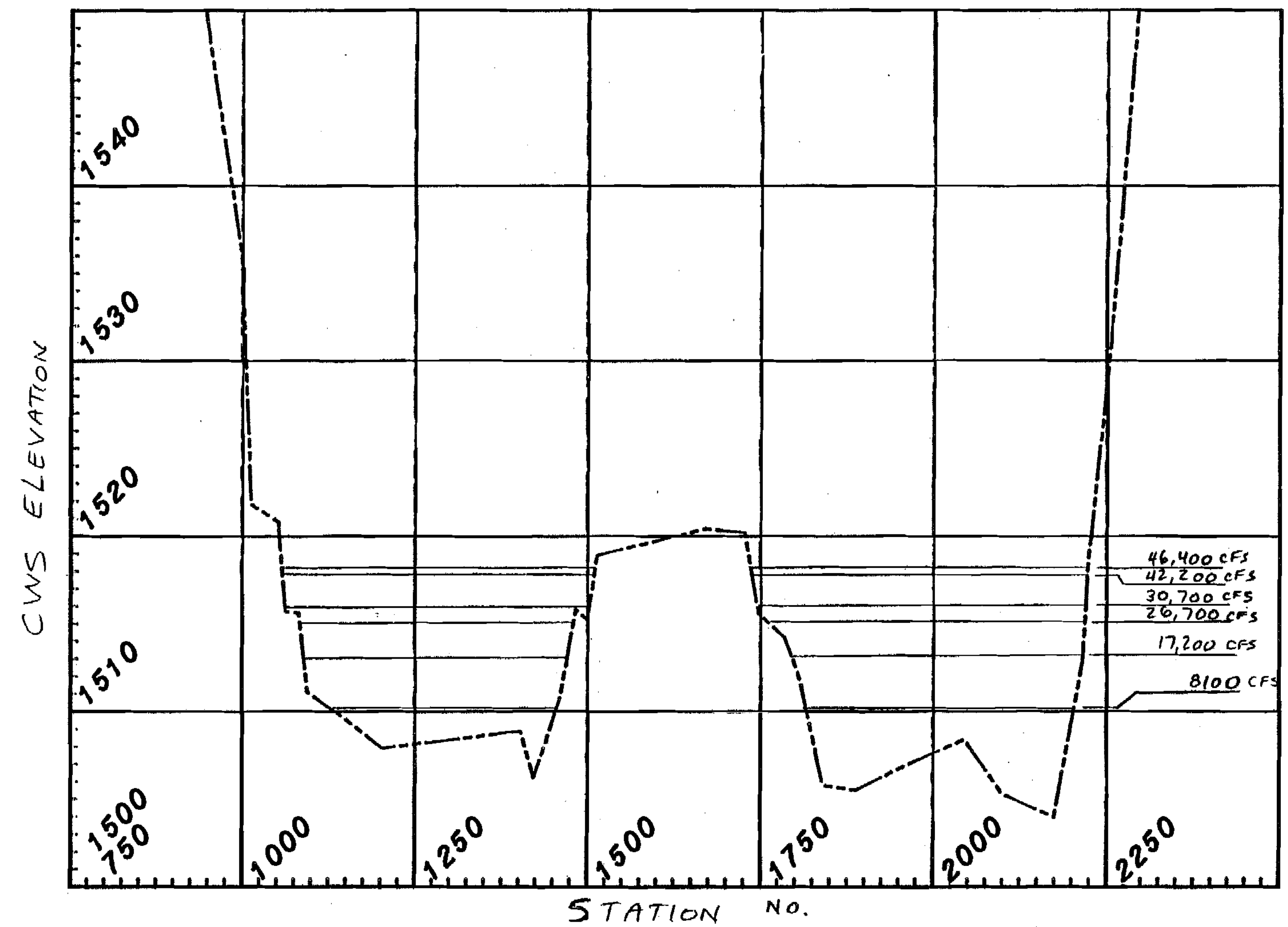
4. Water surface elevations plotted on each cross-section are those computed by the HEC-2 computer model. The streamflows used in this study reach and plotted on all the cross-sections (referenced to the Watana gage) were 8,100; 17,200; 26,700; 30,700; 42,200; and 46,400 cfs. Flows on the plots specify the Watana flow, but at the cross-sections, they were actually adjusted for drainage area, as shown in Table 4.3 of the main report.

5. At several cross-sections, water levels are not shown in low areas of side channels or sloughs. In some cases, this is because no river water is expected there at all. In other cases, there may be water, but no hydraulic connection is apparent; thus, no <u>flow</u> is there, and the actual water level there may be above or below that in the river.

6. Where the cross-section is at a bend in the river or is split between more than one main channel, there are likely to be differences in water surface elevation across the cross-section. The computer model, however, computes just one level, and this is understood to be the <u>mean</u> water surface elevation for the given discharge.

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 1 01



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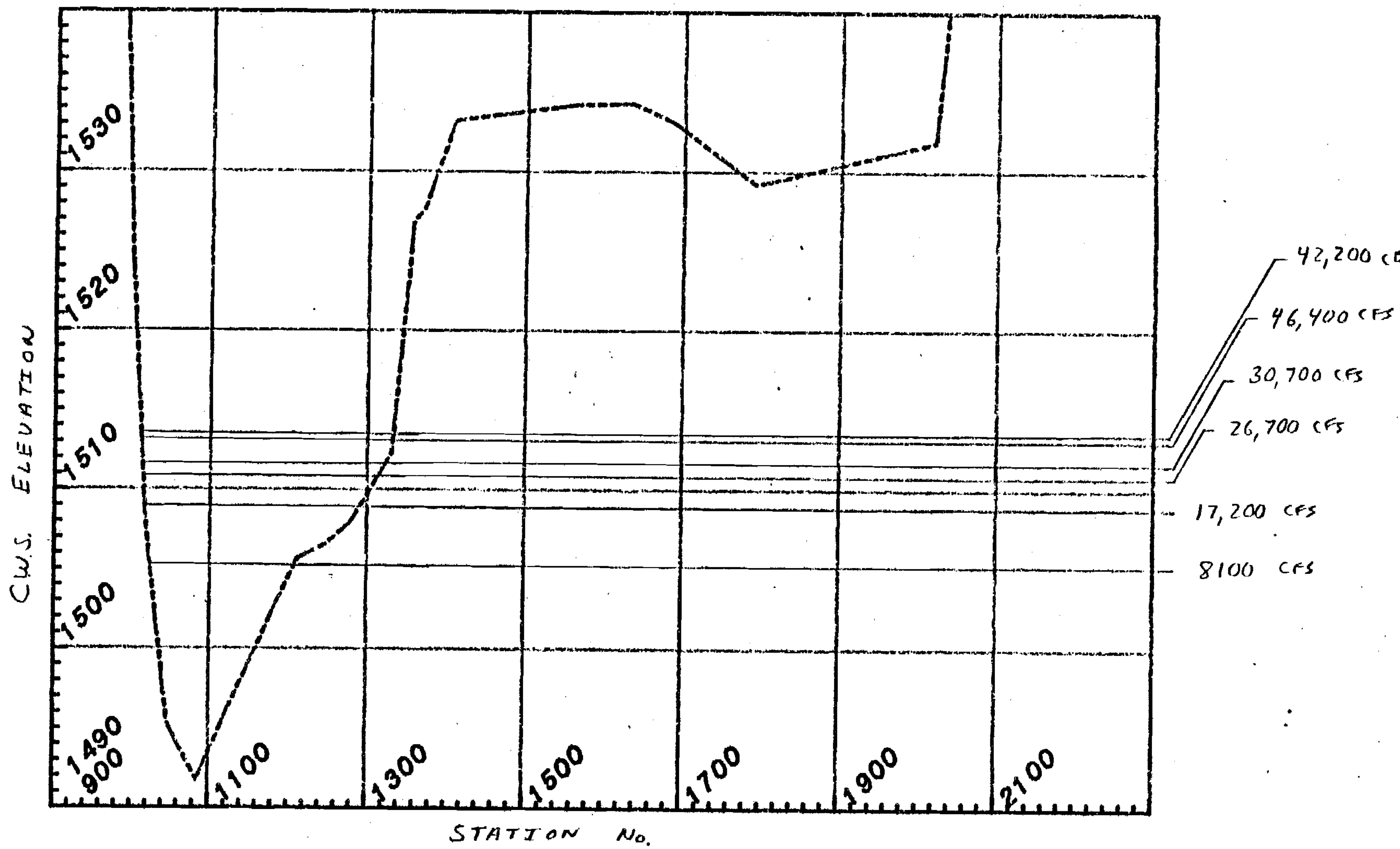
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 102



PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

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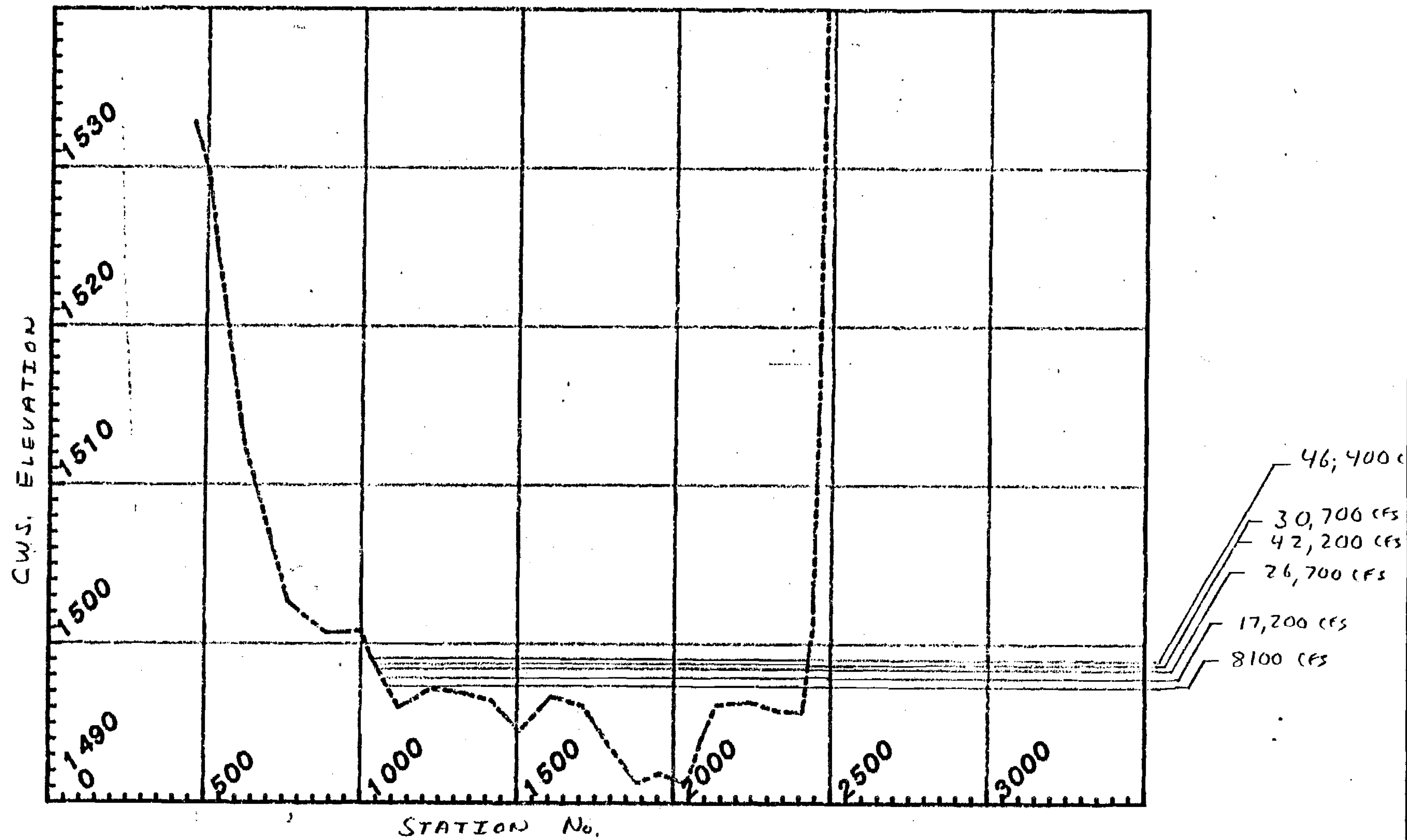
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 103



PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

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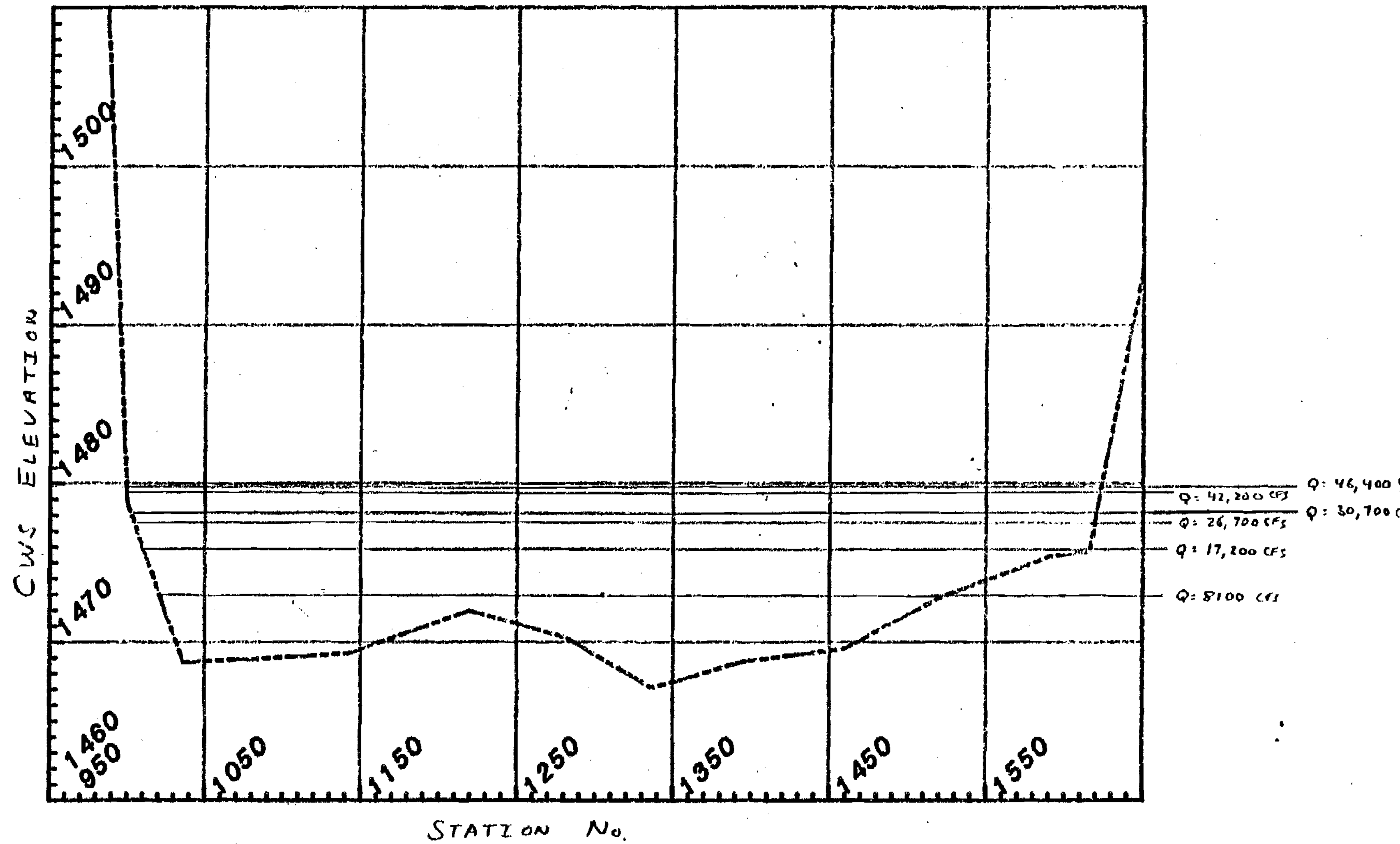
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 104



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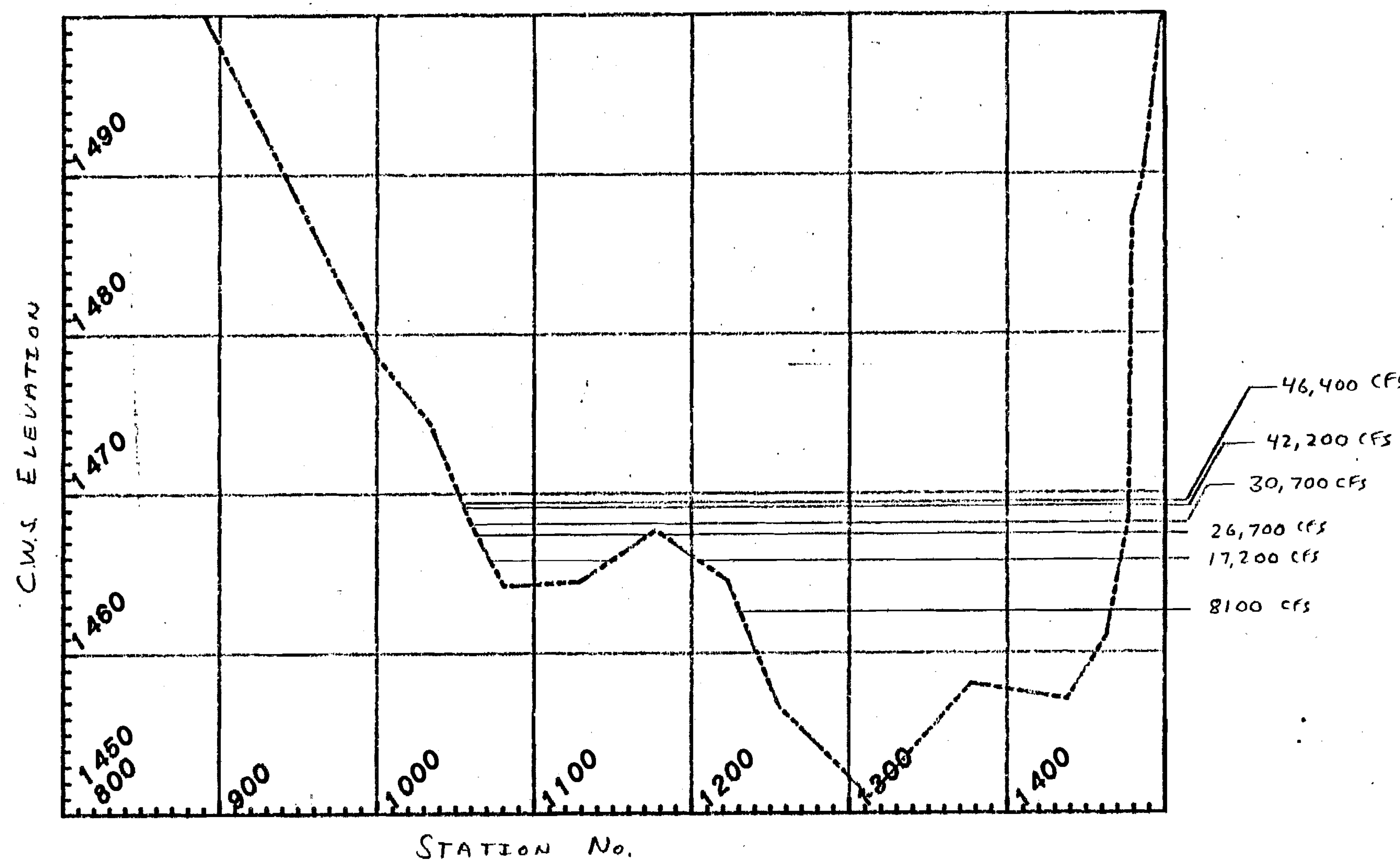
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 105



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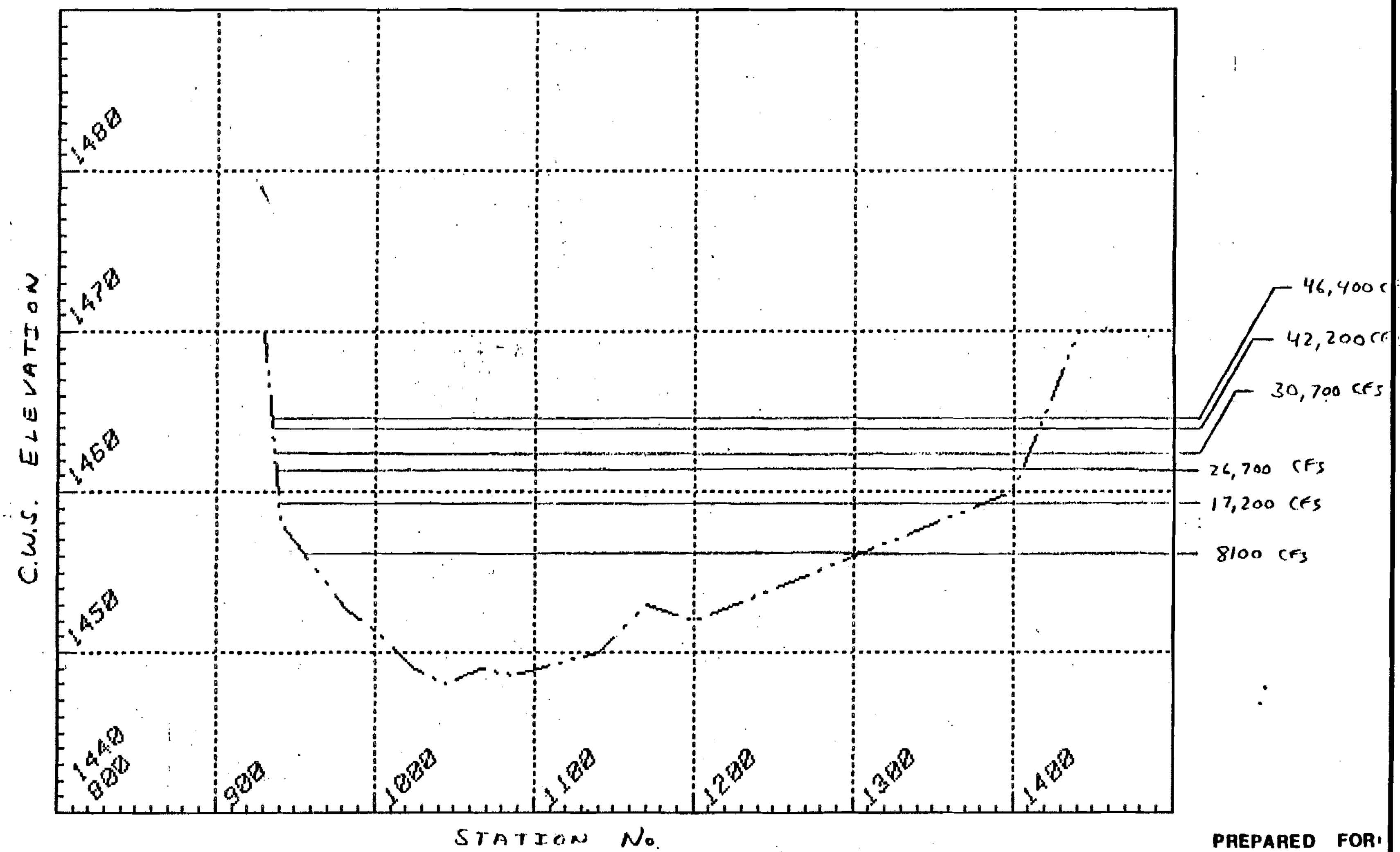
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 106.3



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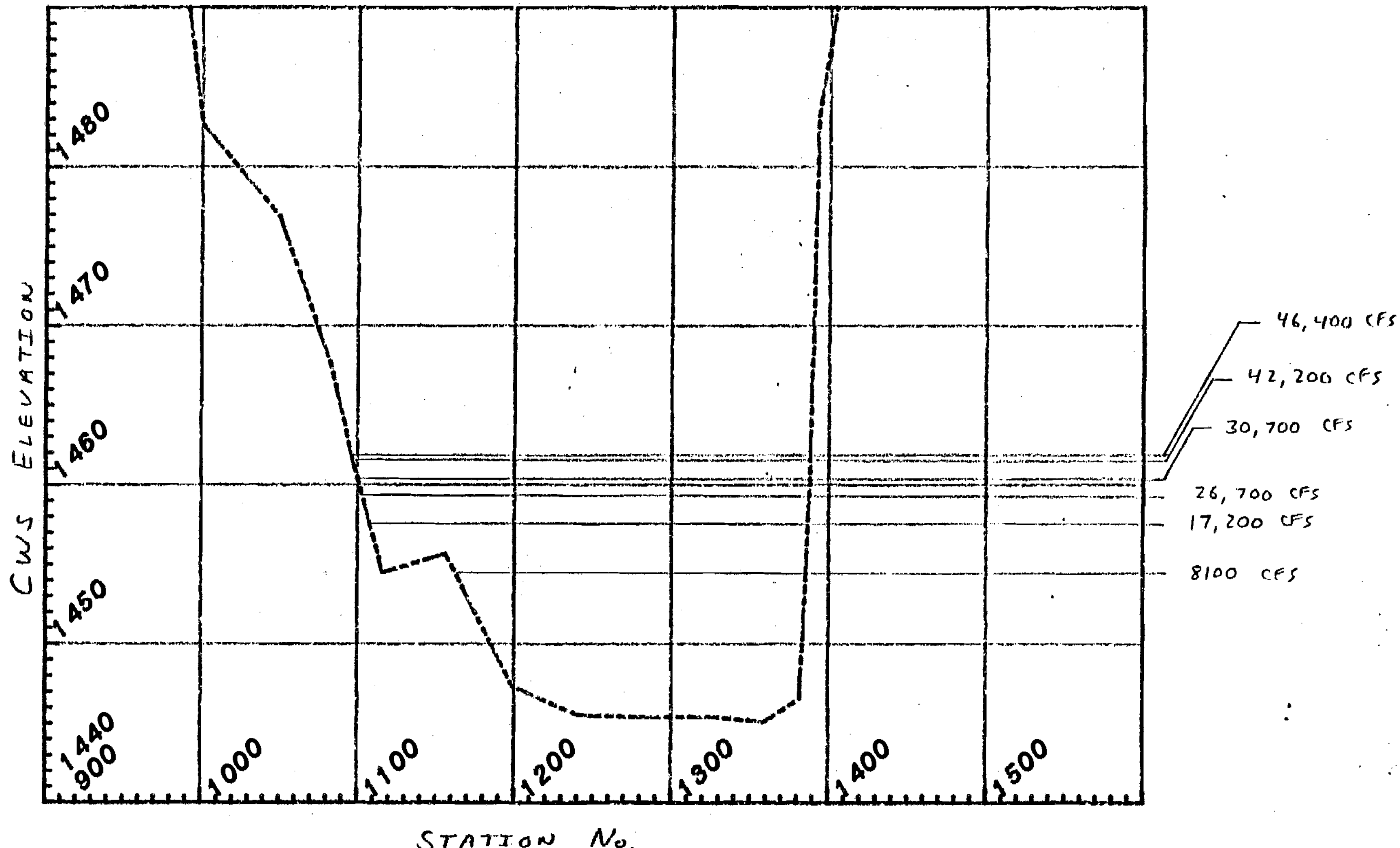
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 107



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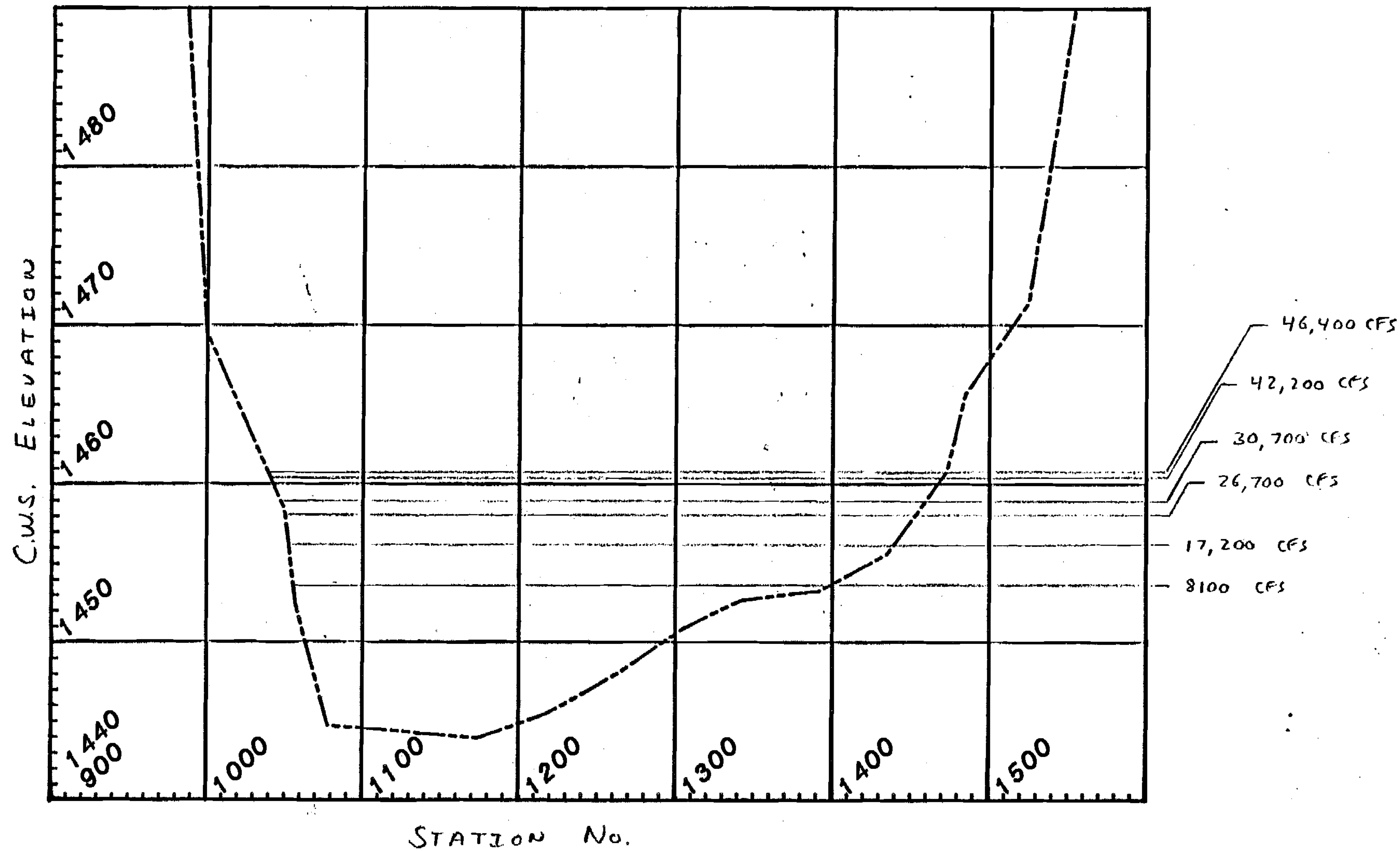
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 207



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PREPARED FOR:

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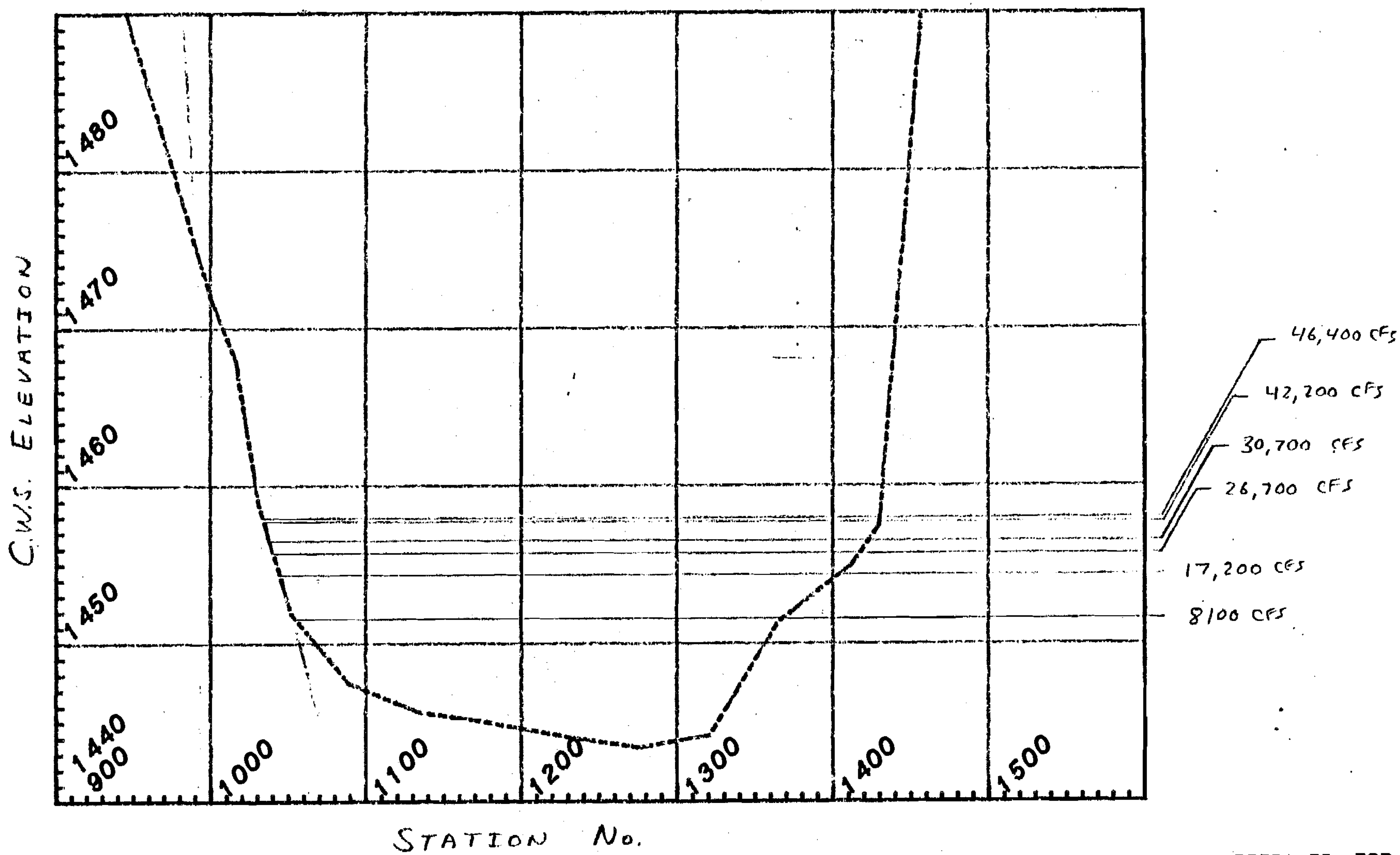
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 108



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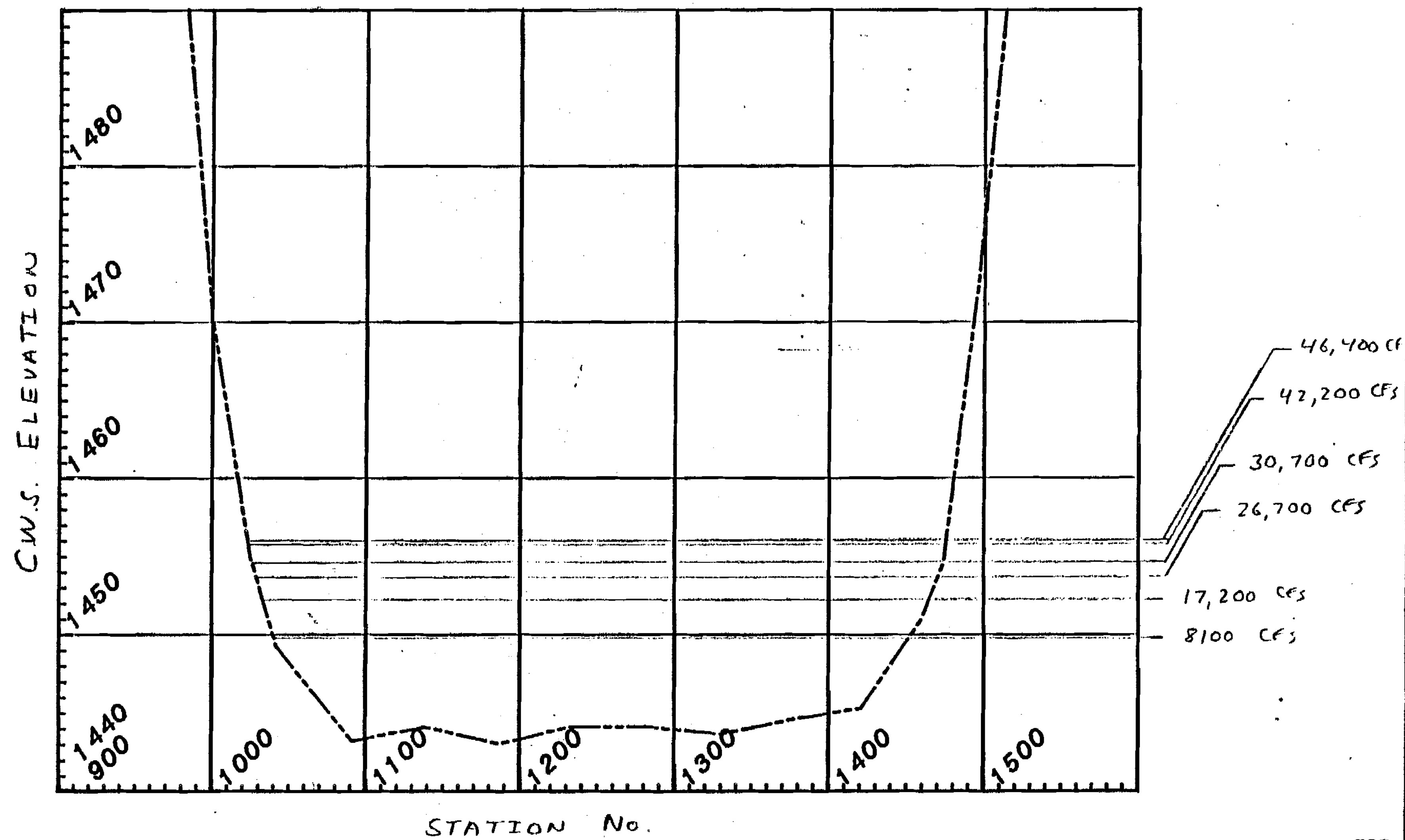
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 208



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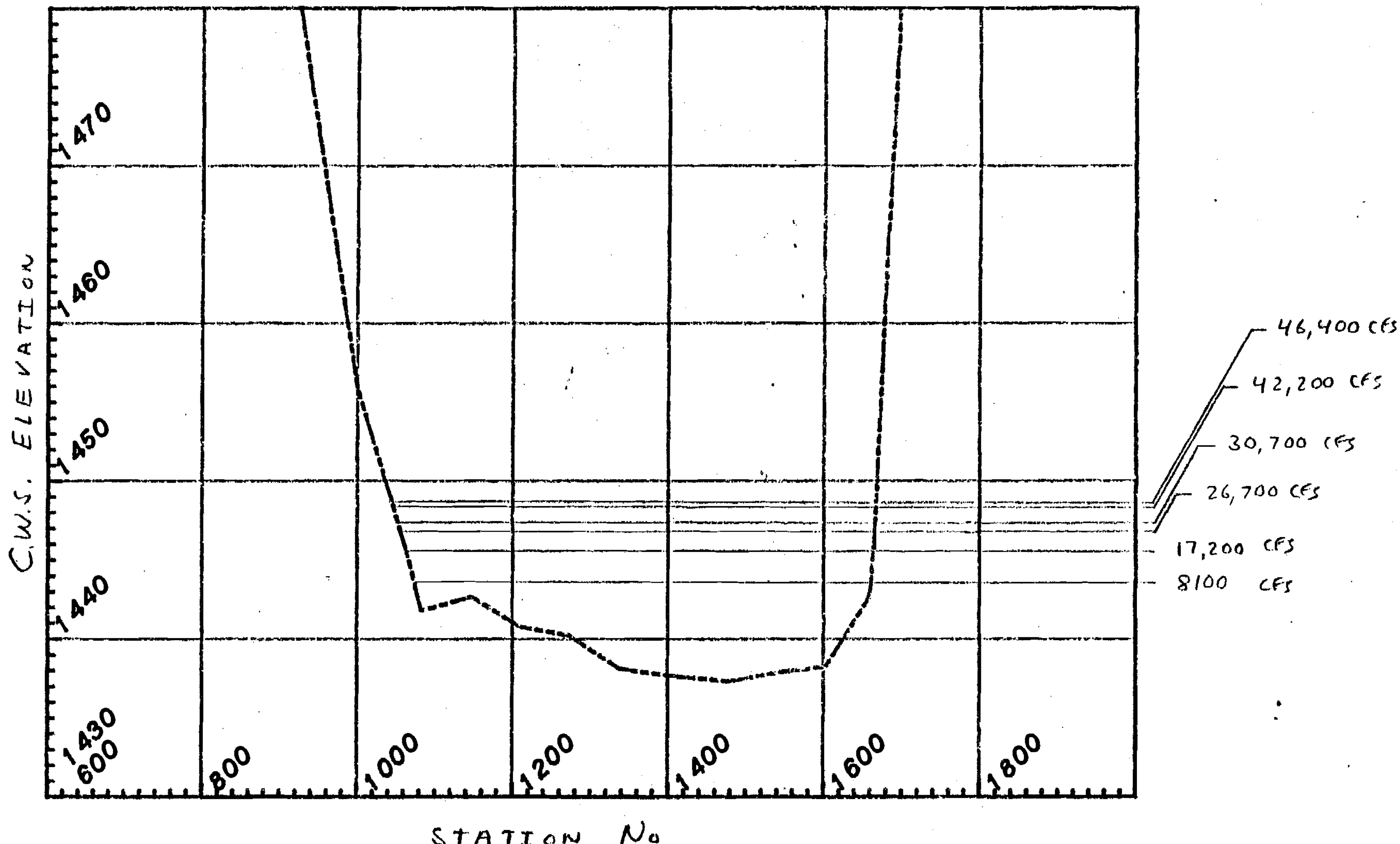
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 109



B-12

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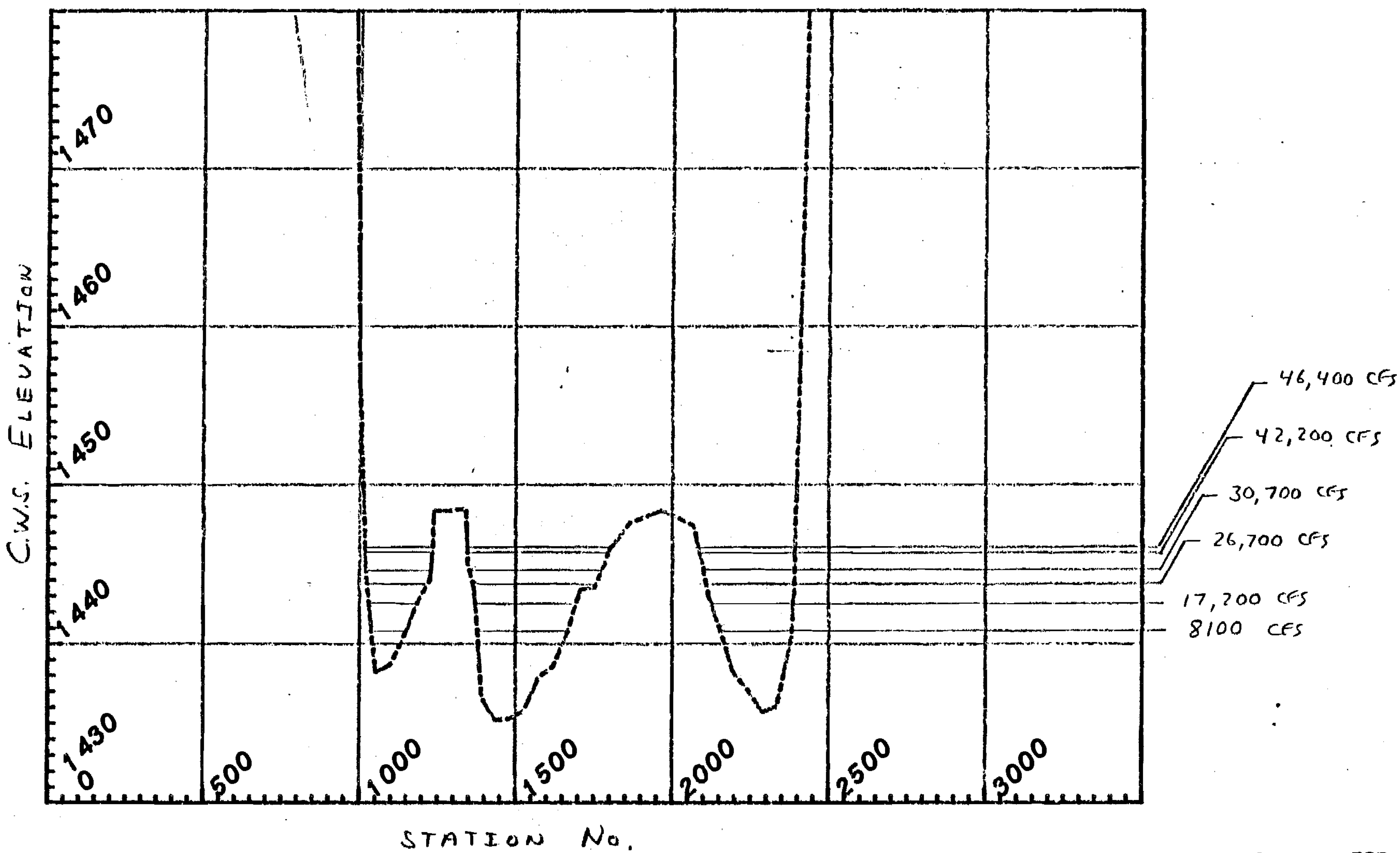
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 110



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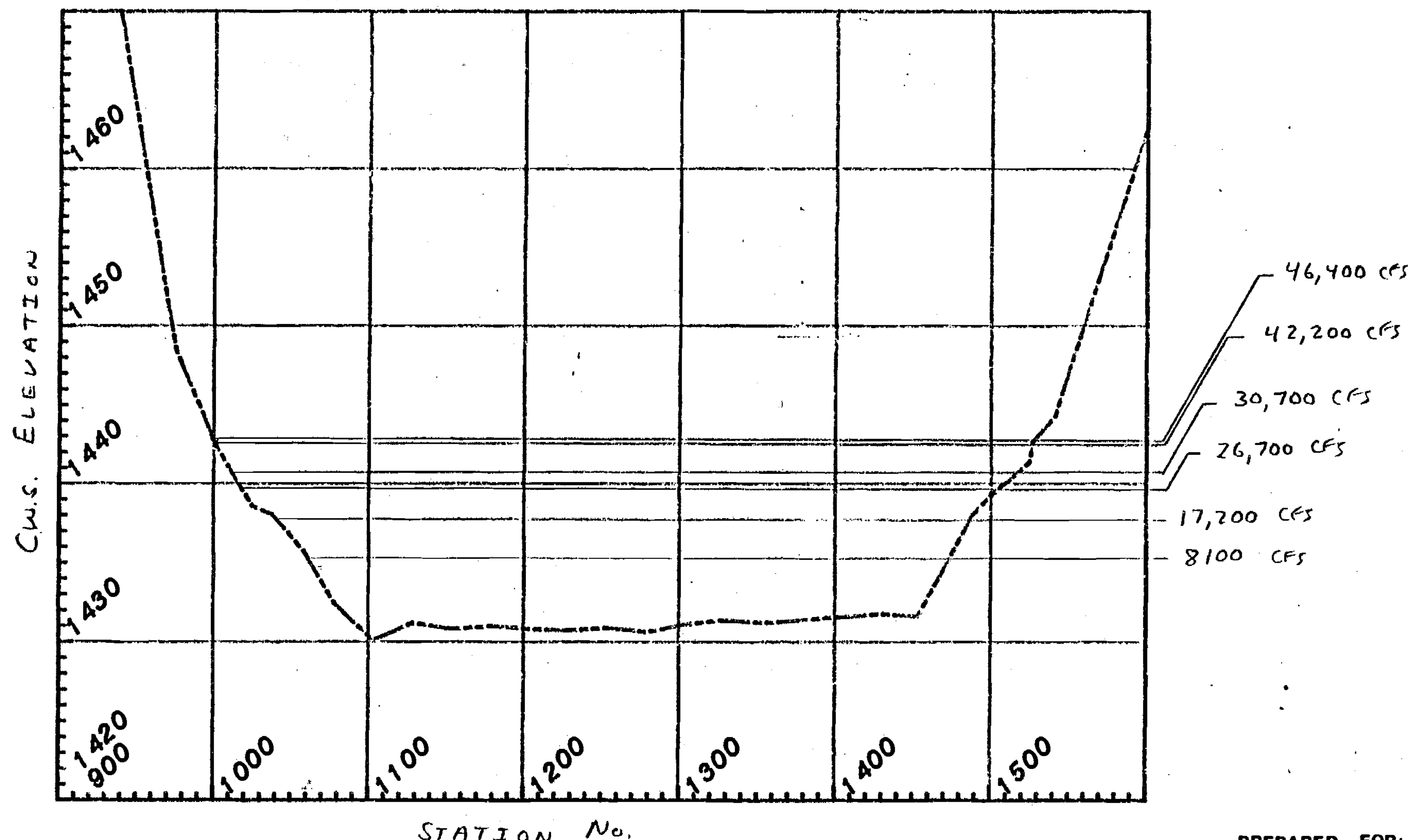
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 111



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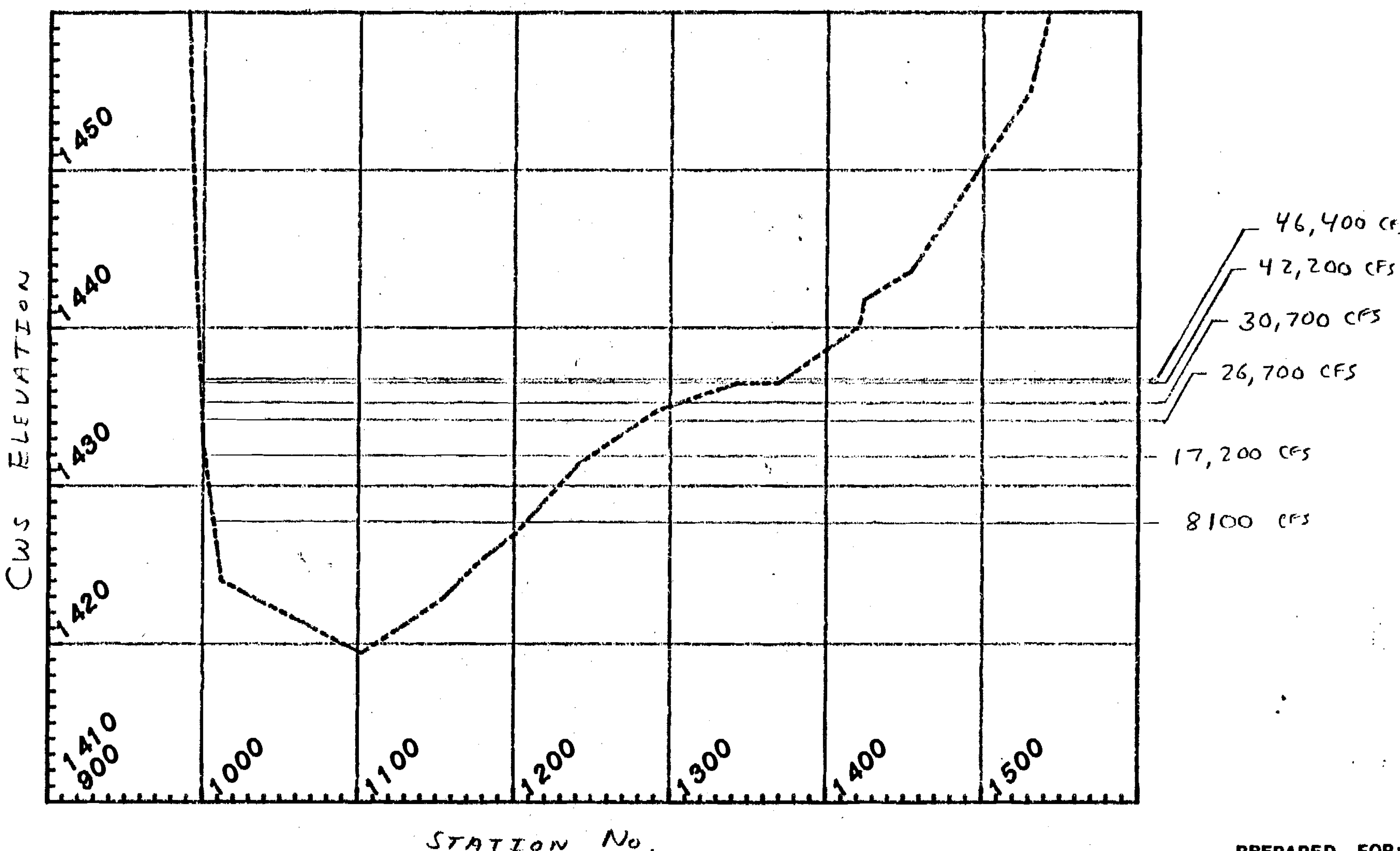
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 112



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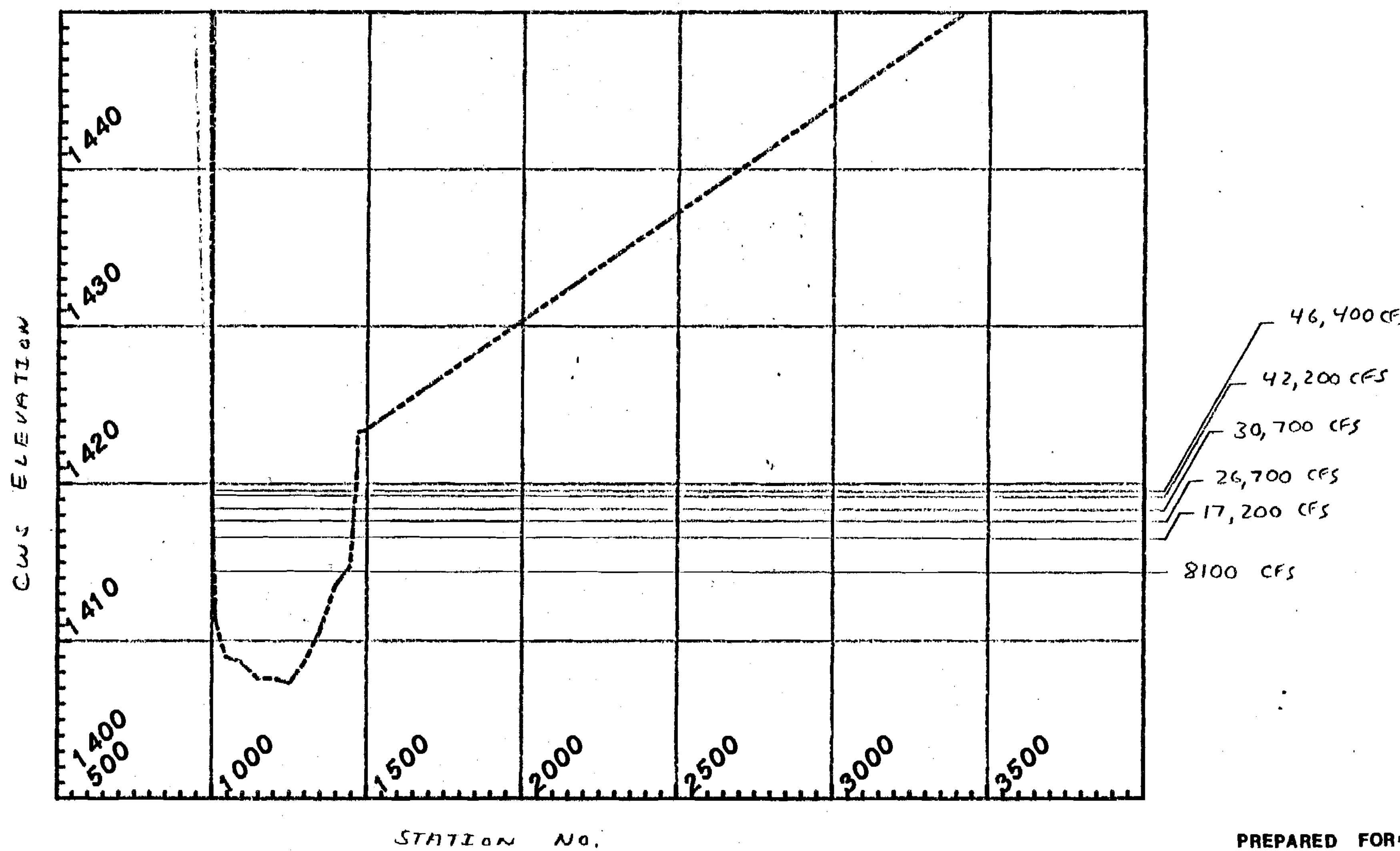
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 113



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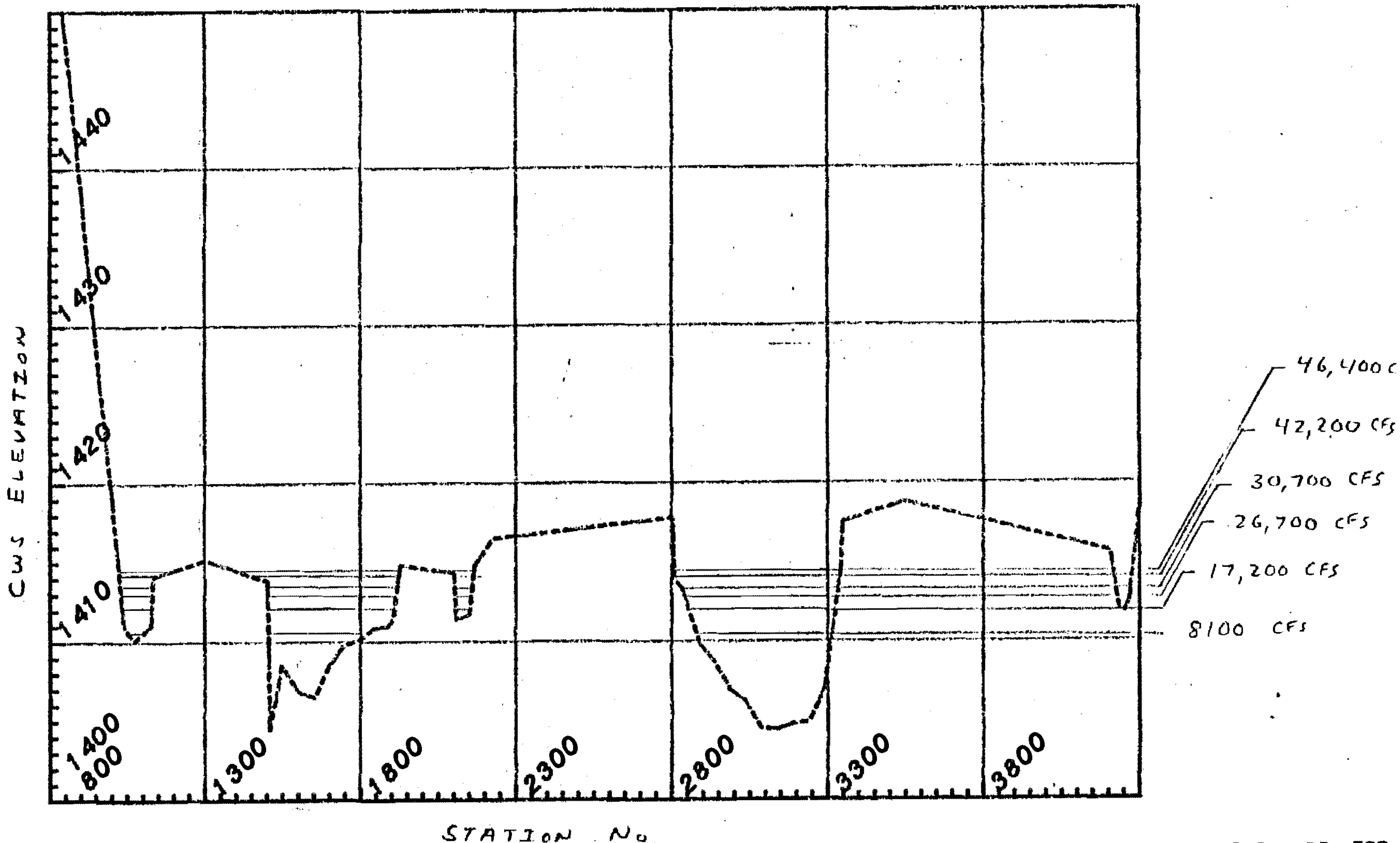
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 114



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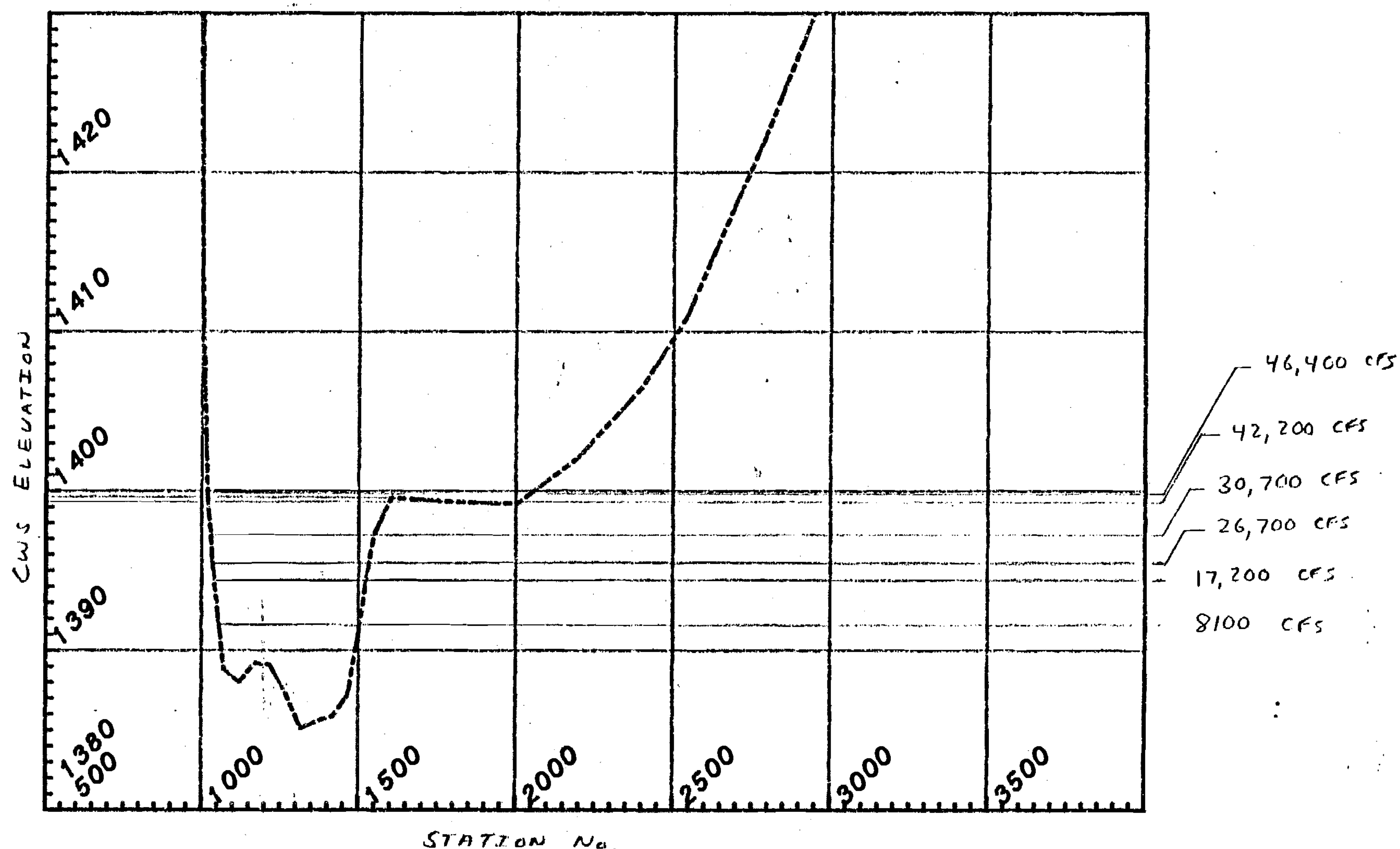
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 115



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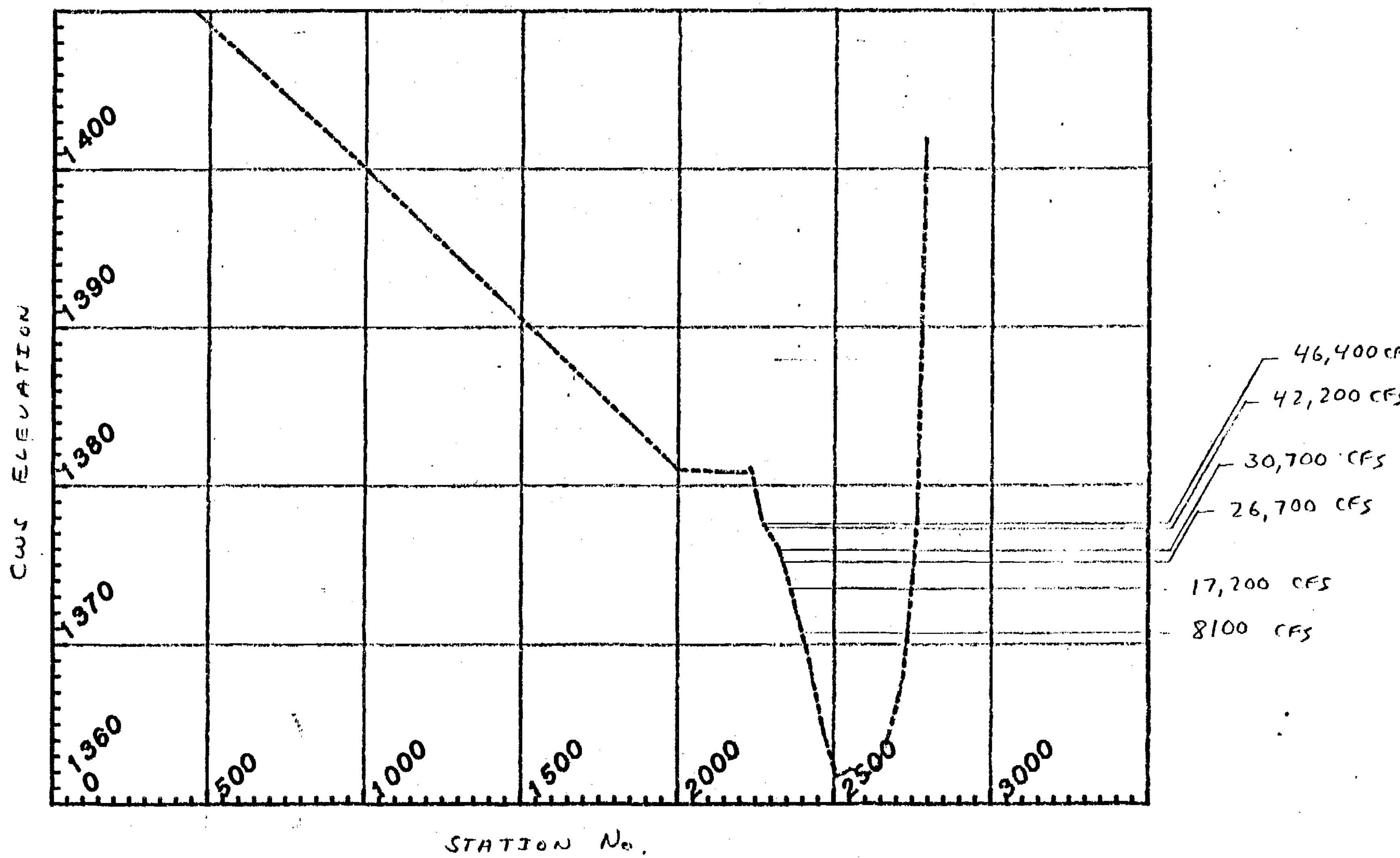
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 116



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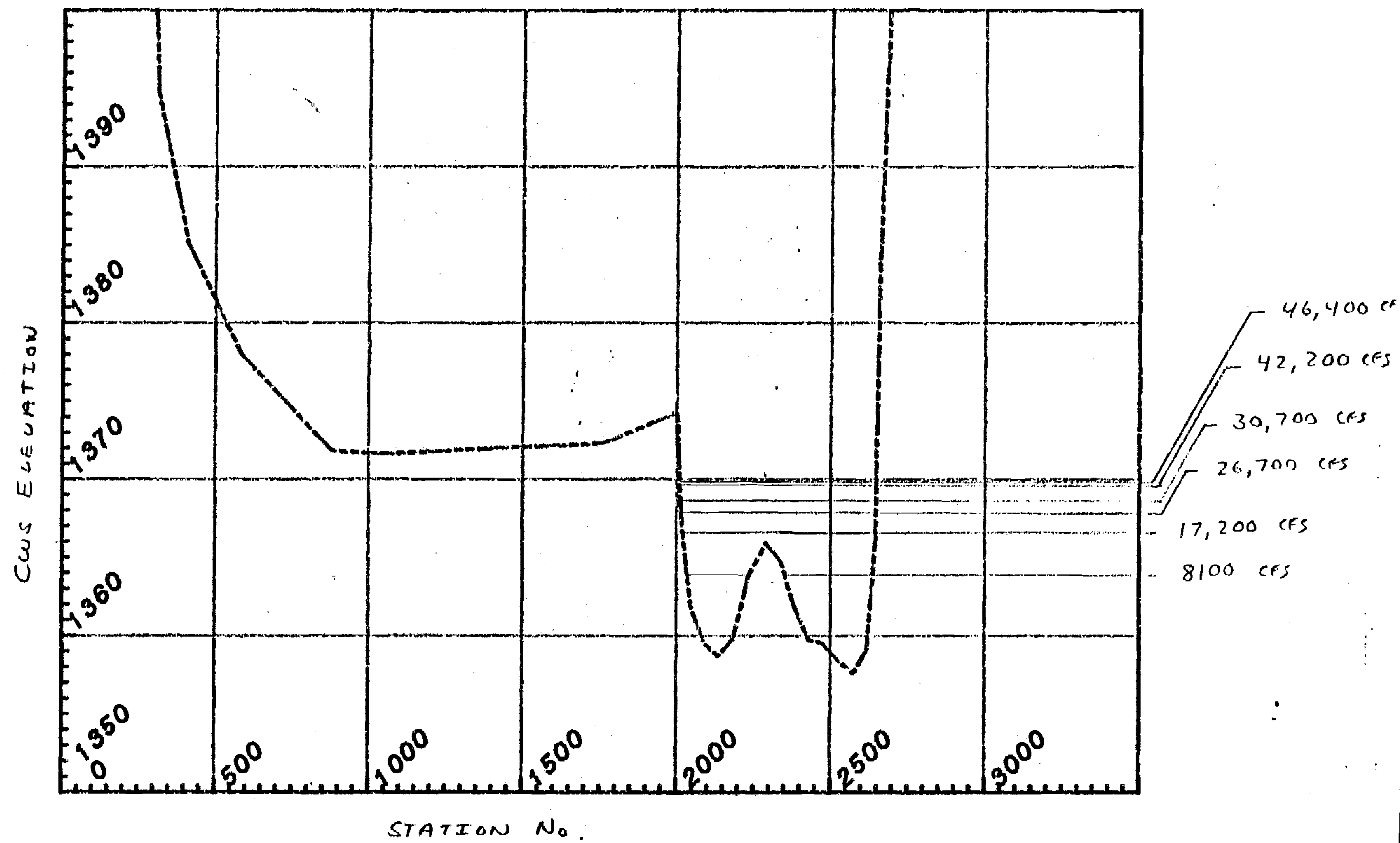
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 117



B-20

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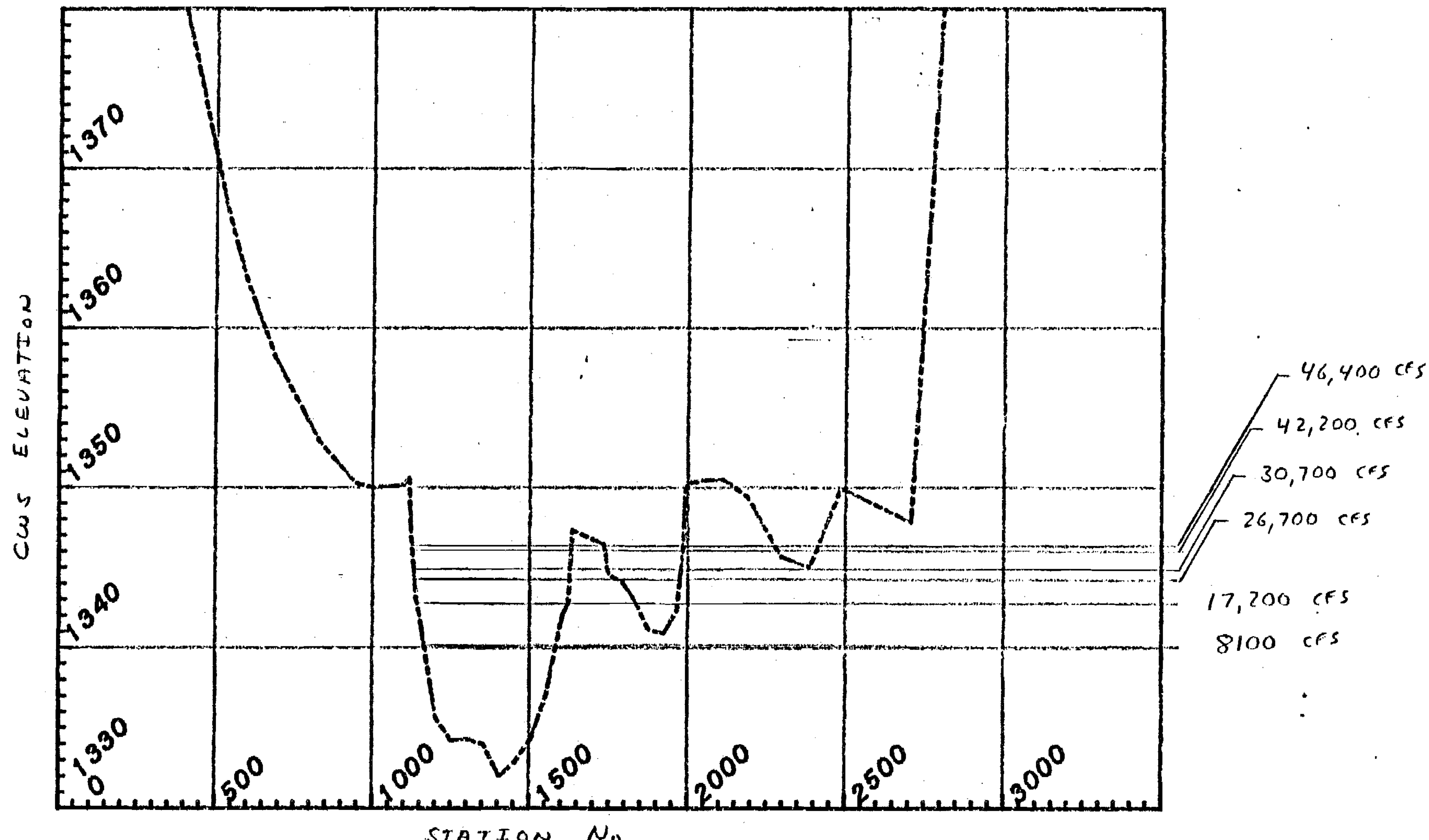
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 118



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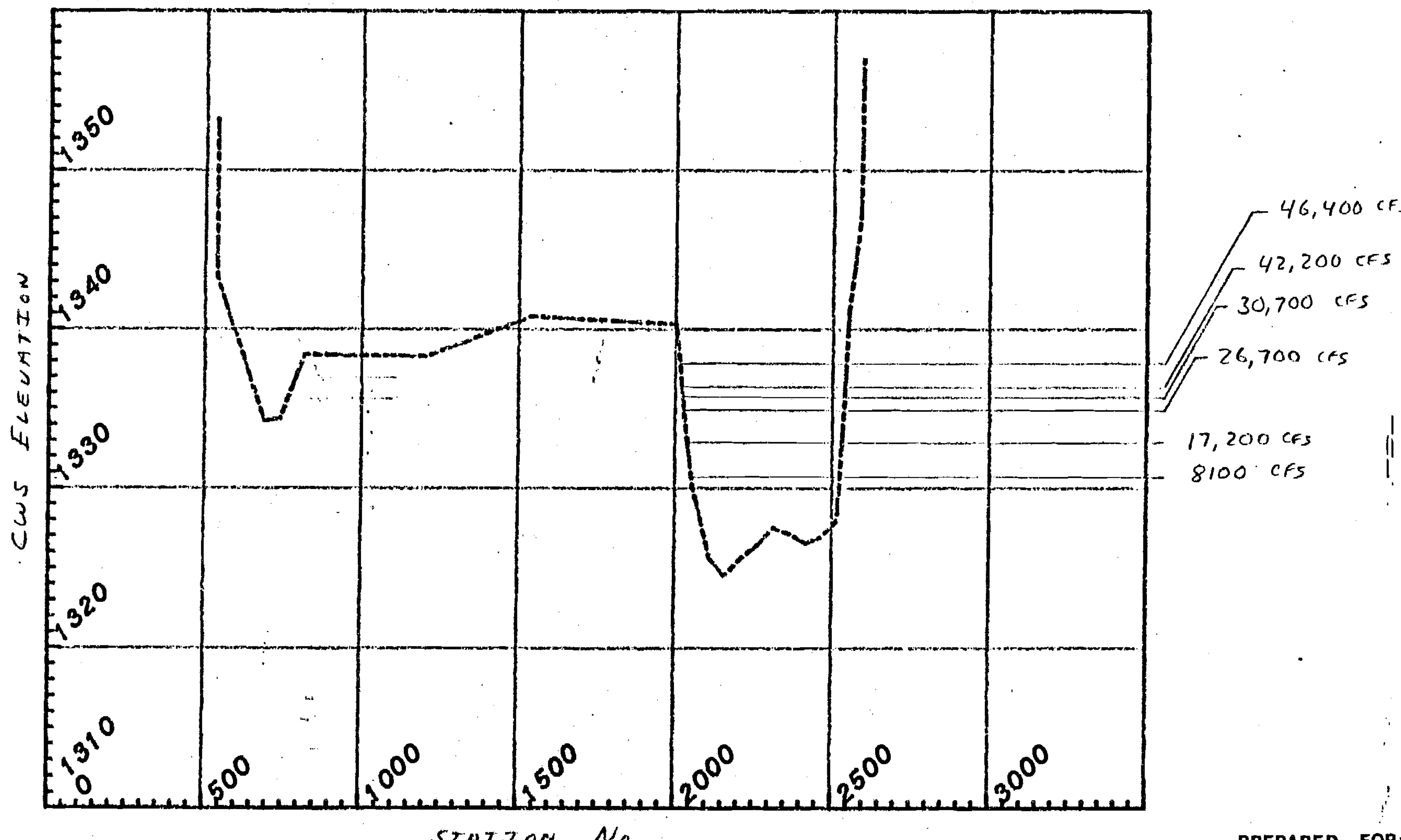
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 119



B-22

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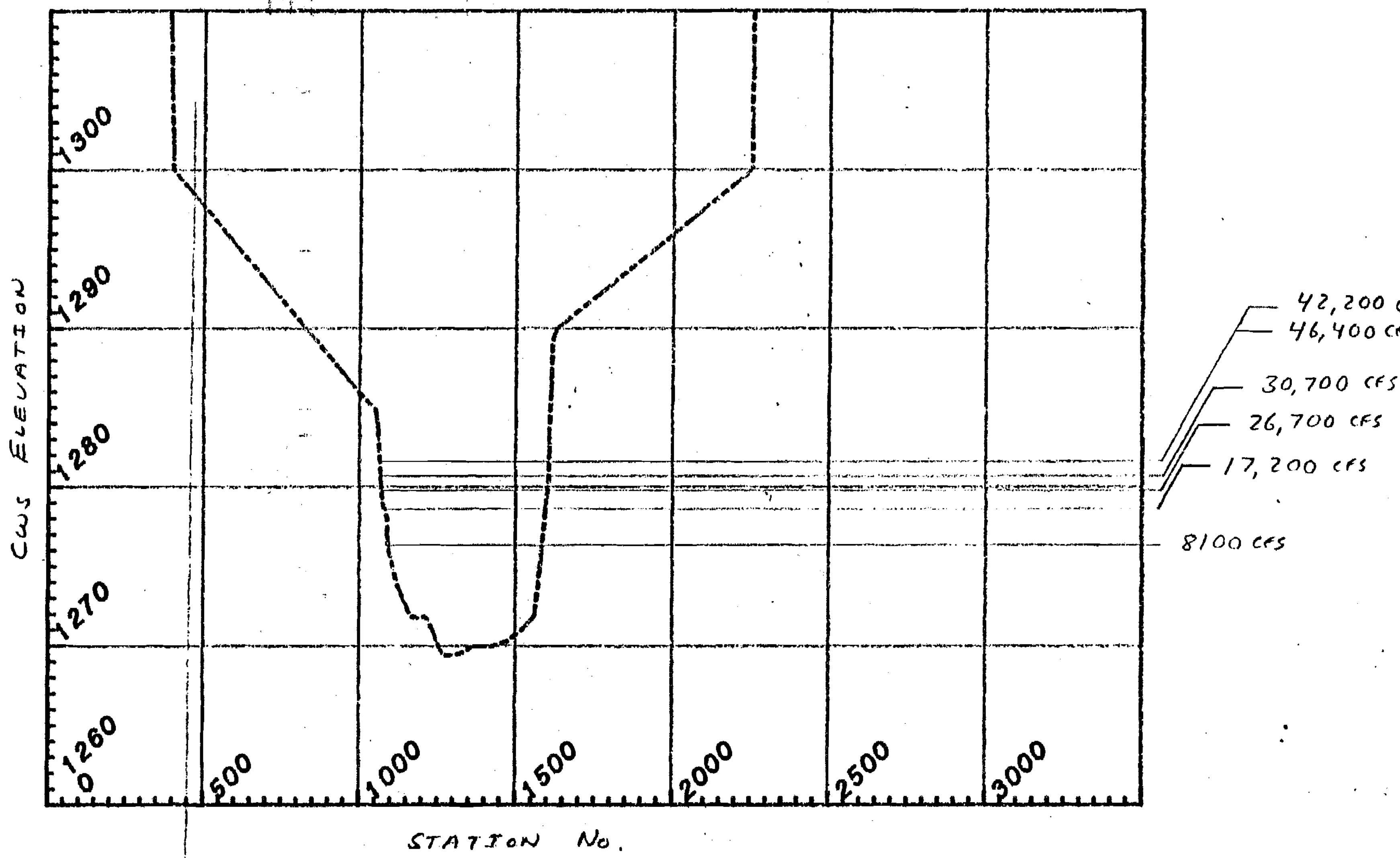
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 120



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R&M CONSULTANTS, INC.

PREPARED FOR:

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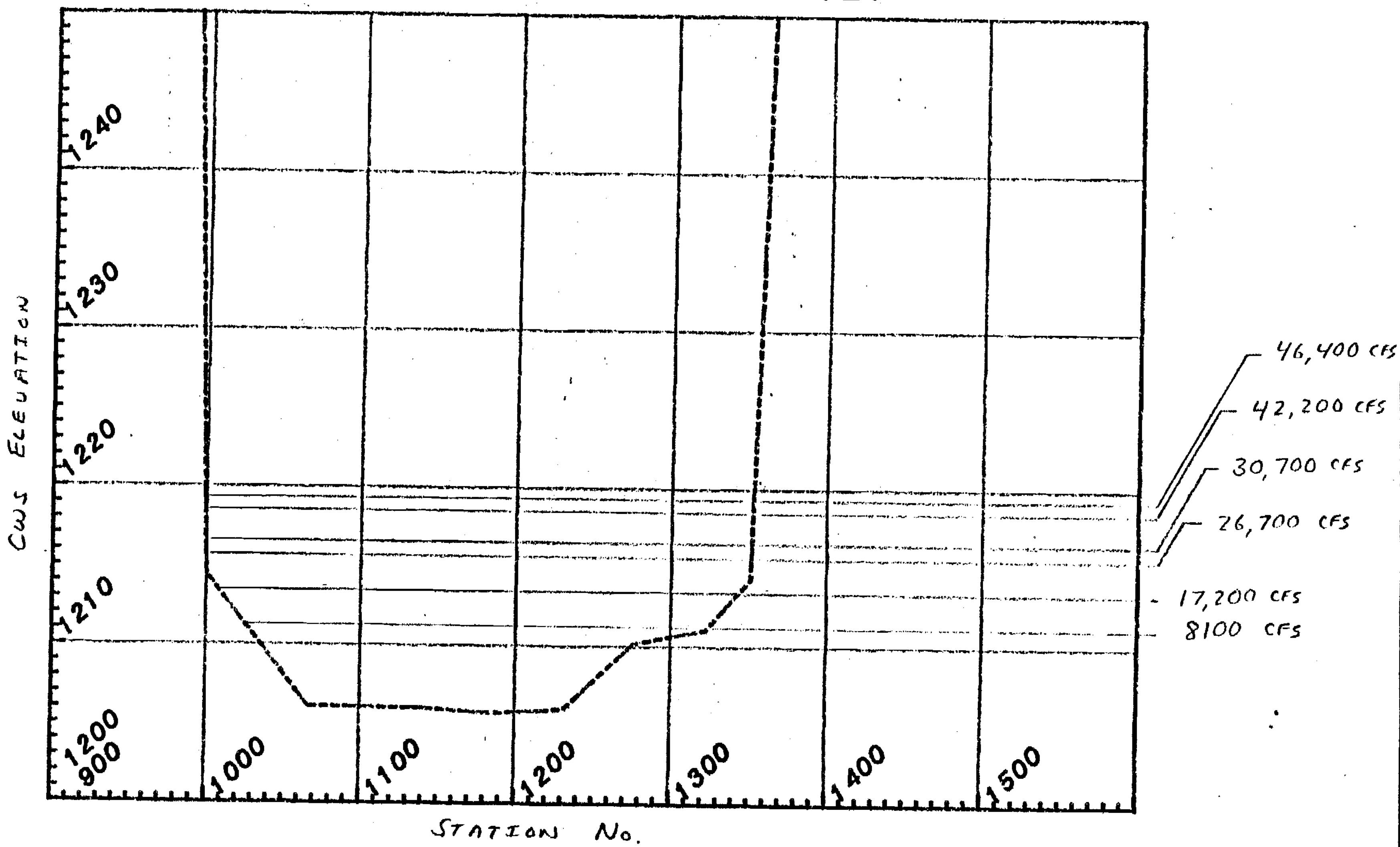
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 121



PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

ATTACHMENT C

COMPUTED WATER SURFACE ELEVATIONS
PLOTTED ON MIDDLE SUSITNA CROSS-SECTIONS

s14/m3

NOTES ON CROSS-SECTION PLOTS - MIDDLE SUSITNA

1. Cross-sections are in sequence from the upstream to the downstream end of the reach. Number 68 is the most-upstream cross-section, and Number 3 is the most-downstream.

2. Plotting scales used vary somewhat from cross-section to cross-section. All are plotted with 10 feet to the inch vertically, but the horizontal scale used is either 100, 200, 250, 500 or 1000 feet per inch.

3. All cross-sections are plotted looking downstream.

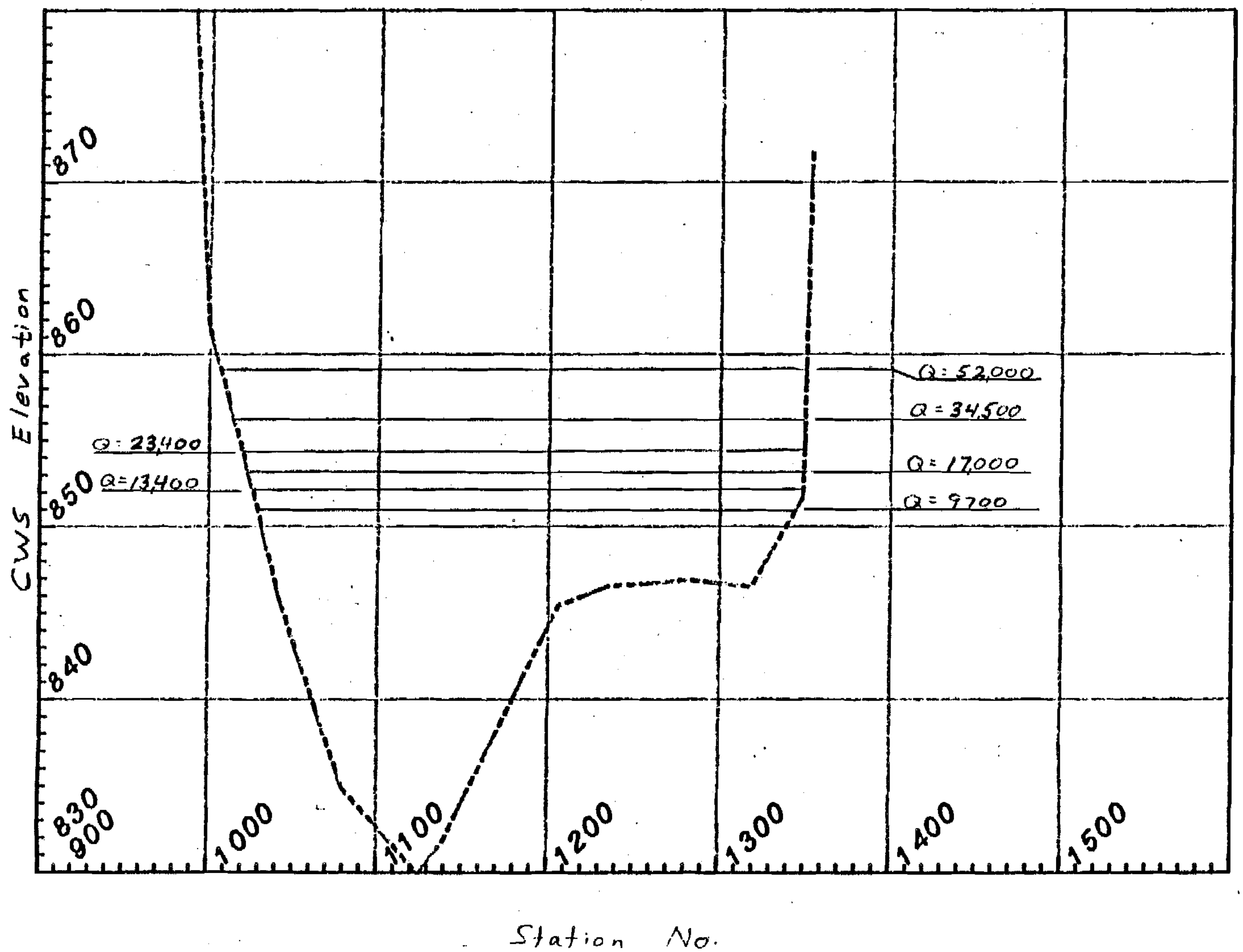
4. Water surface elevations plotted on each cross-section are those computed by the HEC-2 computer model. The streamflows used in this study reach and plotted on all the cross-sections (referenced to the Gold Creek gage) were 9,700; 13,400; 17,000; 23,400; 34,500; and 52,000 cfs. Flows on the plots specify the Gold Creek flow, but at the cross-sections they were actually adjusted for drainage area, as shown in Table 4.4 of the main report.

5. At several cross-sections, water levels are not shown in low areas of side channels or sloughs. In some cases, this is because no river water is expected there at all. In other cases, there may be water, but no hydraulic connection is apparent; thus, no flow is there, and the actual water level there may be above or below that in the river.

6. Where the cross-section is at a bend in the river or is split between more than one main channel, there are likely to be differences in water surface elevation across the cross-section. The computer model, however, computes just one level, and this is understood to be the mean water surface elevation for the given discharge.

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 68



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PREPARED FOR:

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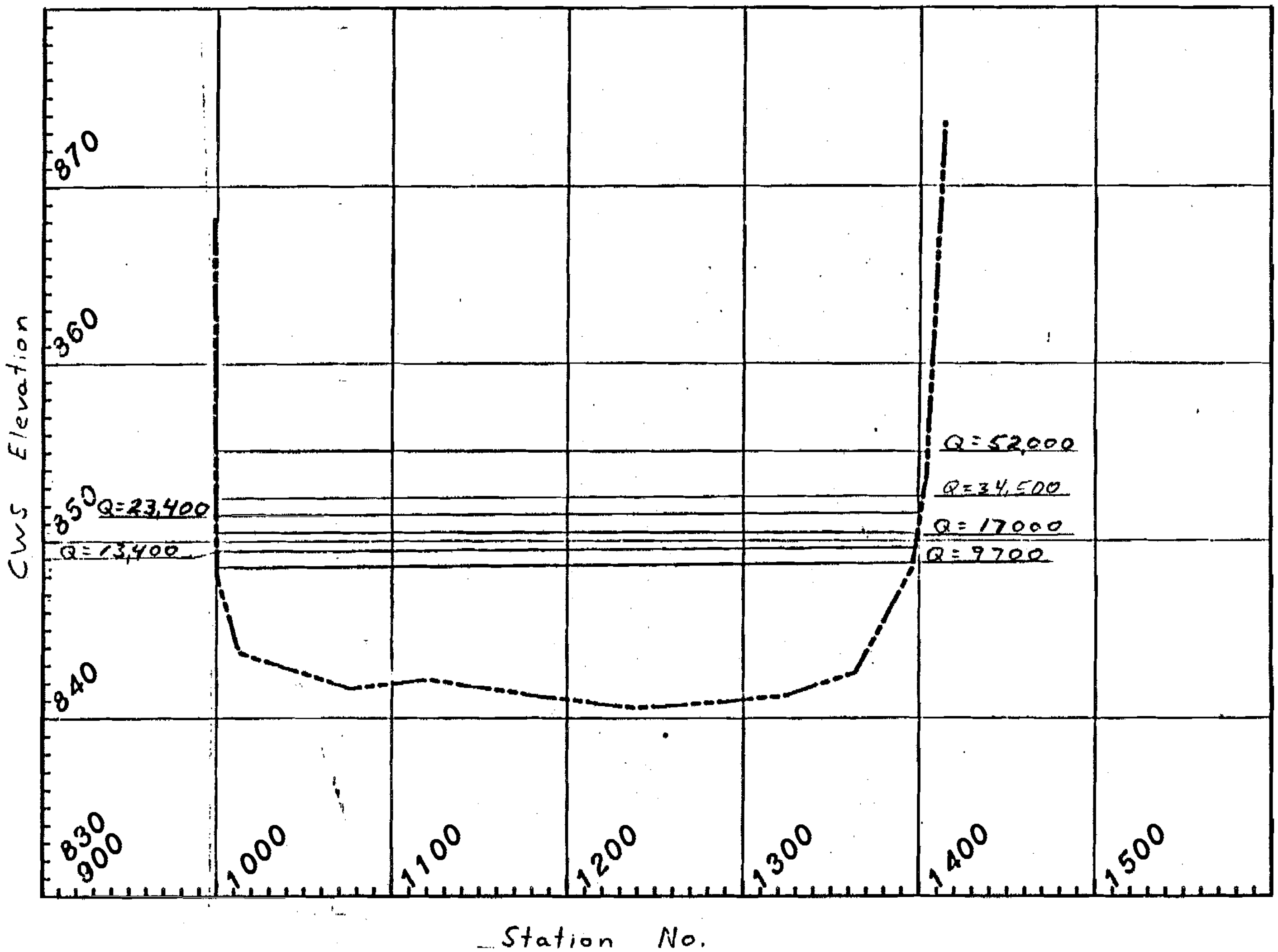
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 67



PREPARED BY:

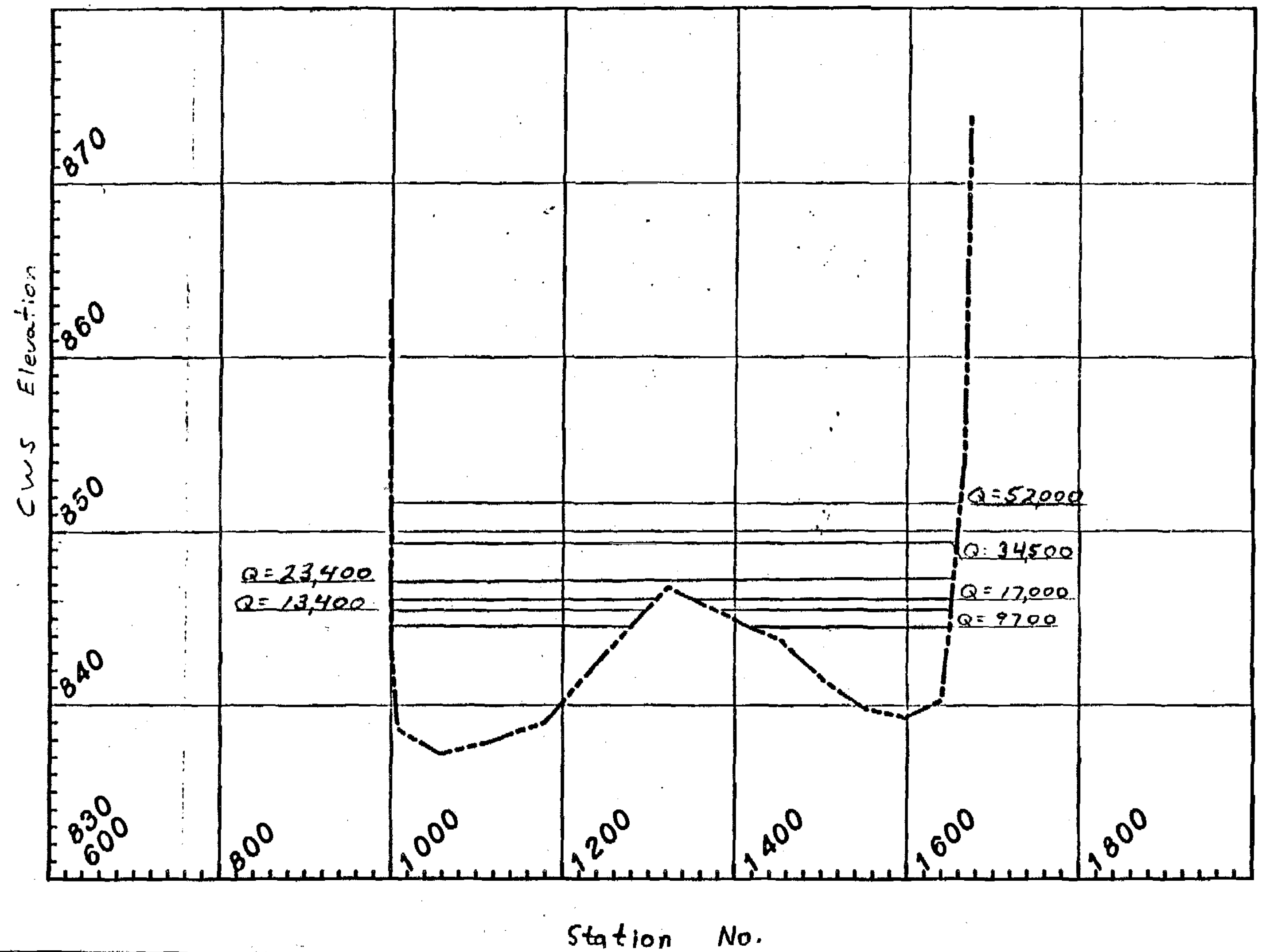
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 66



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PREPARED FOR:

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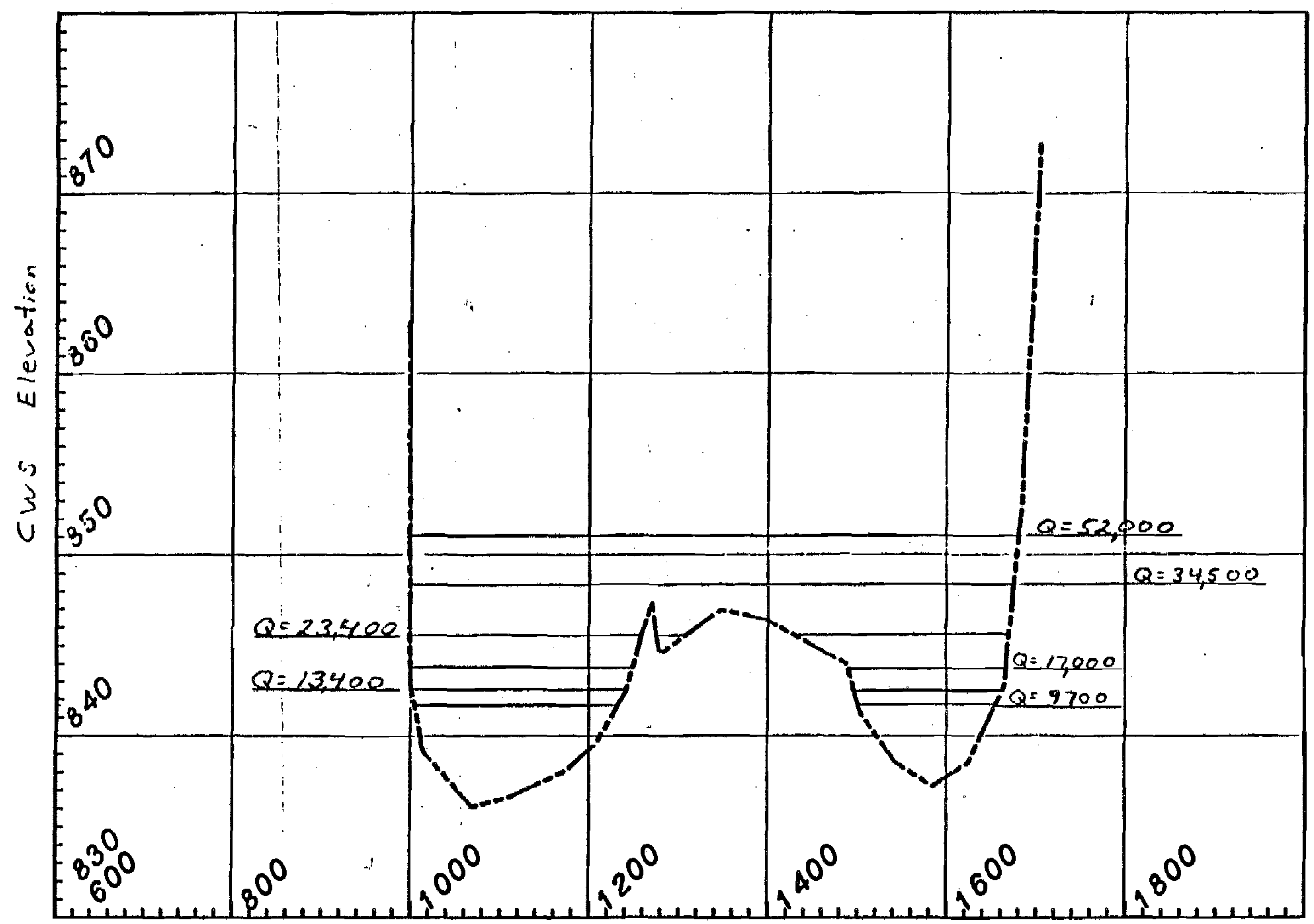
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 65



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R&M CONSULTANTS, INC.

PREPARED FOR:

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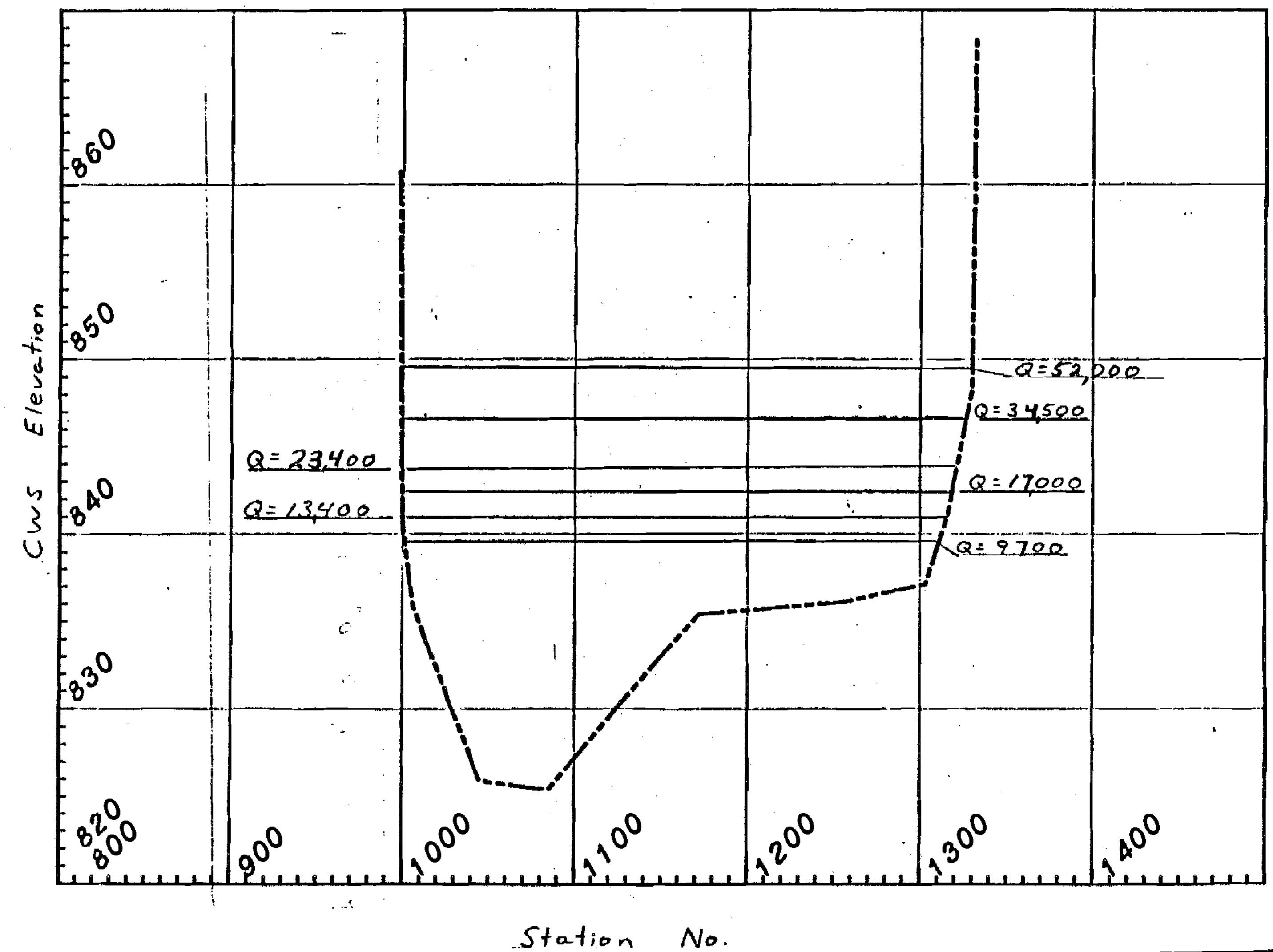
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 64



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R&M CONSULTANTS, INC.

PREPARED FOR:

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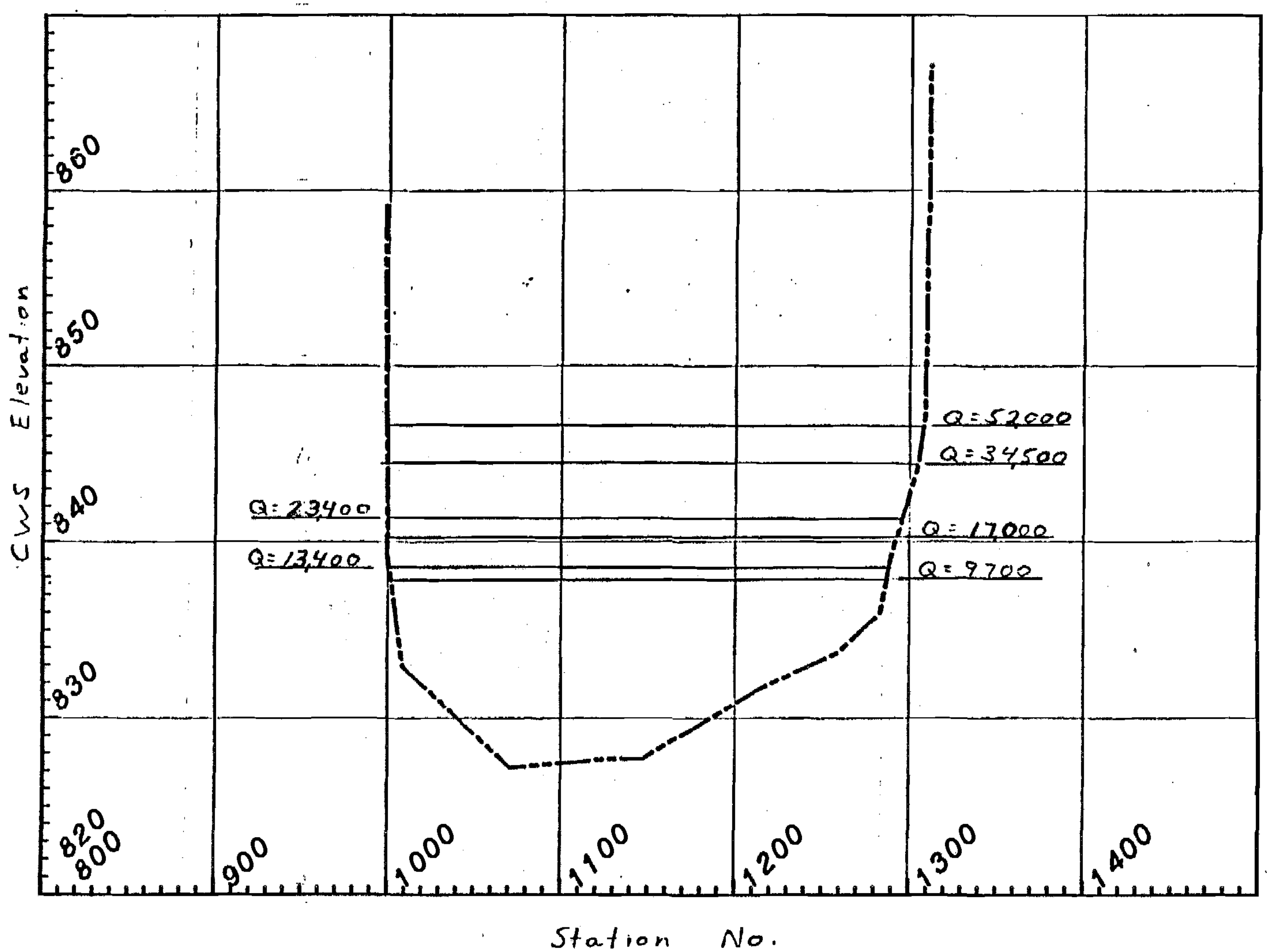
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 63



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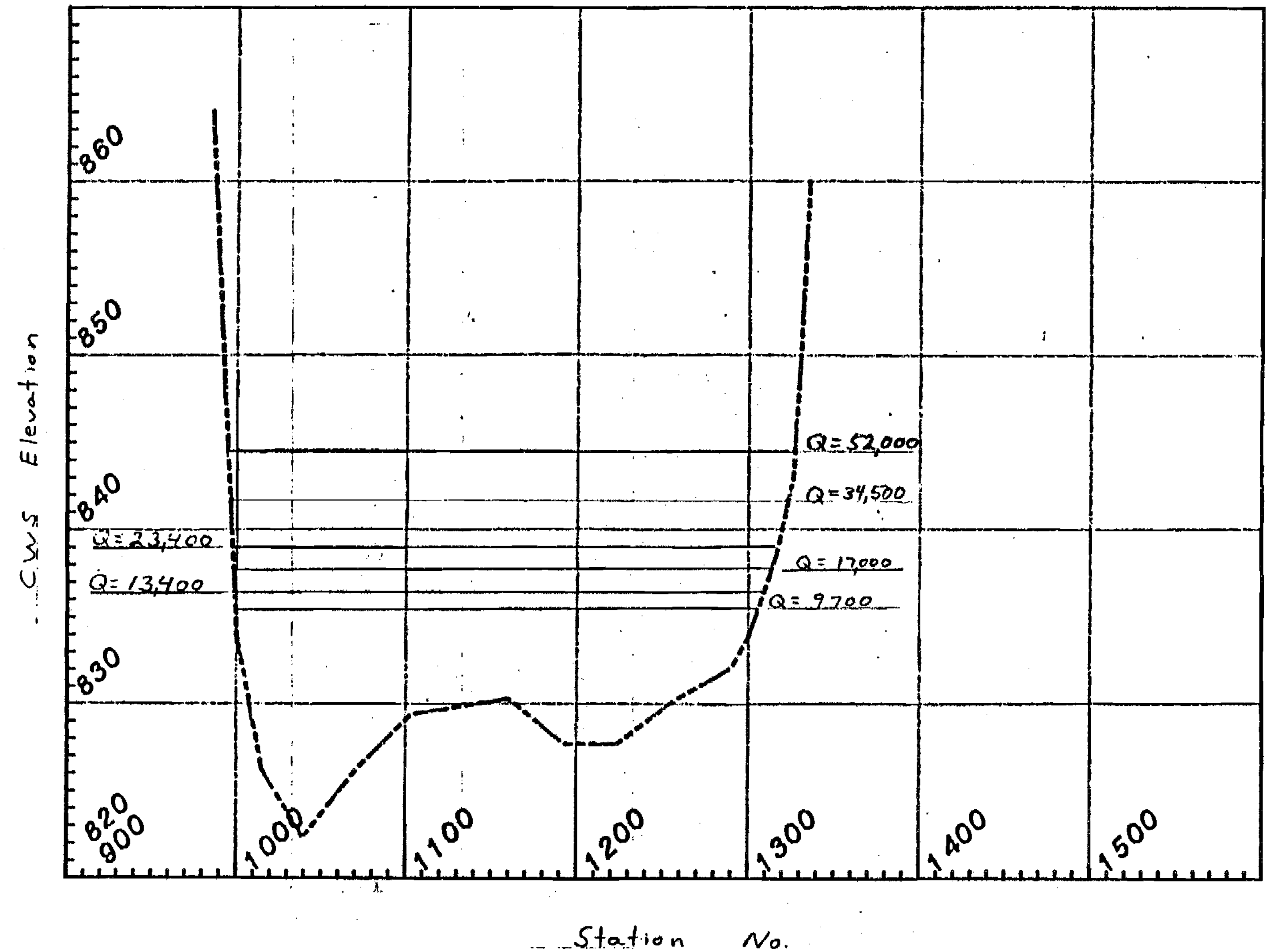
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 62



PREPARED BY:

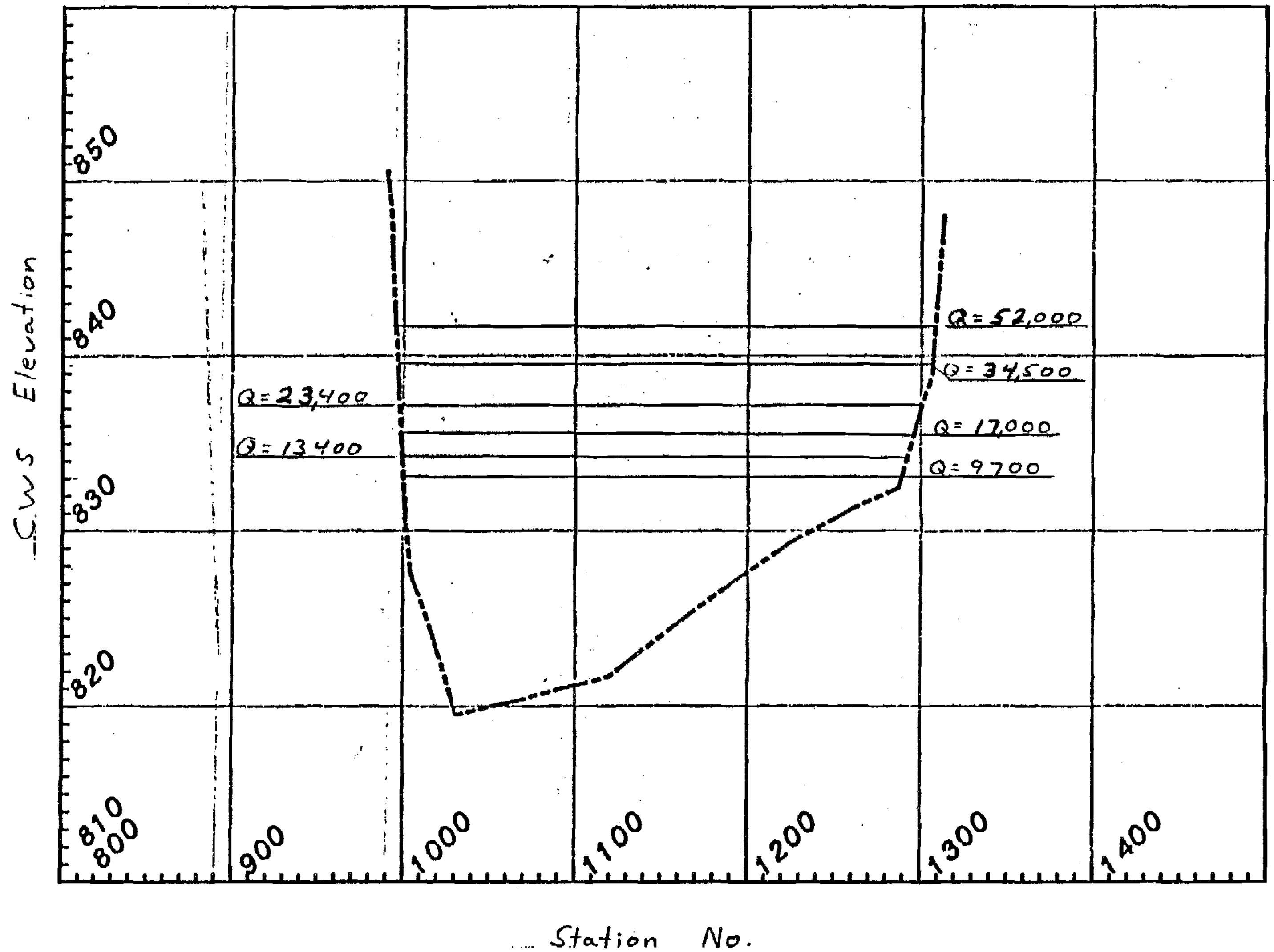
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 61



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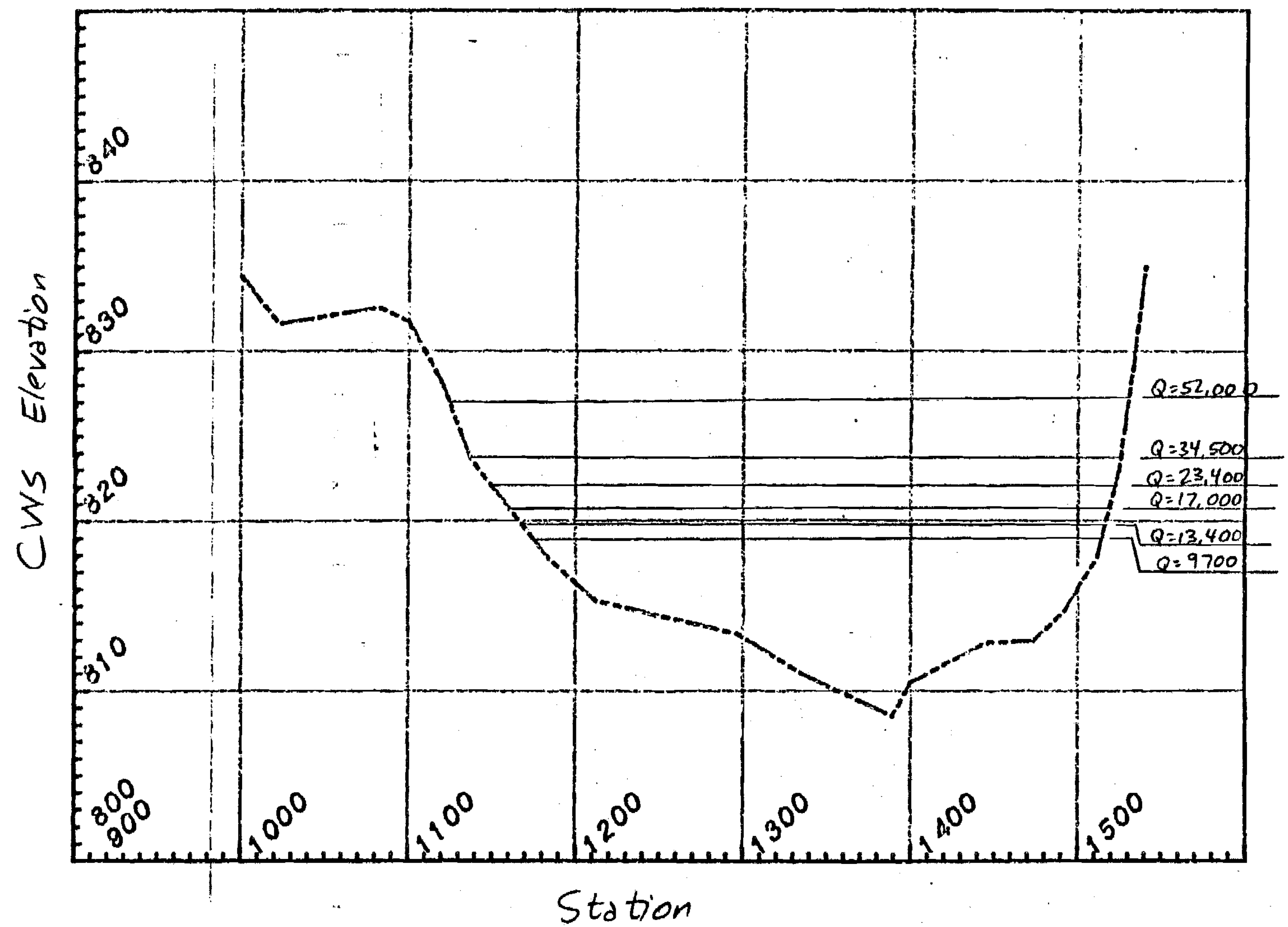
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 60



C-10

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PREPARED FOR:

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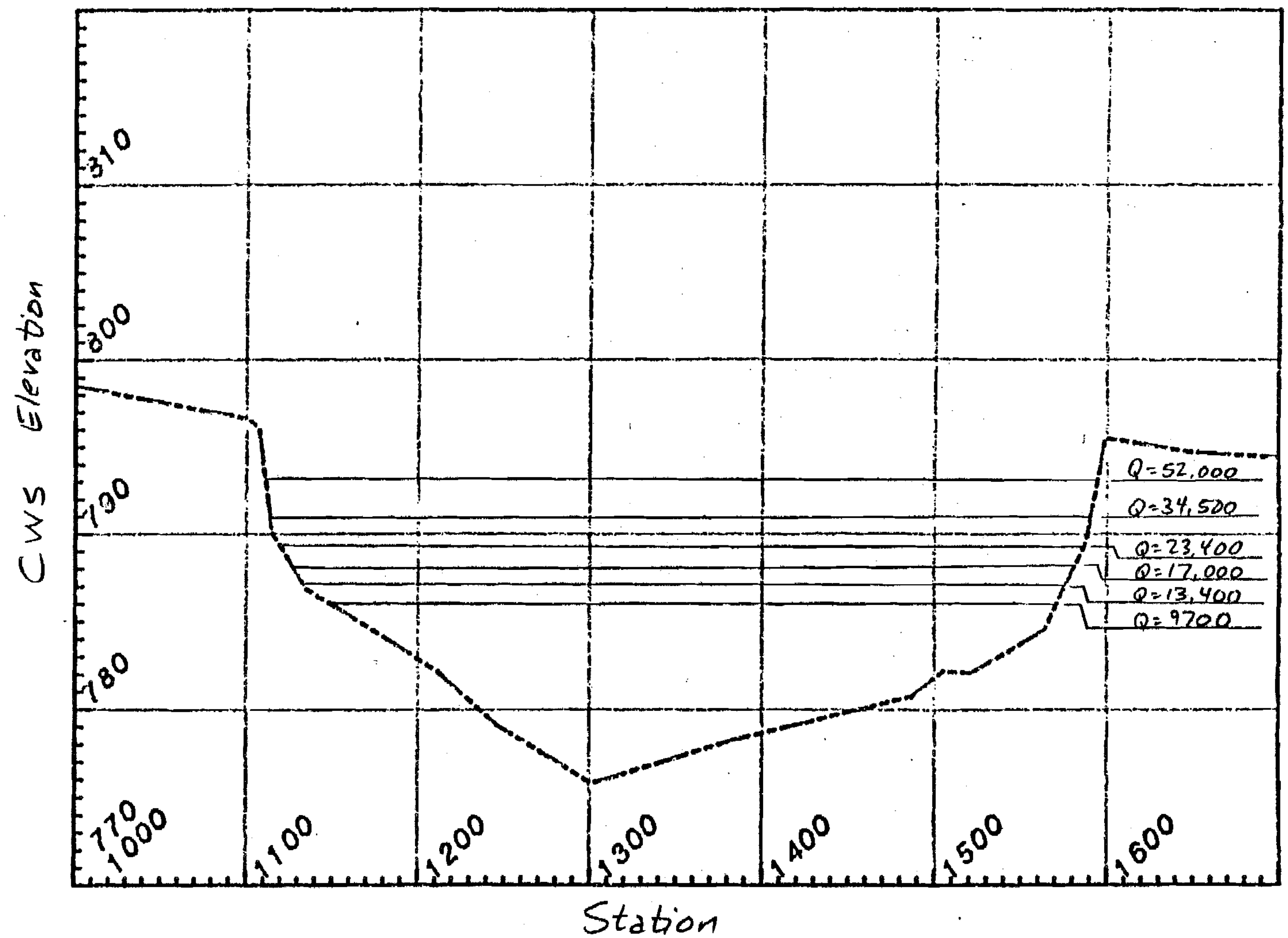
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 59



PREPARED BY:

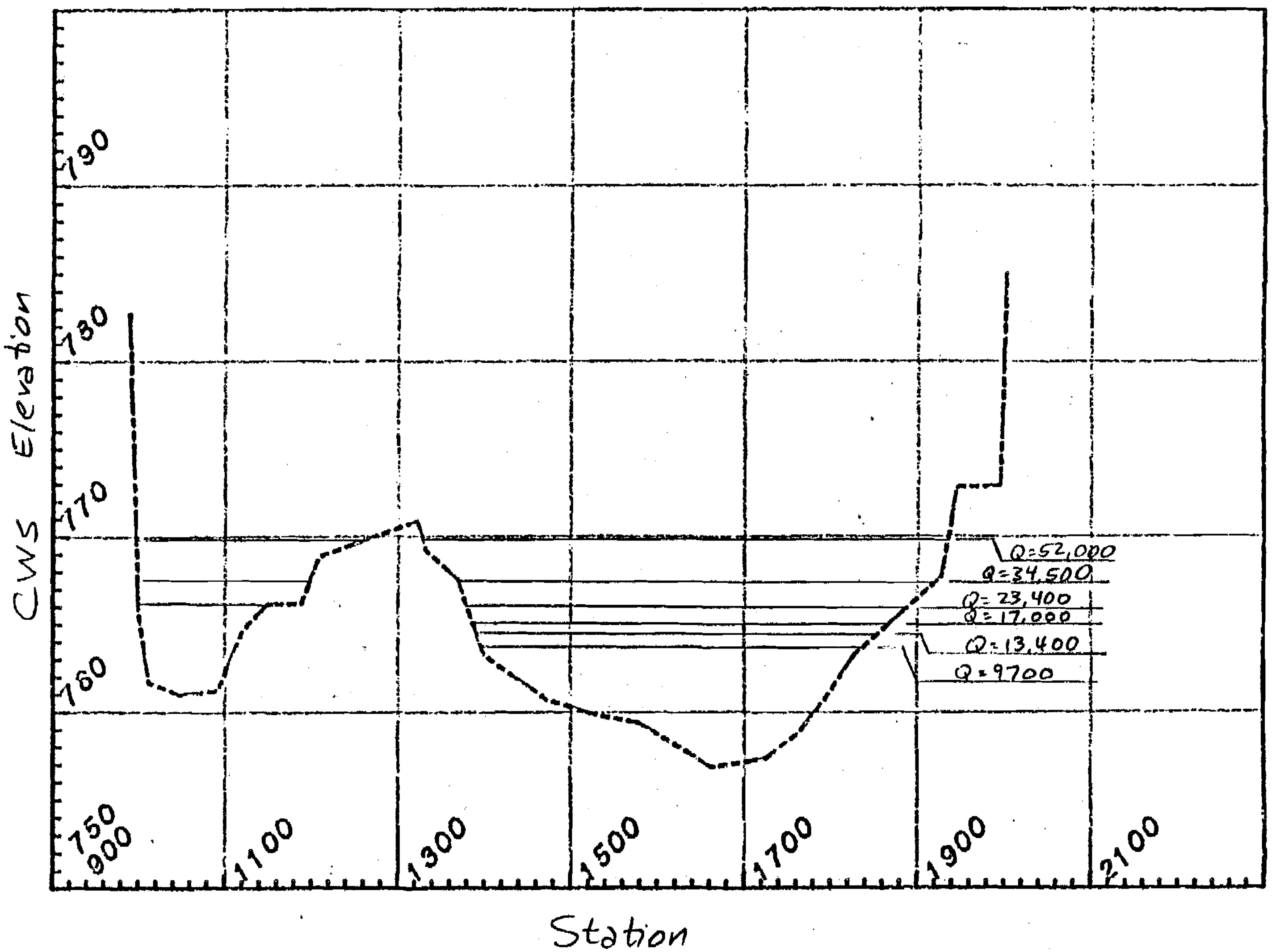
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 58



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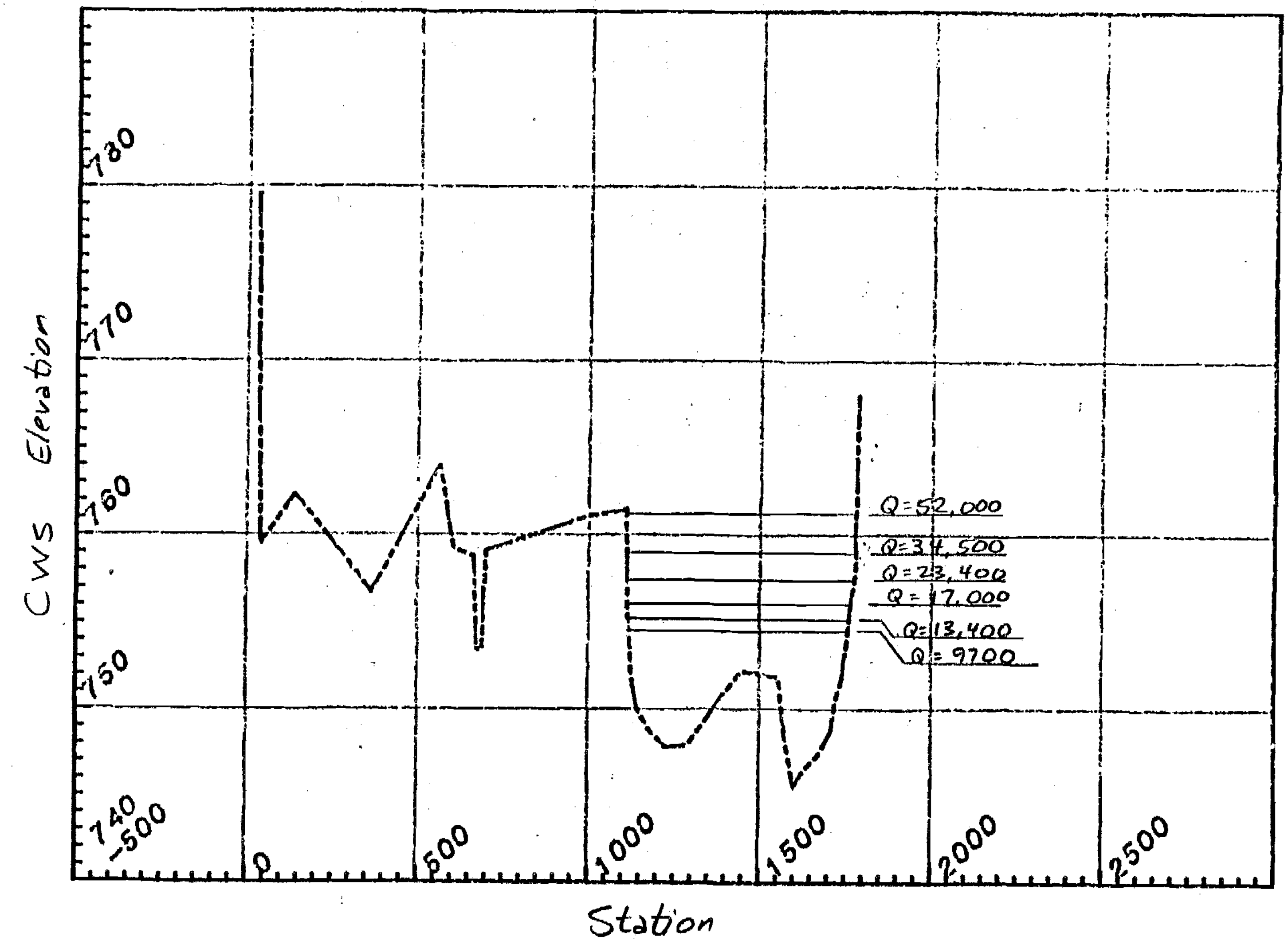
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 57



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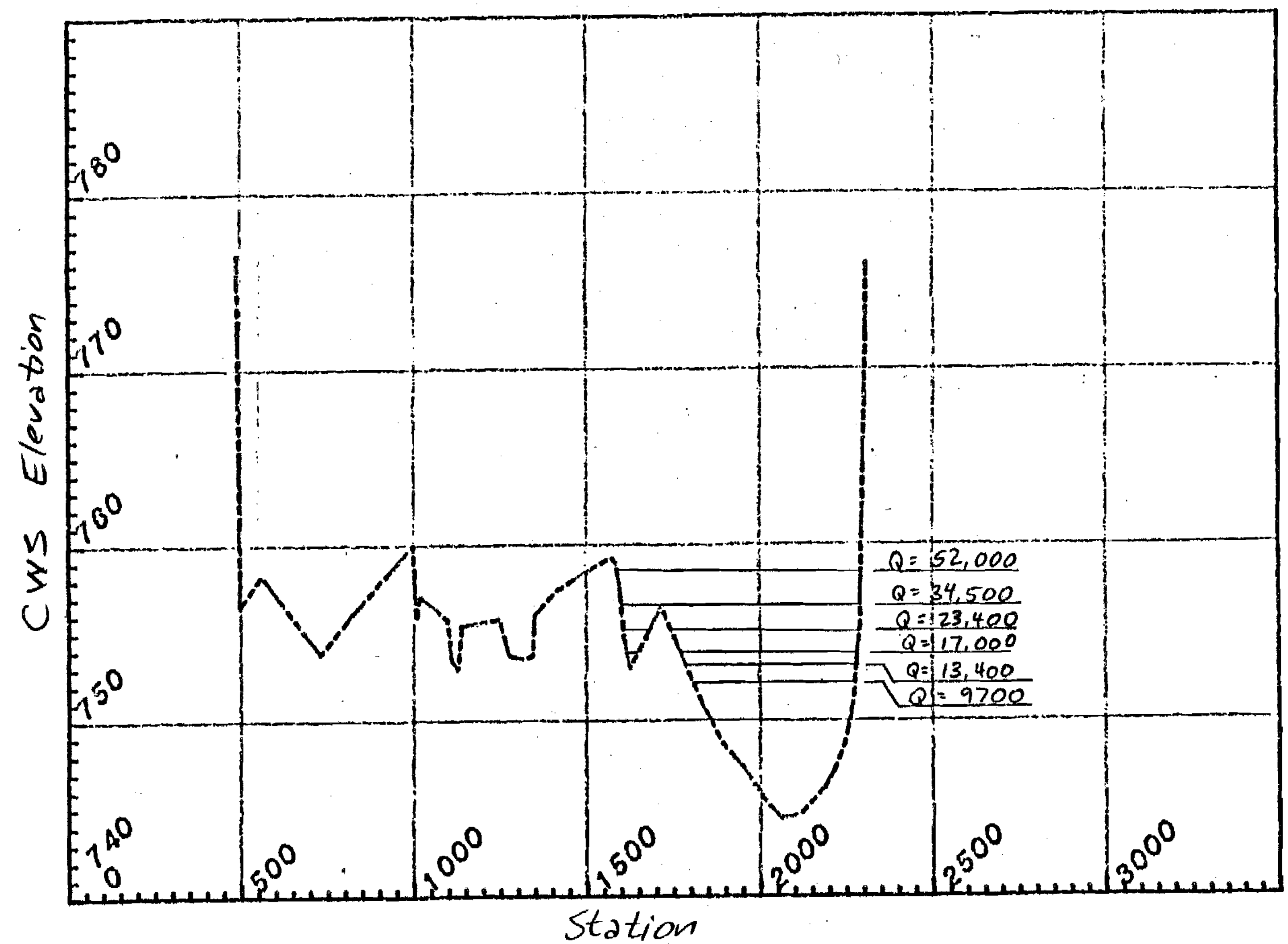
R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 56



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PREPARED FOR:

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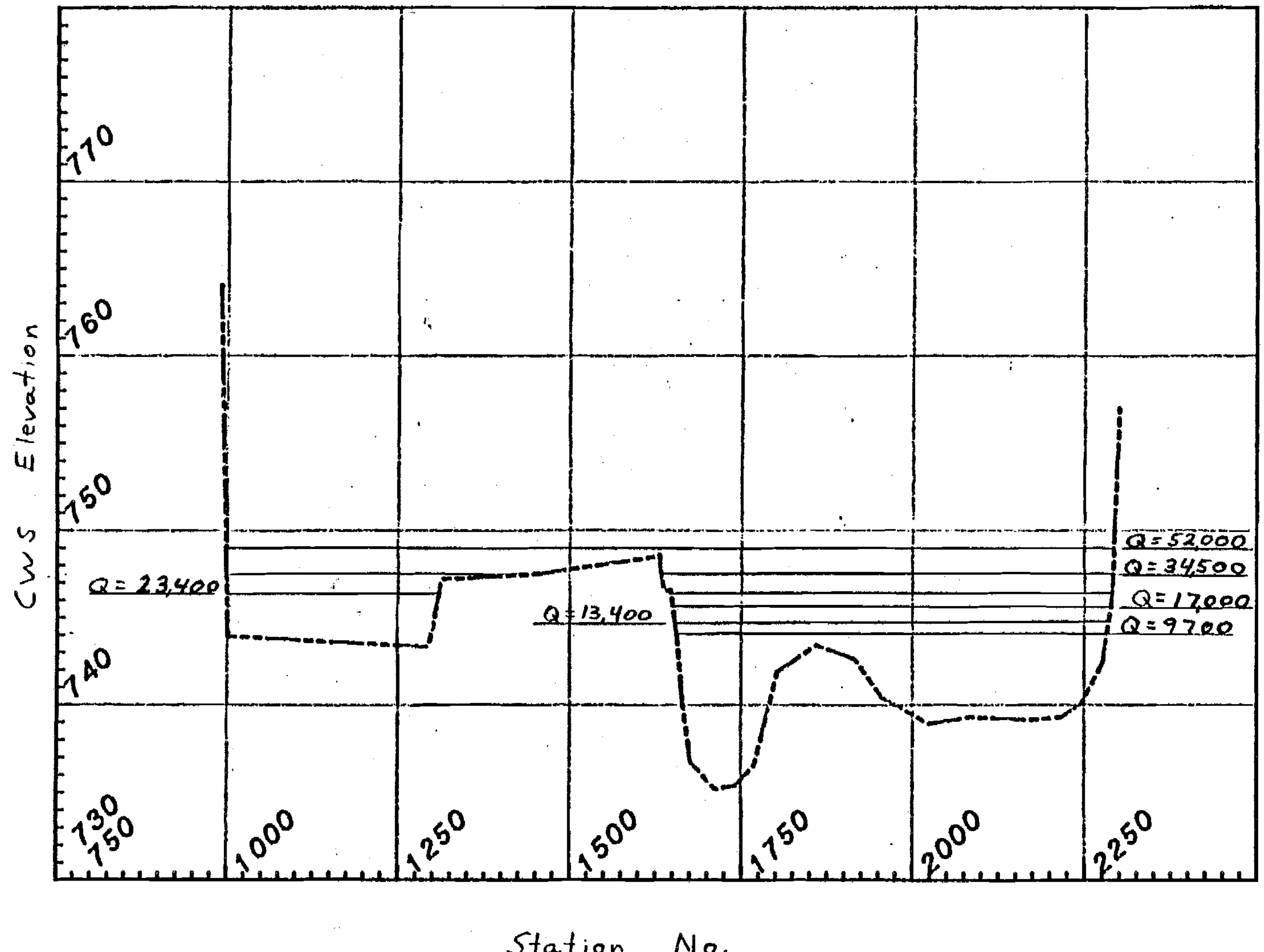
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 55



C-15

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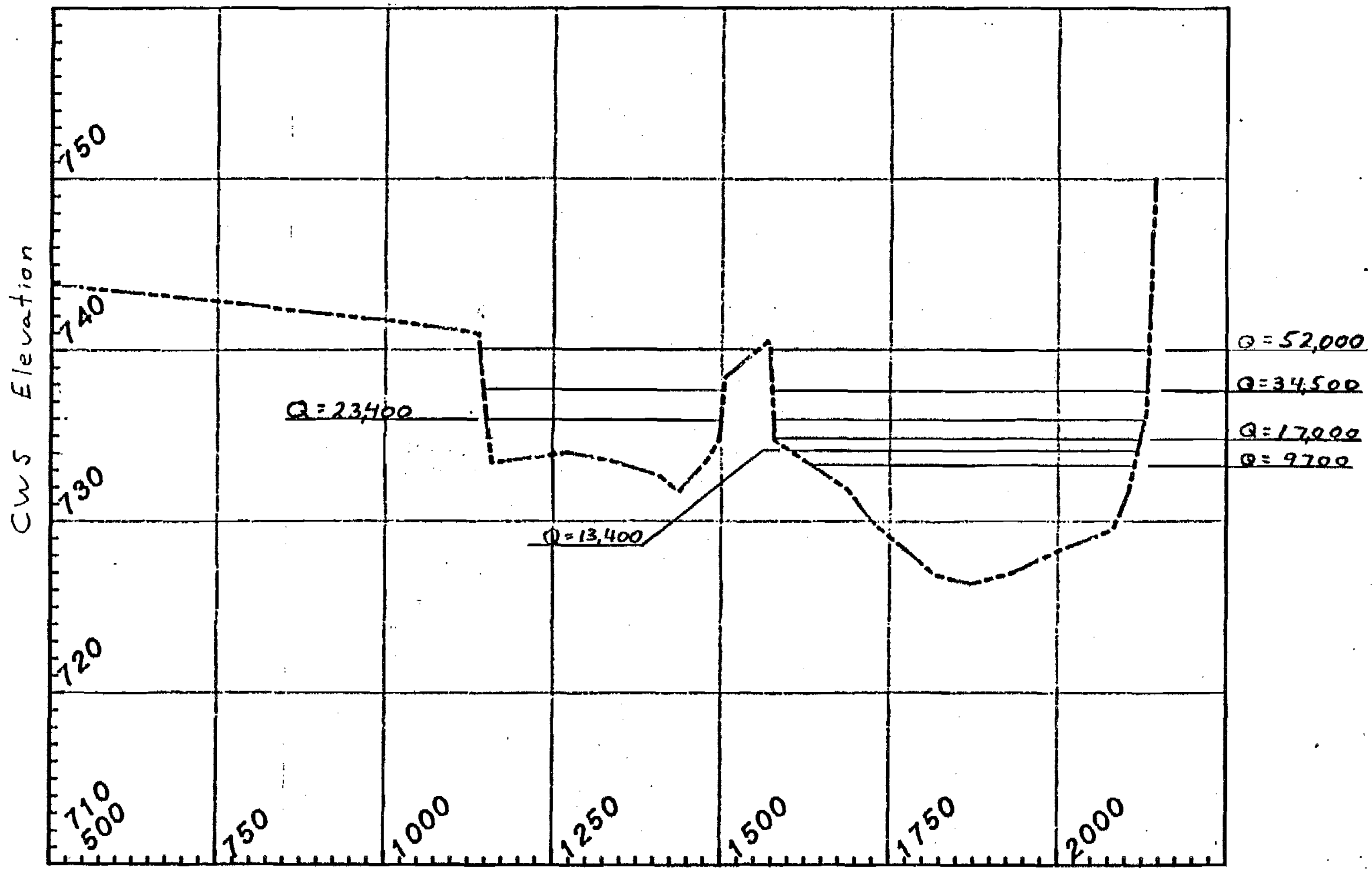
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 54



Station No.

PREPARED BY:

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PREPARED FOR:

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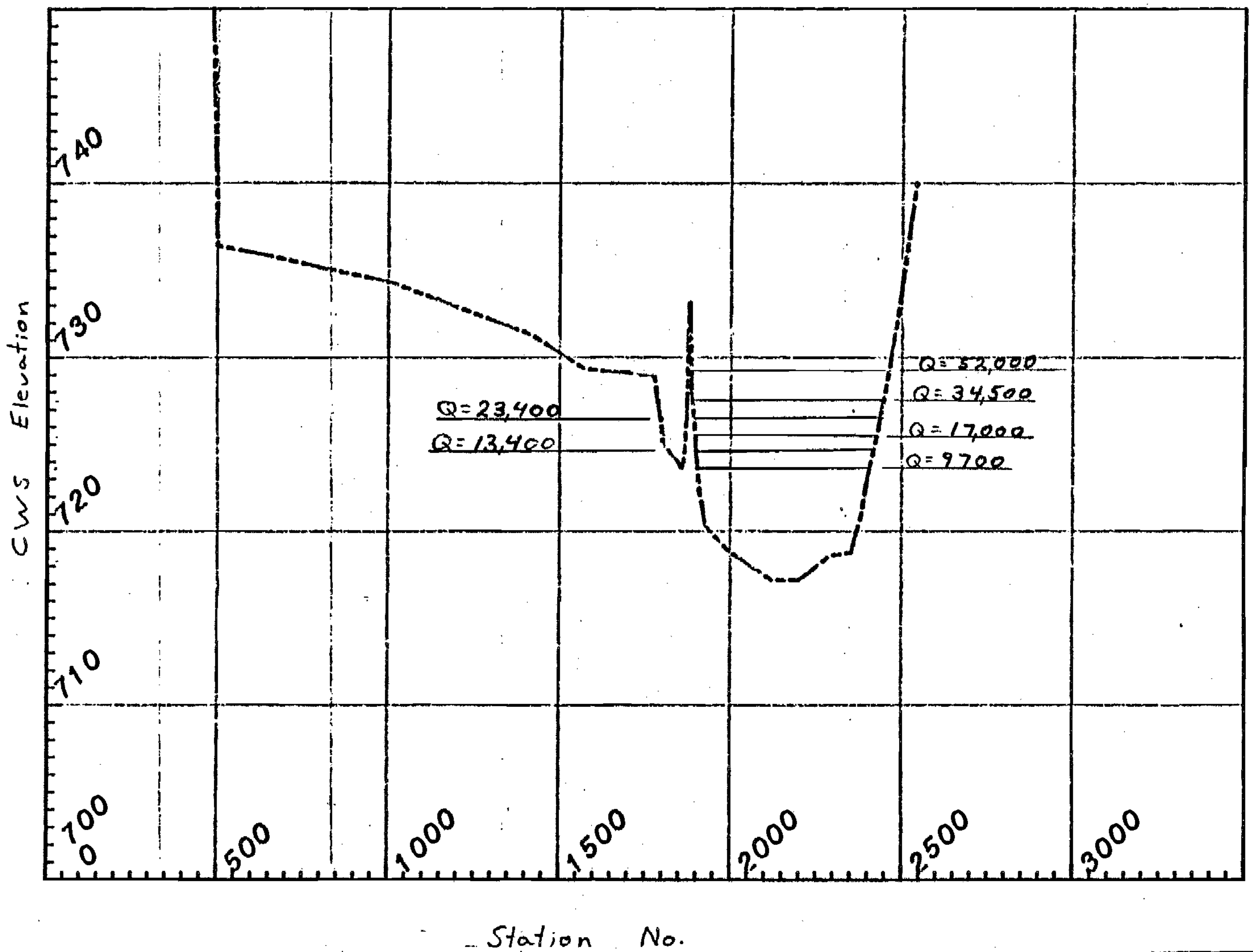
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 53



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PREPARED BY:

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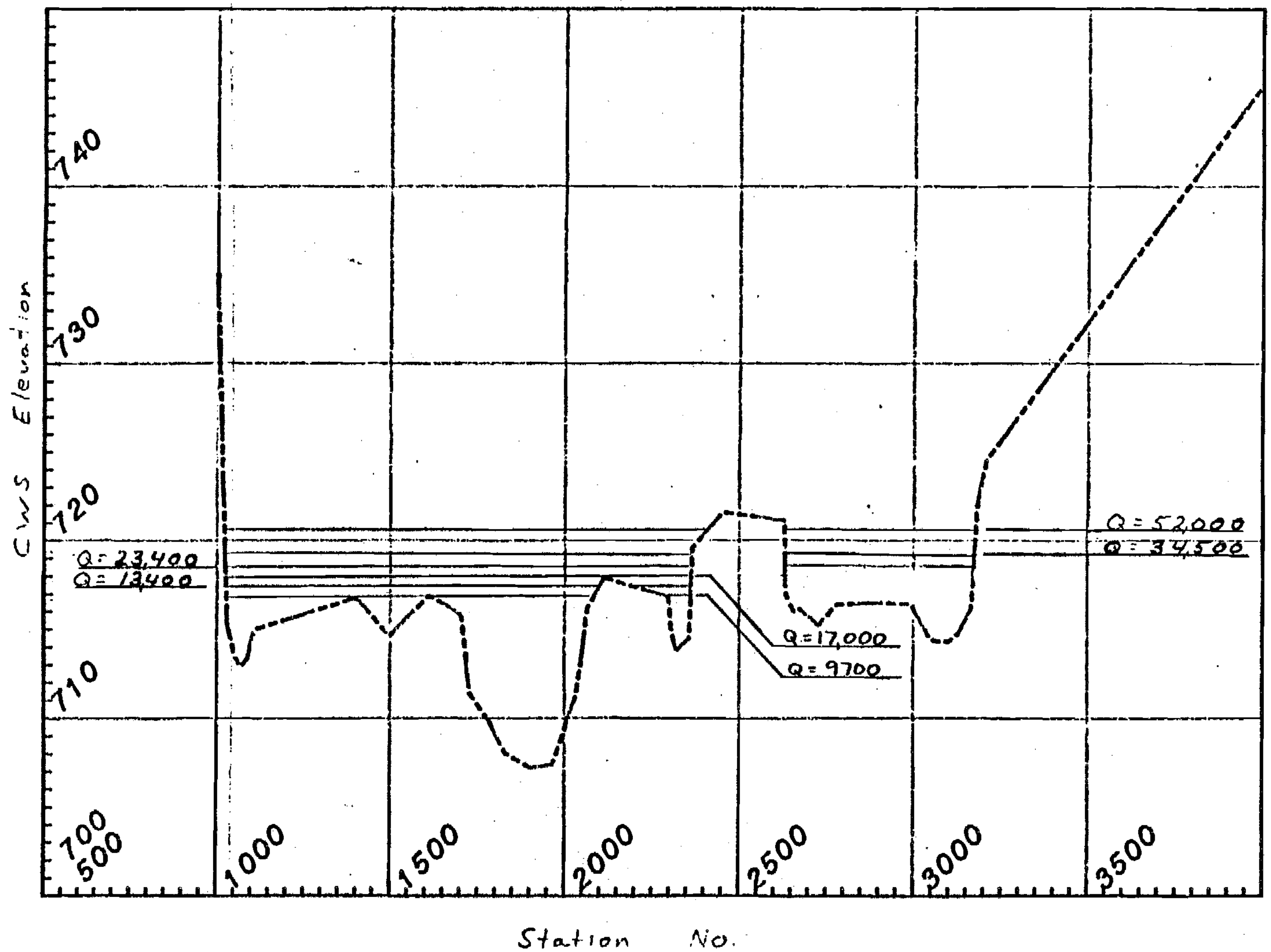
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 52



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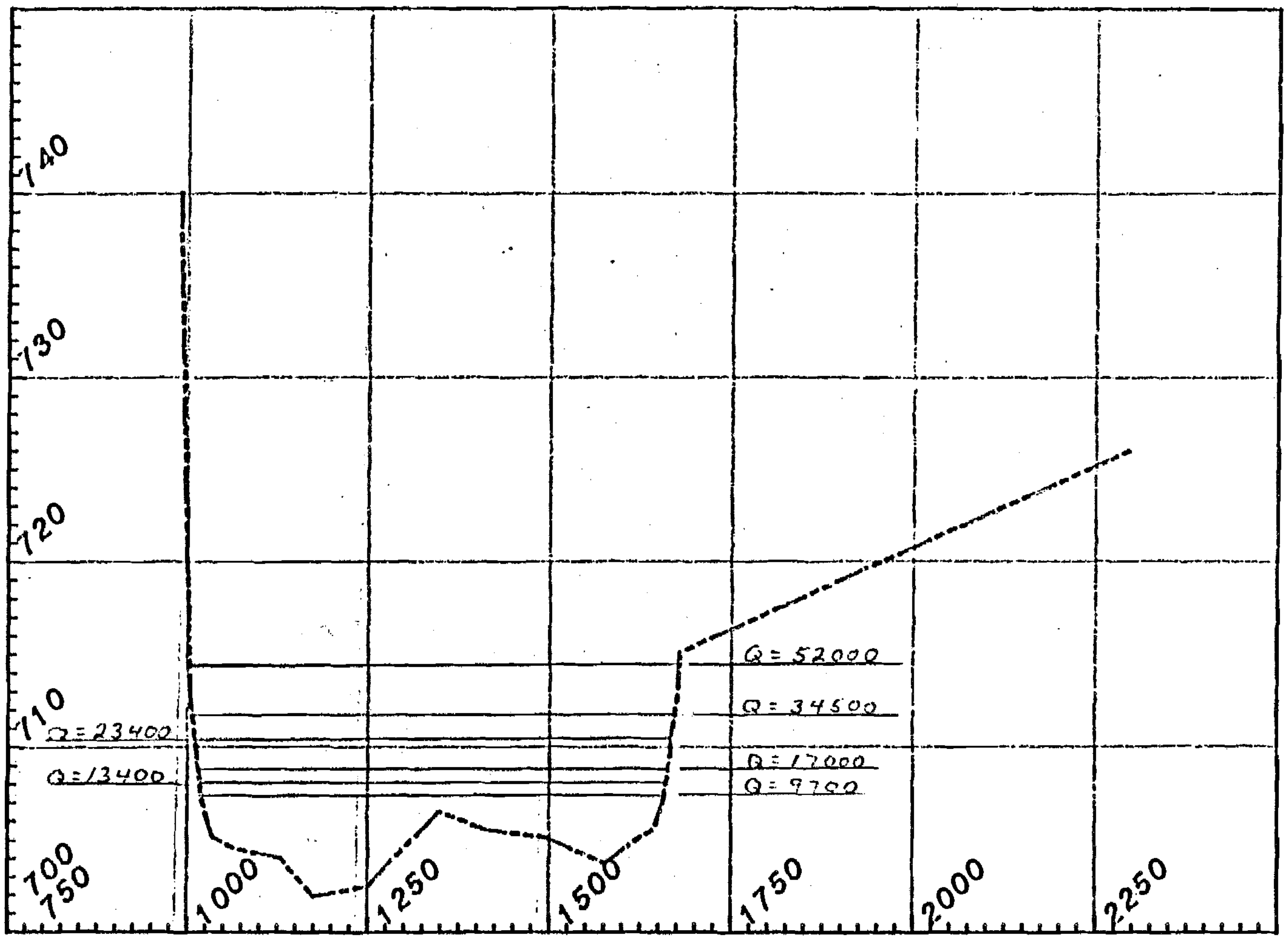
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 51



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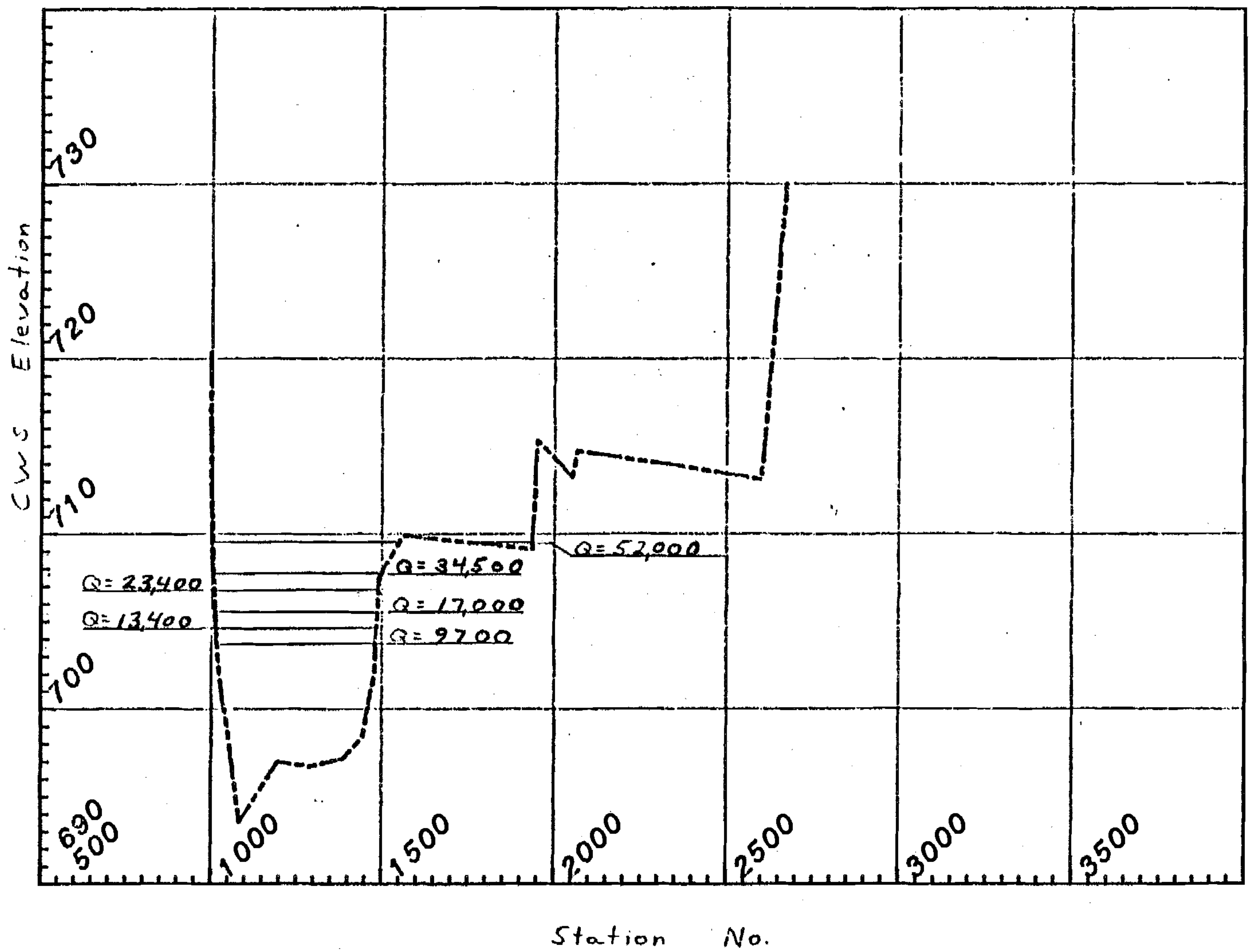
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 50



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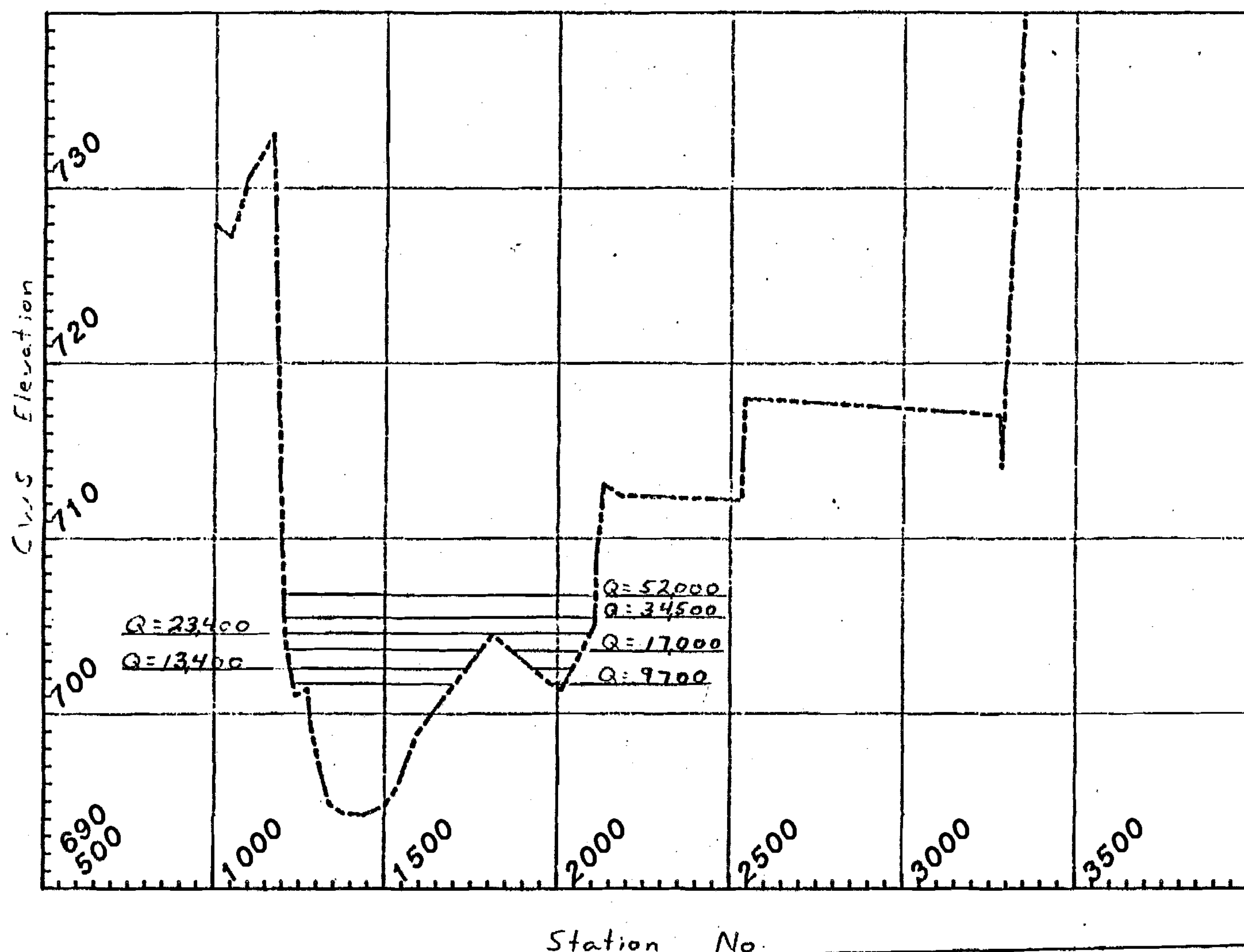
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 49



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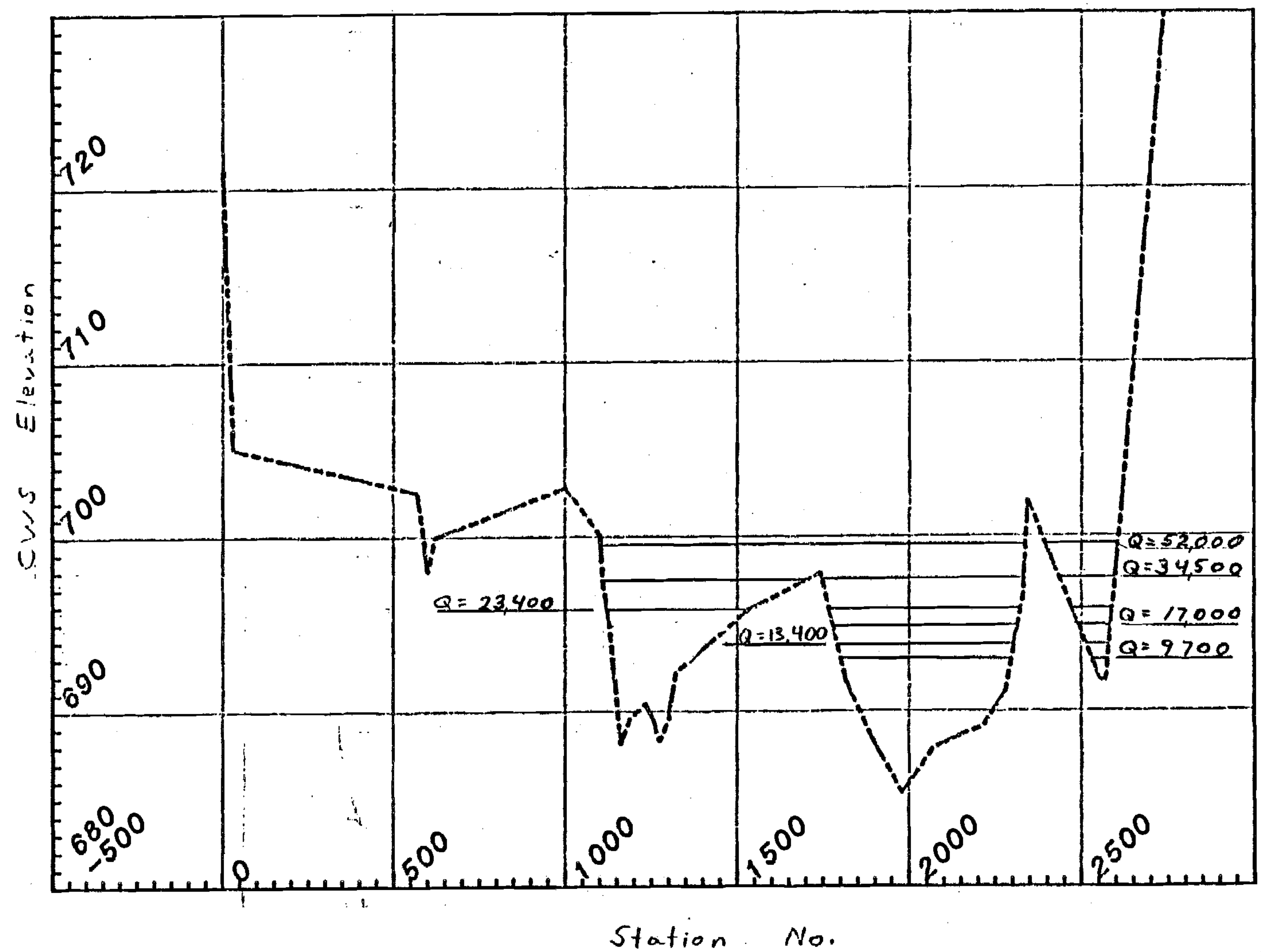
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 48



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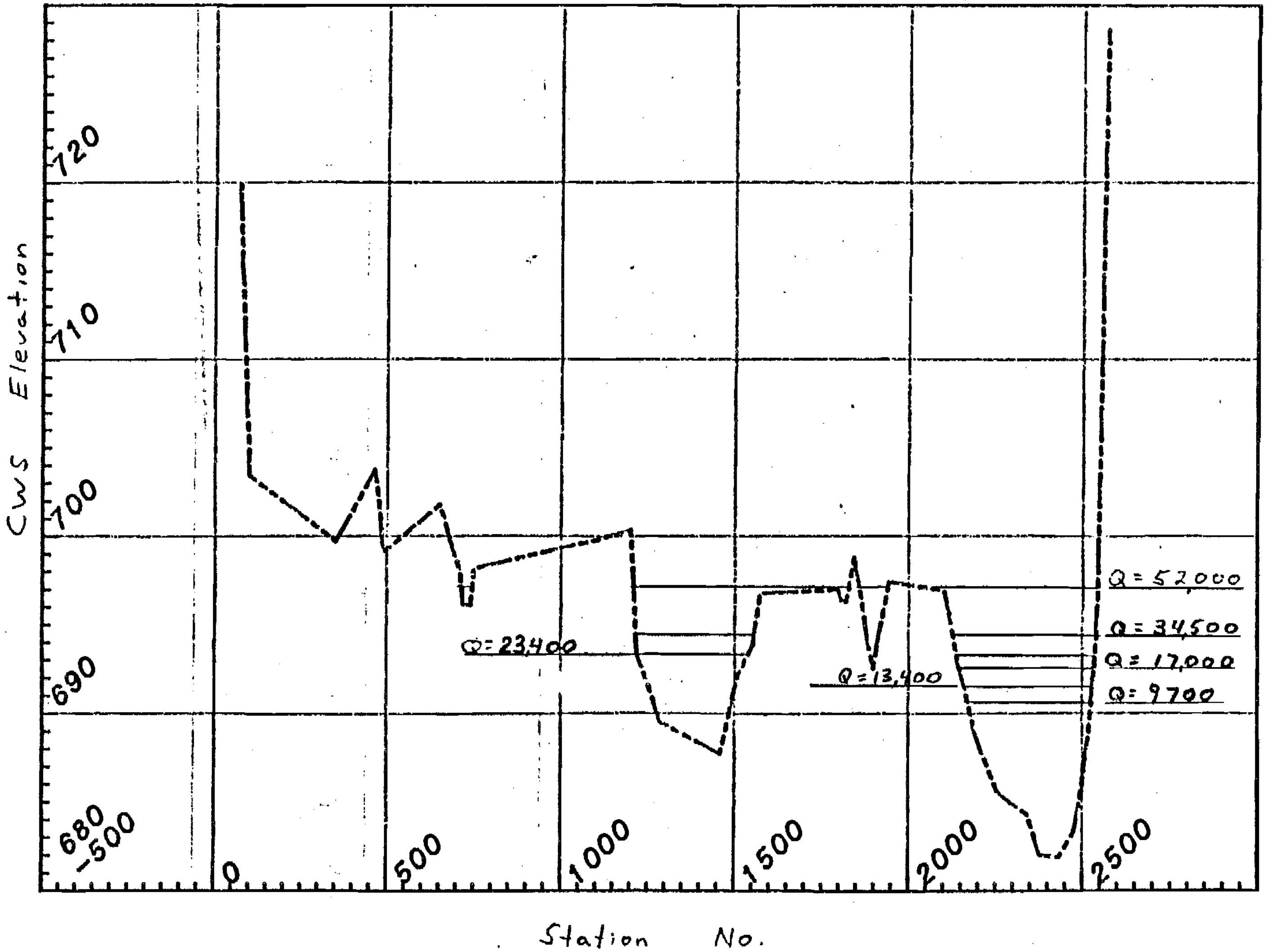
CROSS-SECTION Number 47



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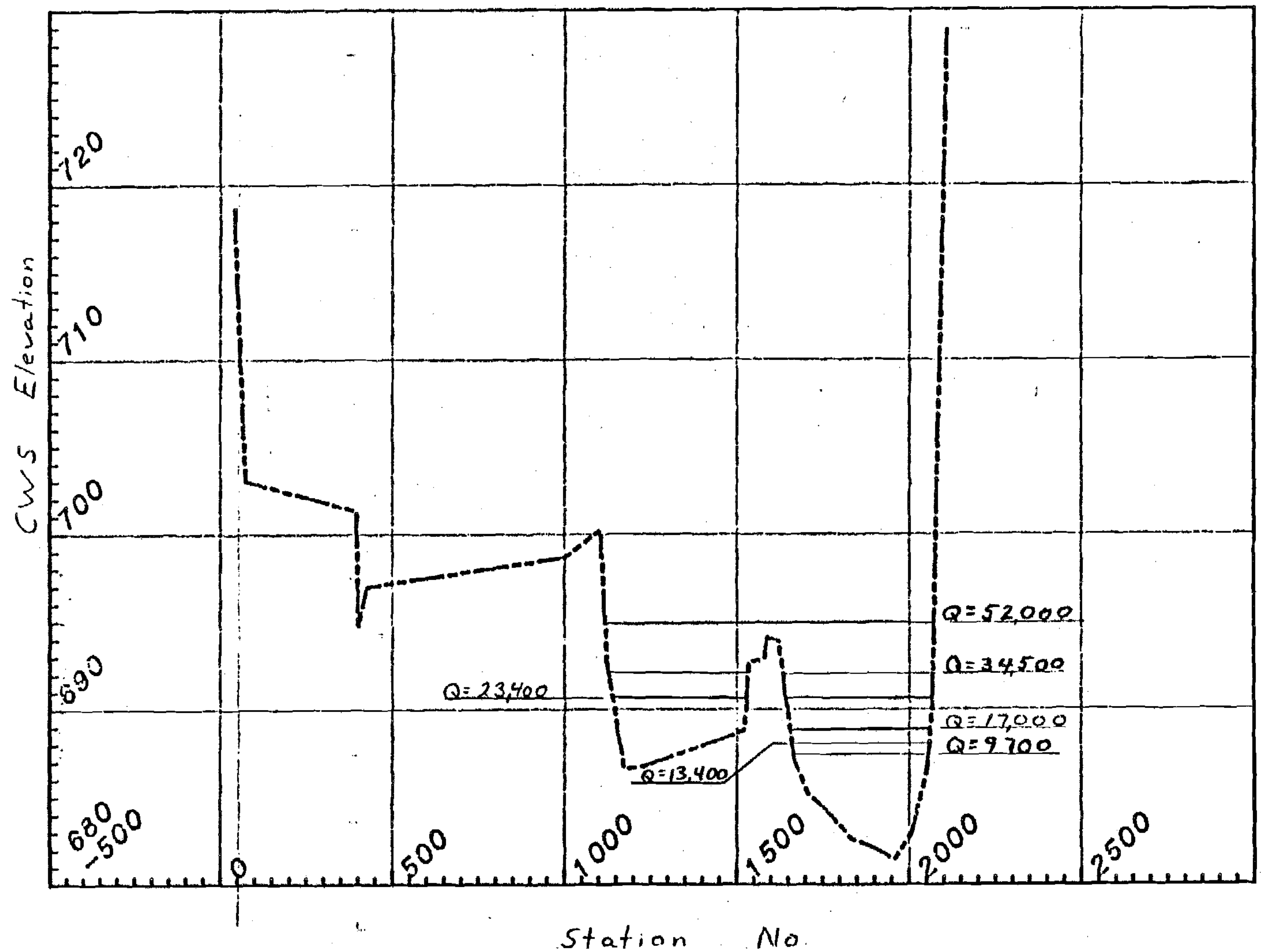
CROSS-SECTION Number 46



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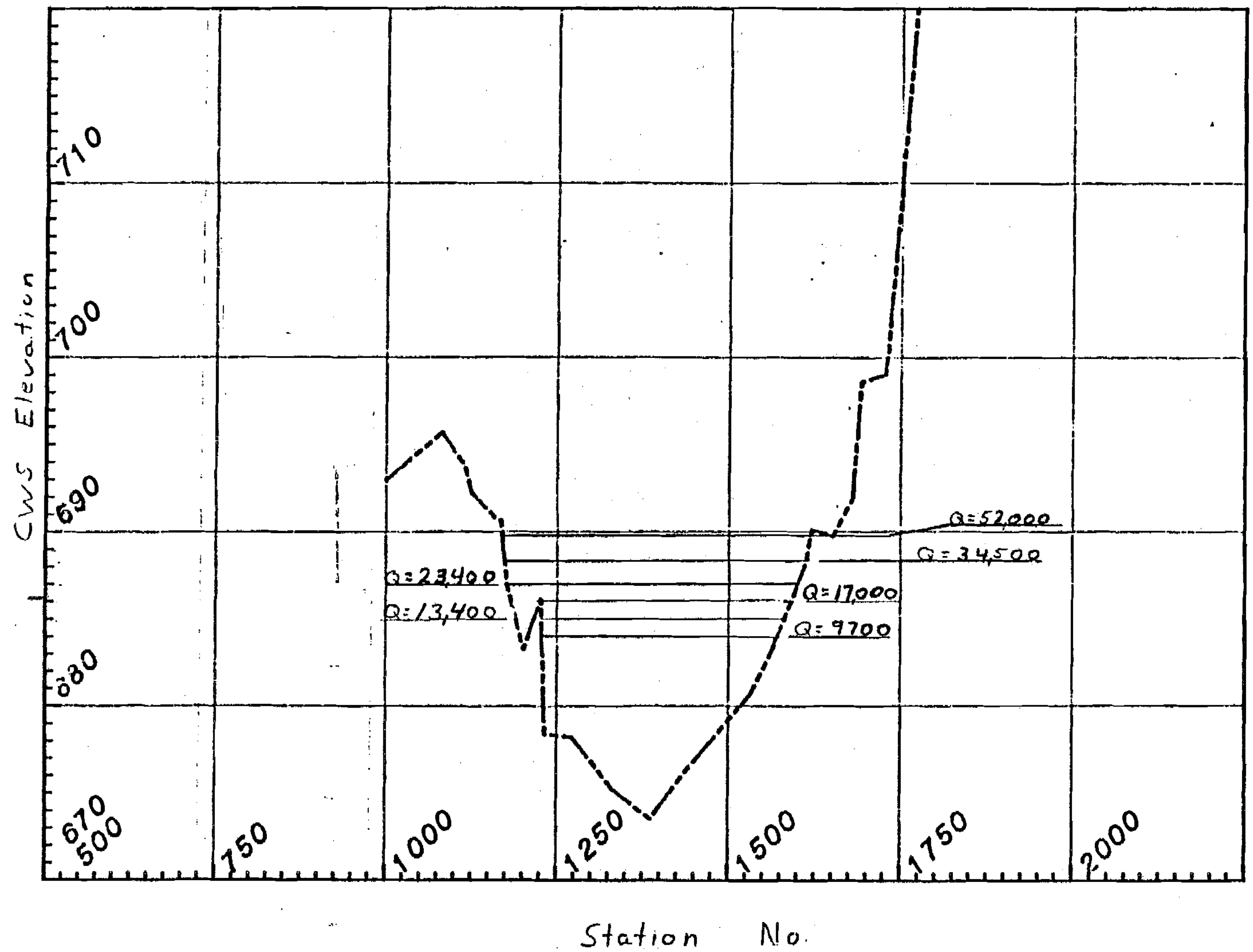
CROSS-SECTION Number 45



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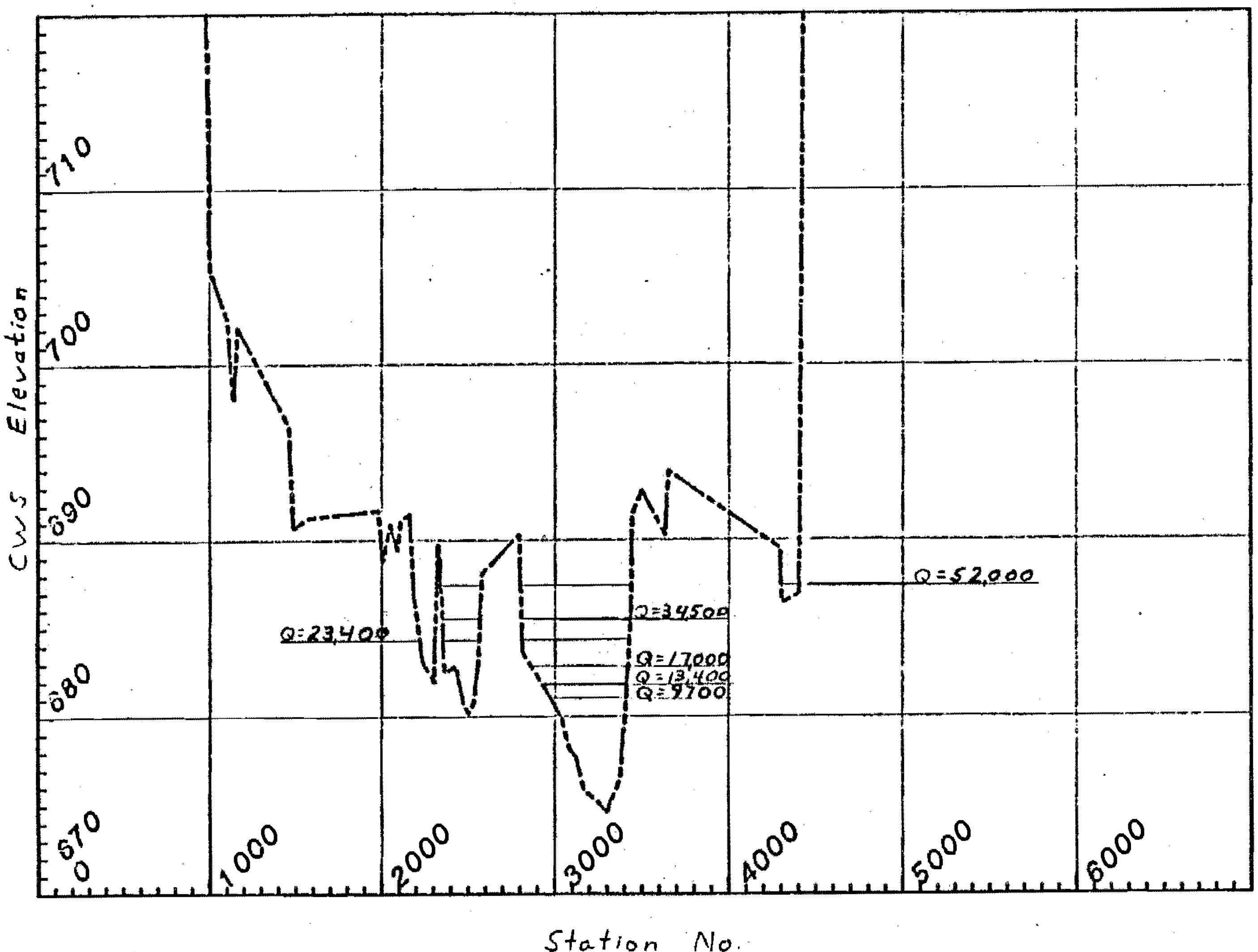
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 44



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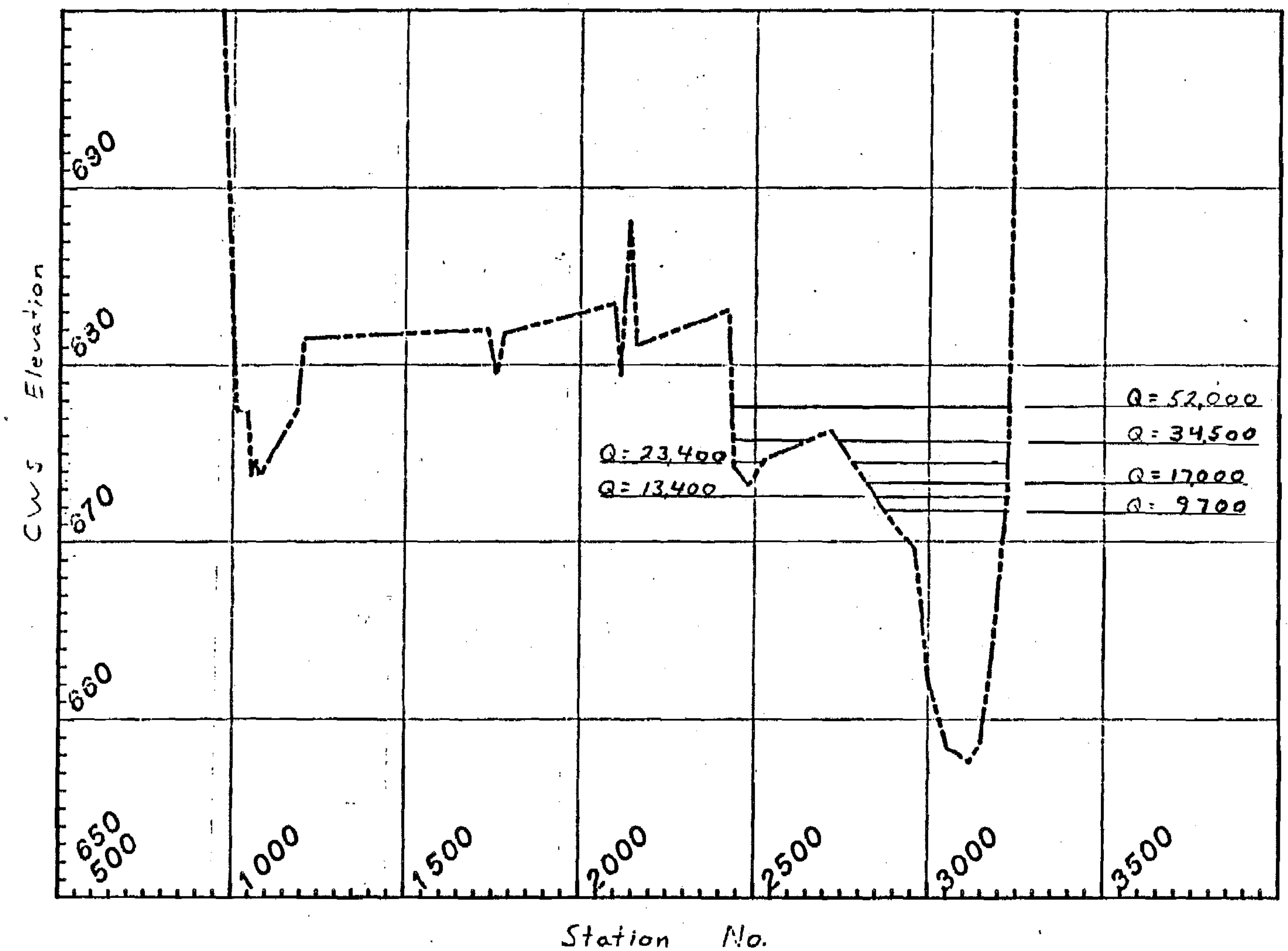
CROSS-SECTION Number 43



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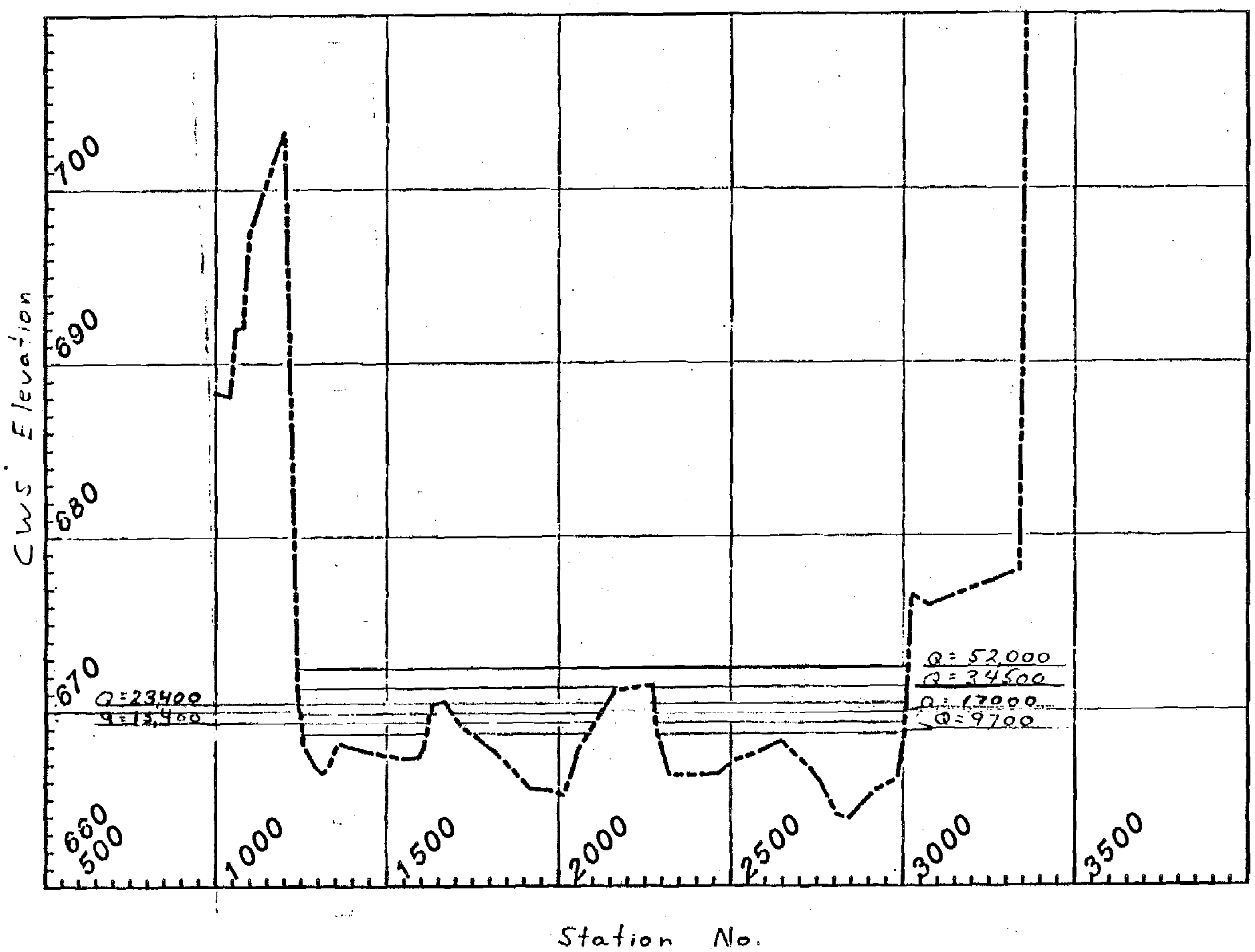

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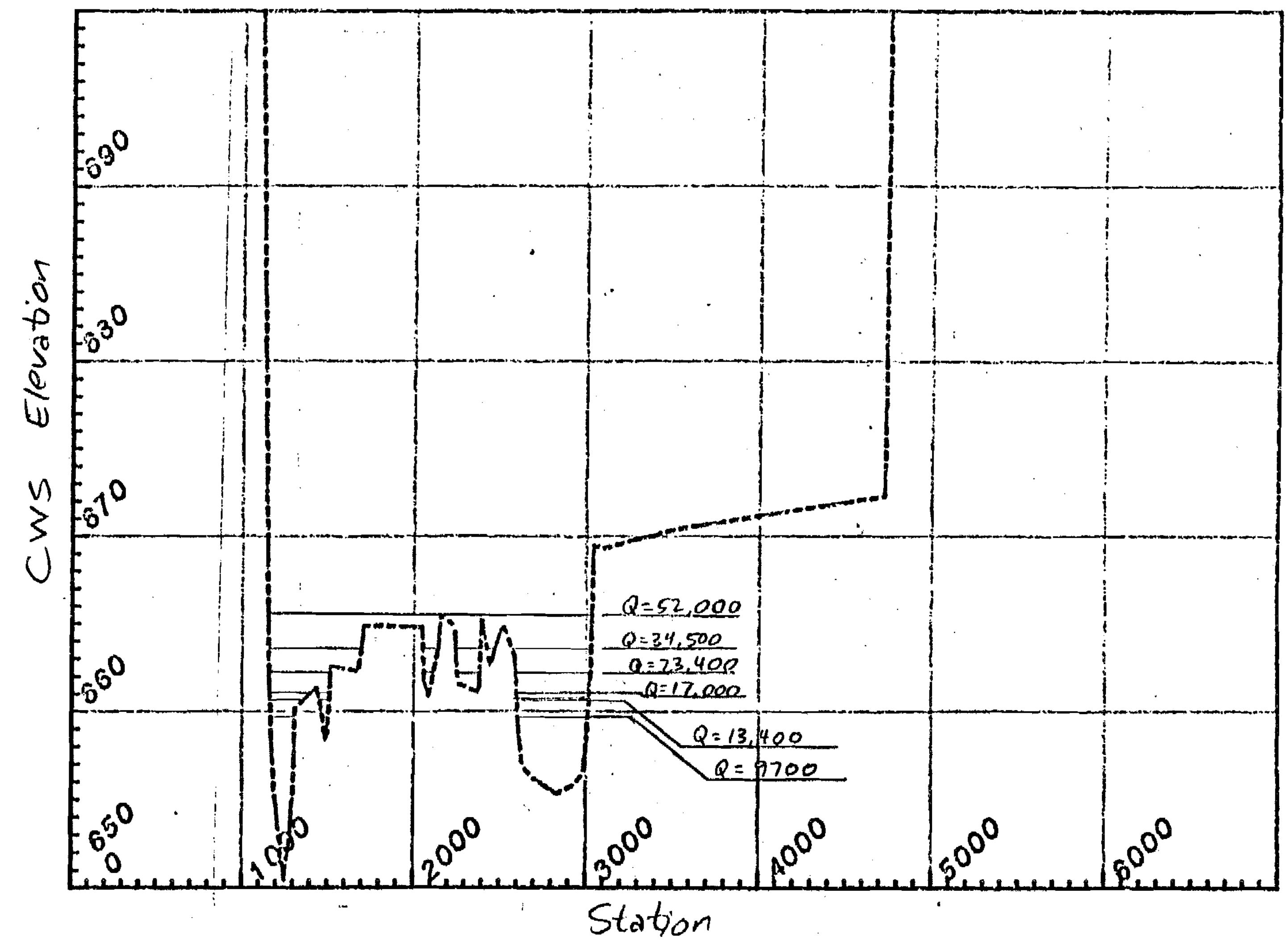
CROSS-SECTION Number 41



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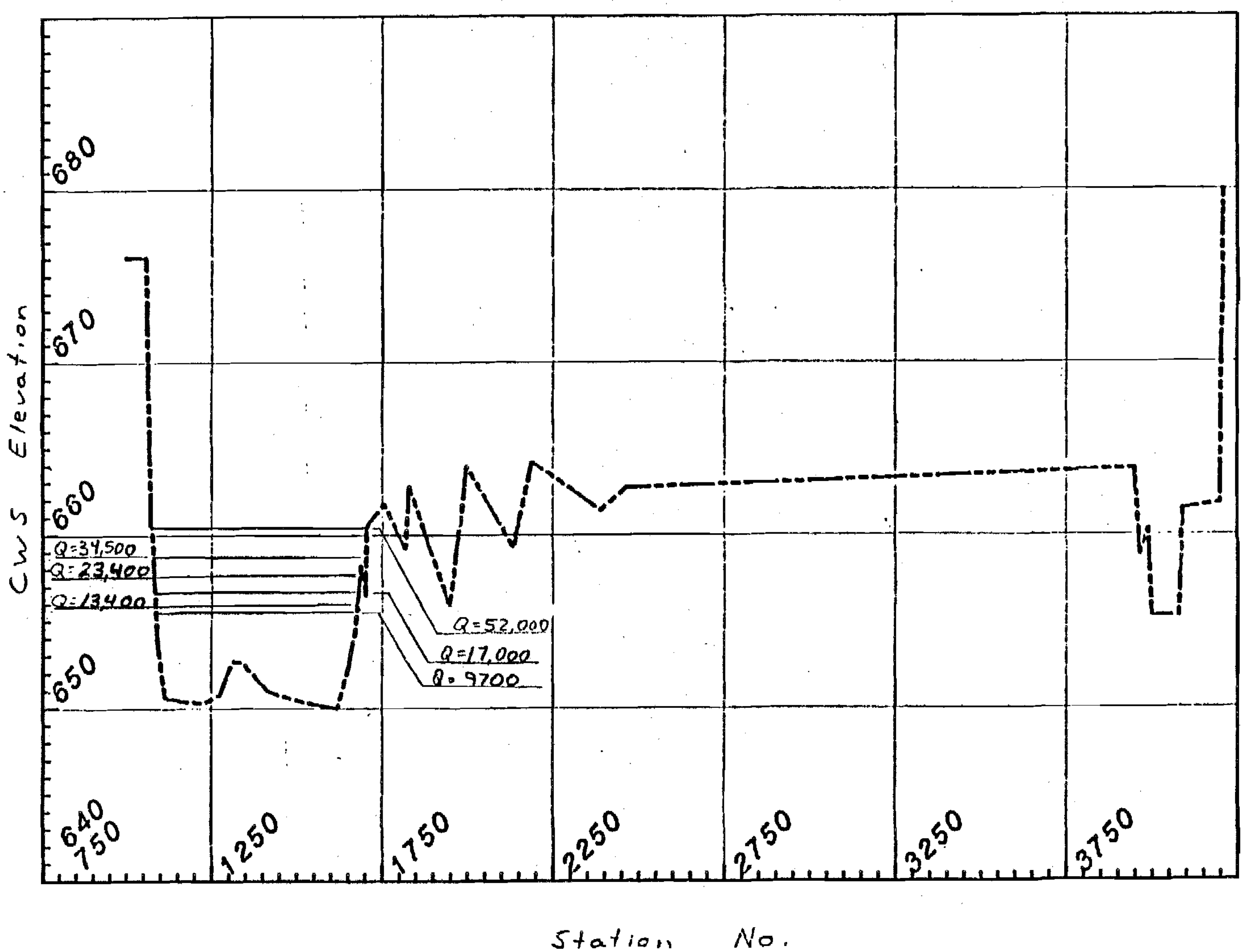
CROSS-SECTION Number 40



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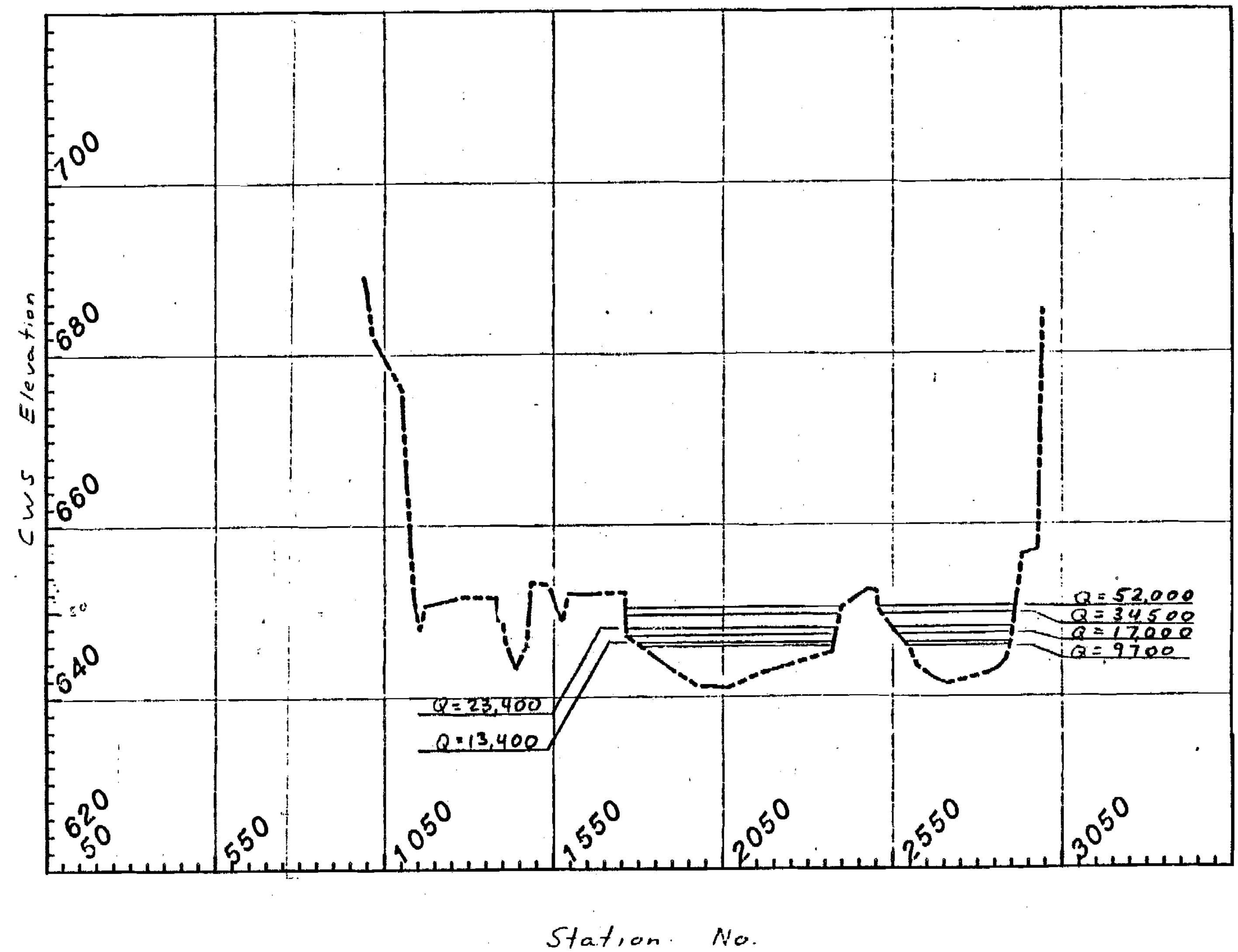
CROSS-SECTION Number 39



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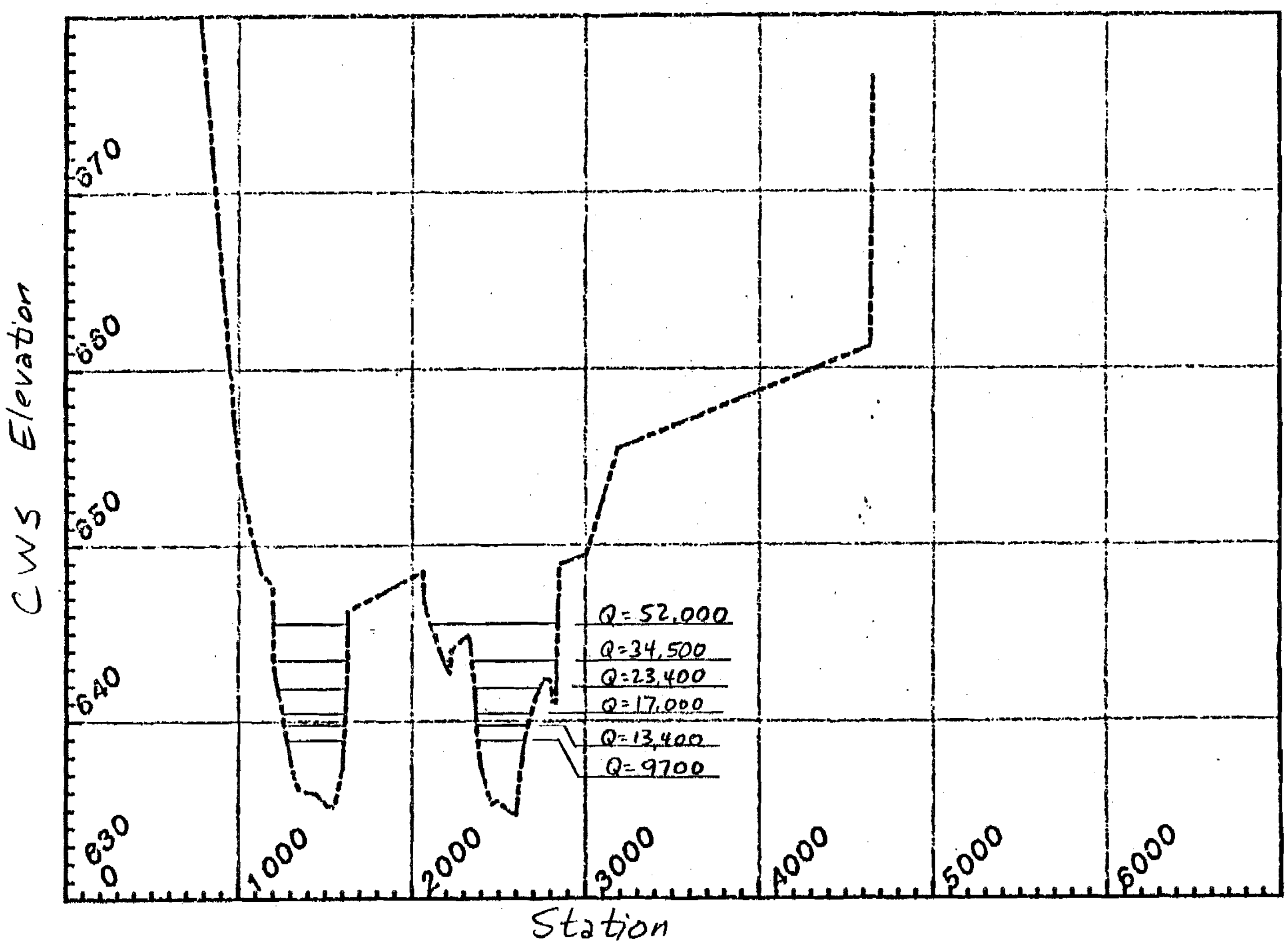

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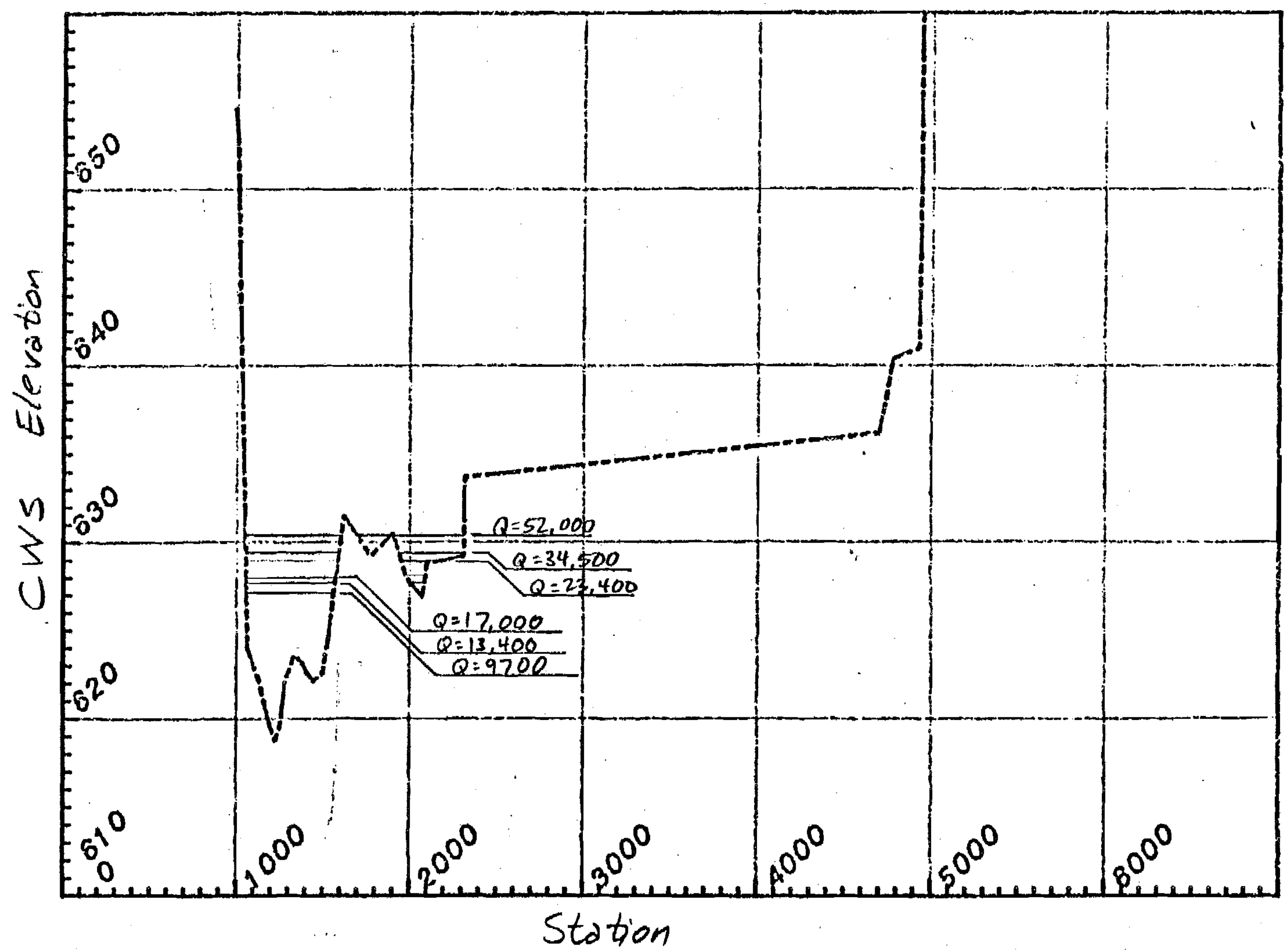
CROSS-SECTION Number 37



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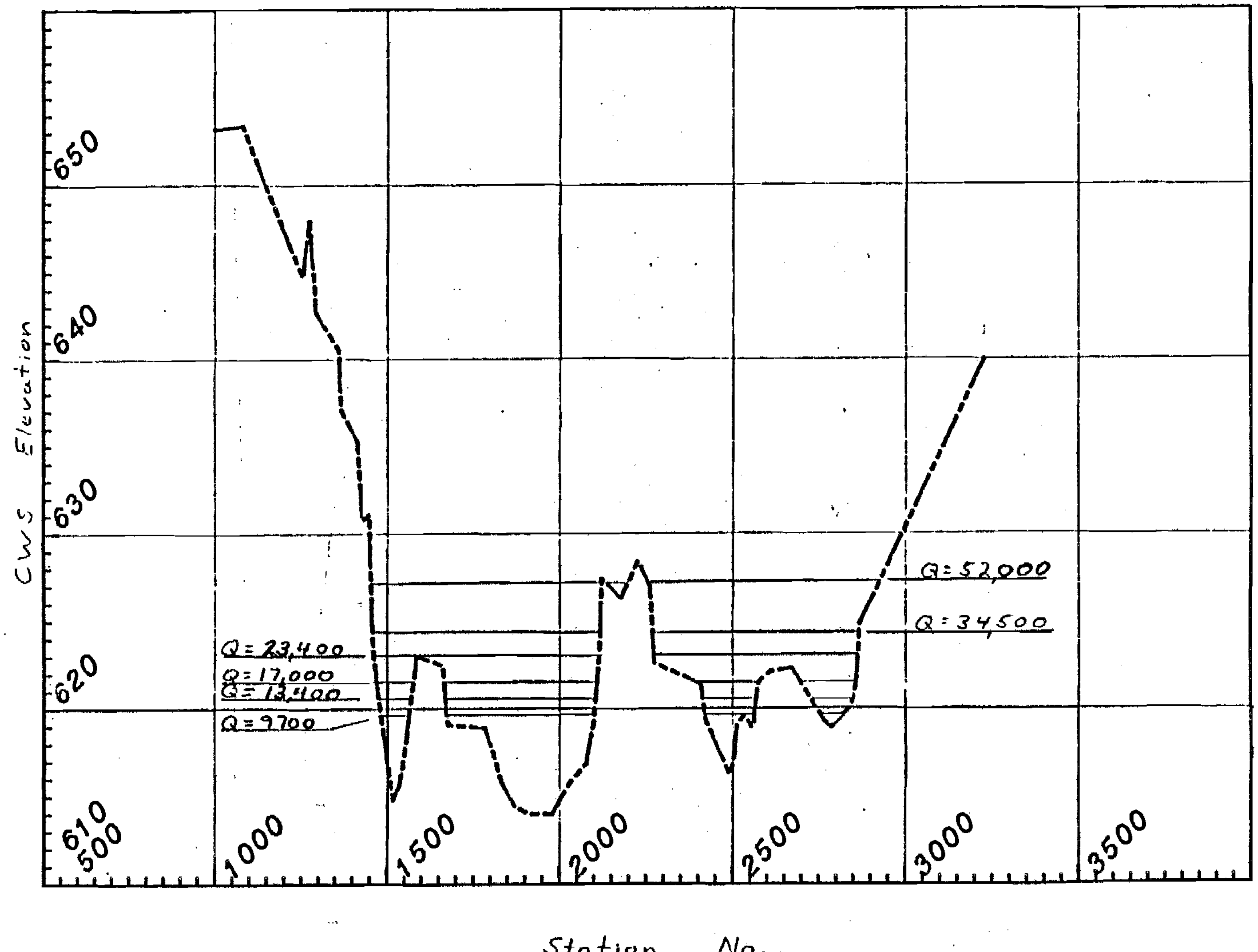

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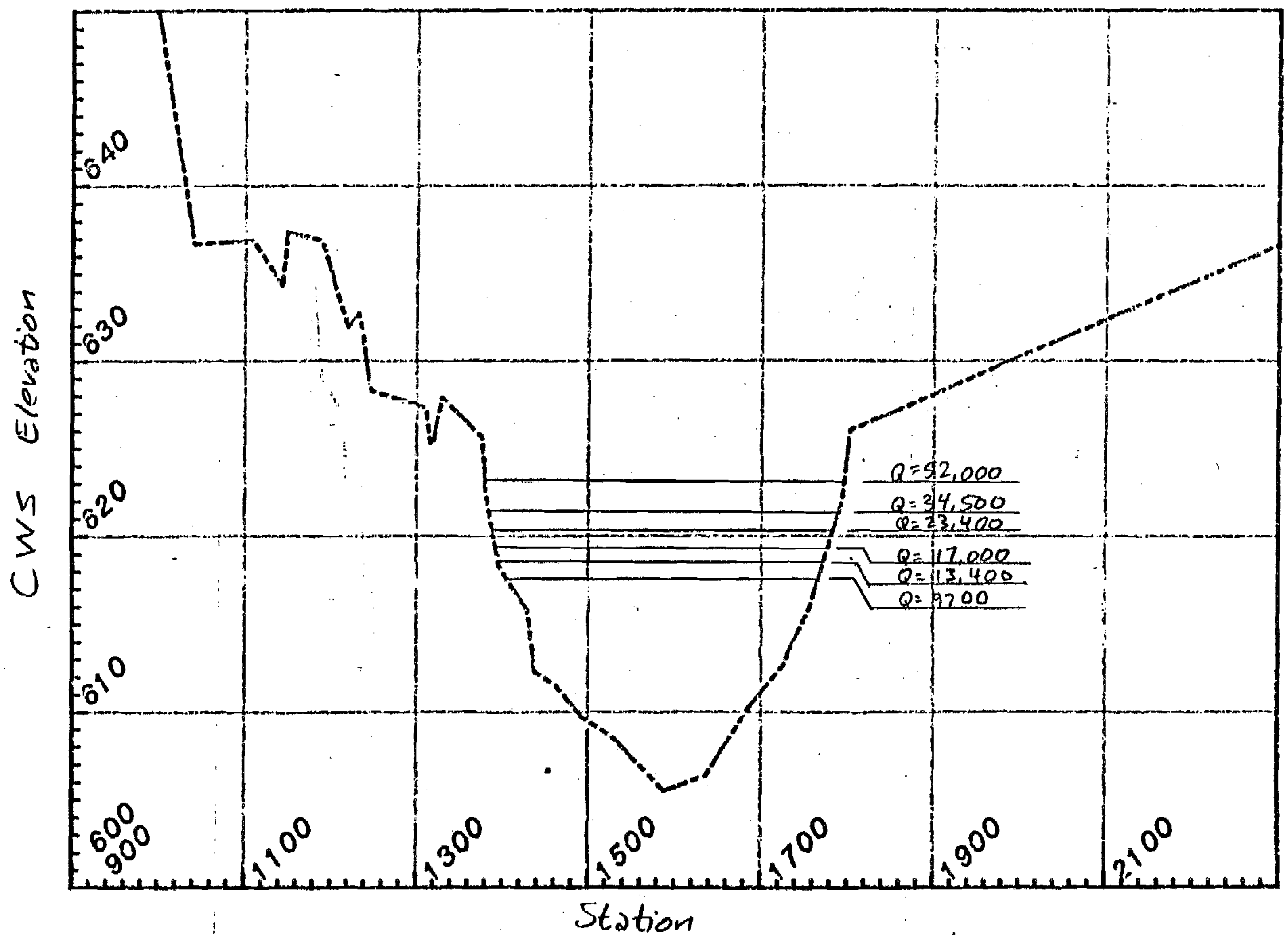
CROSS-SECTION Number 35



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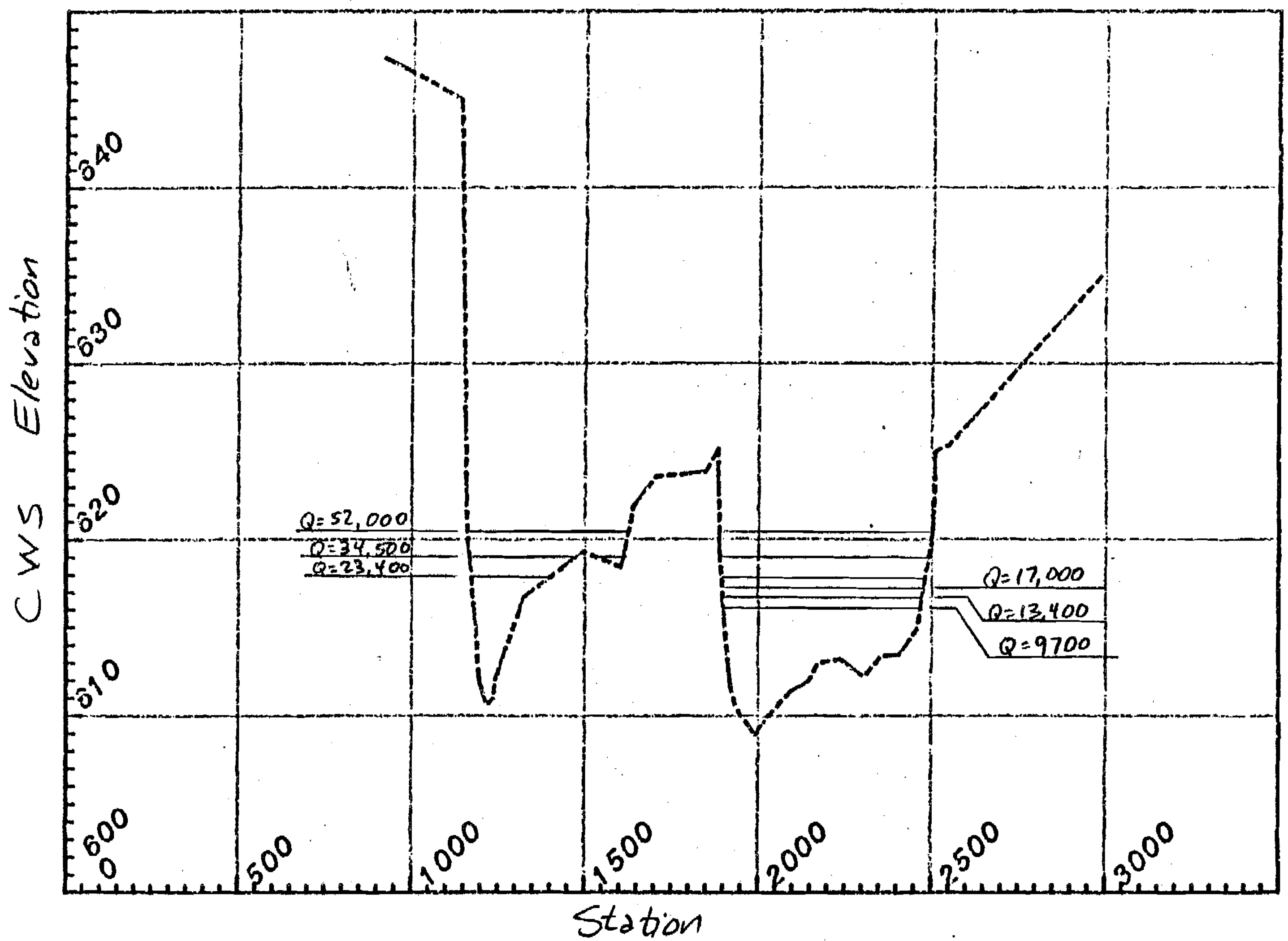
CROSS-SECTION Number 34



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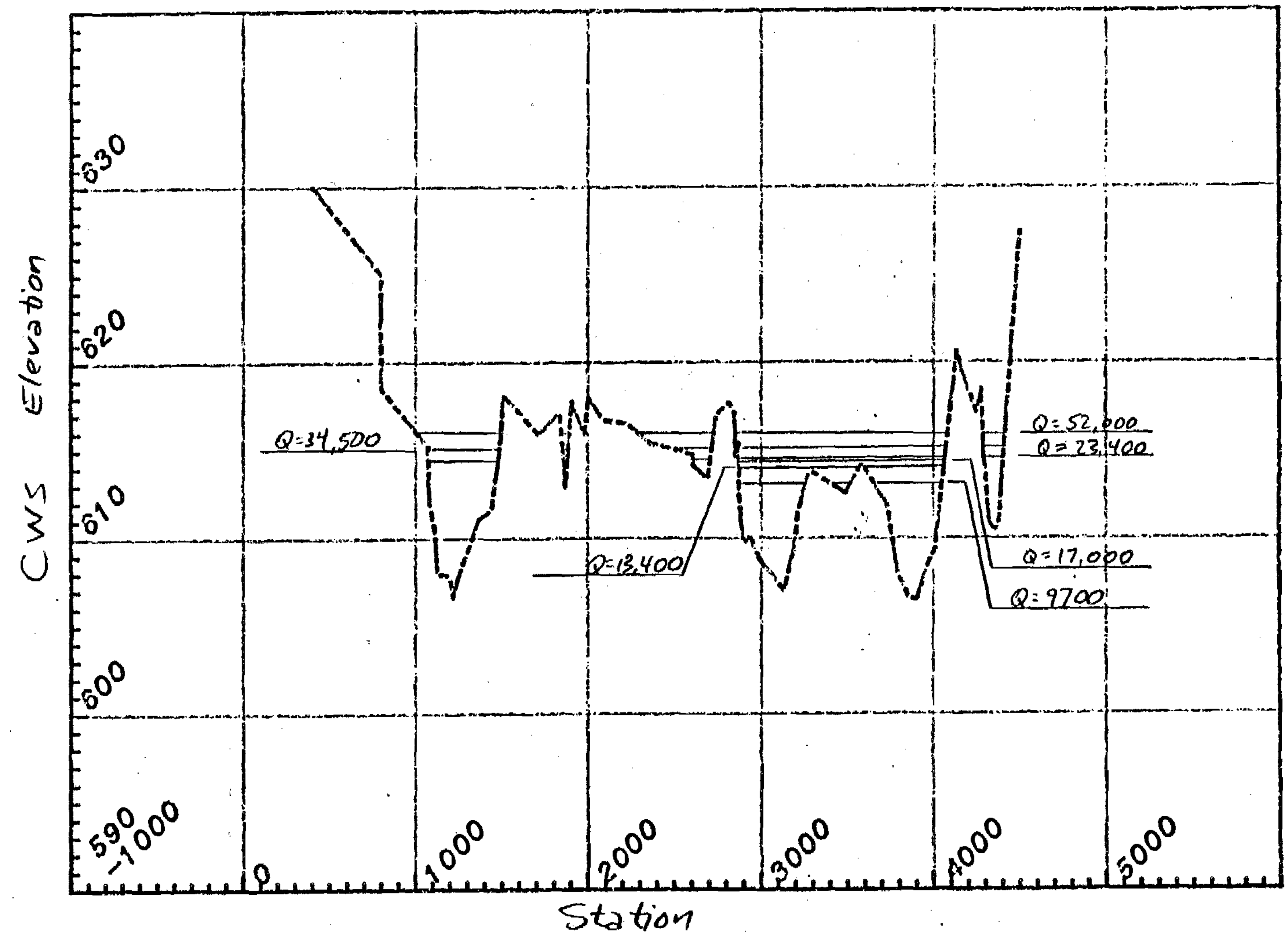

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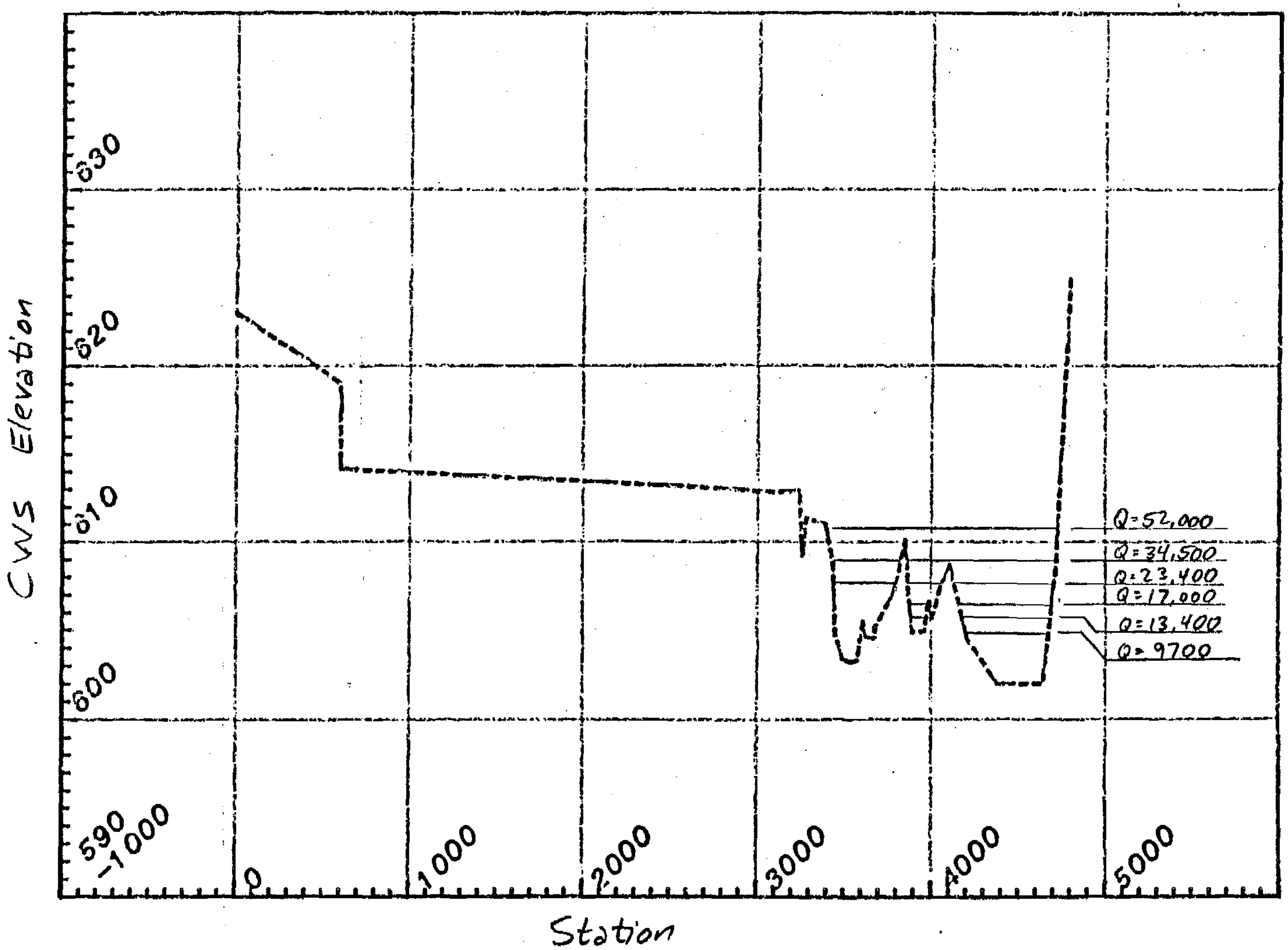

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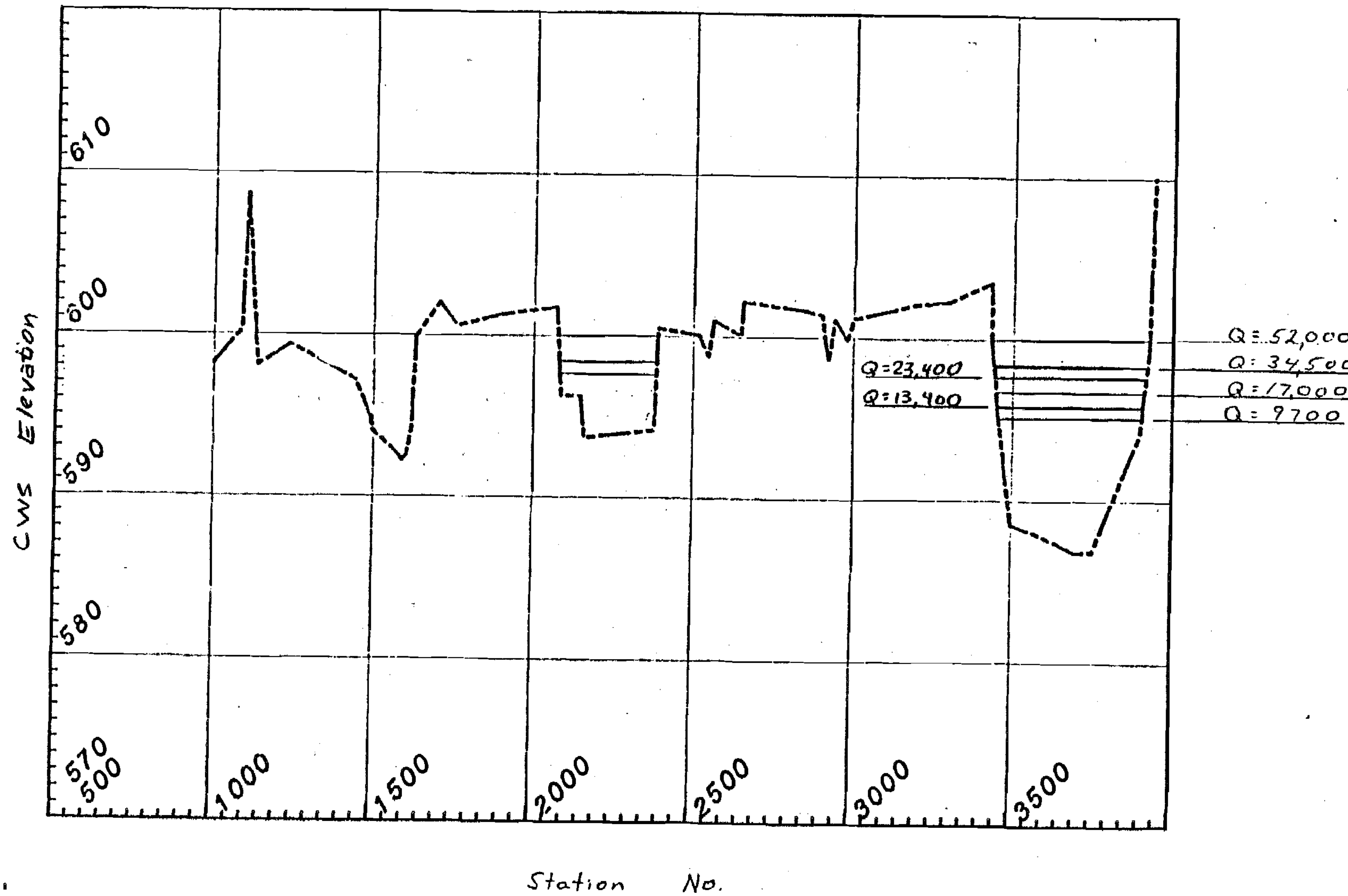

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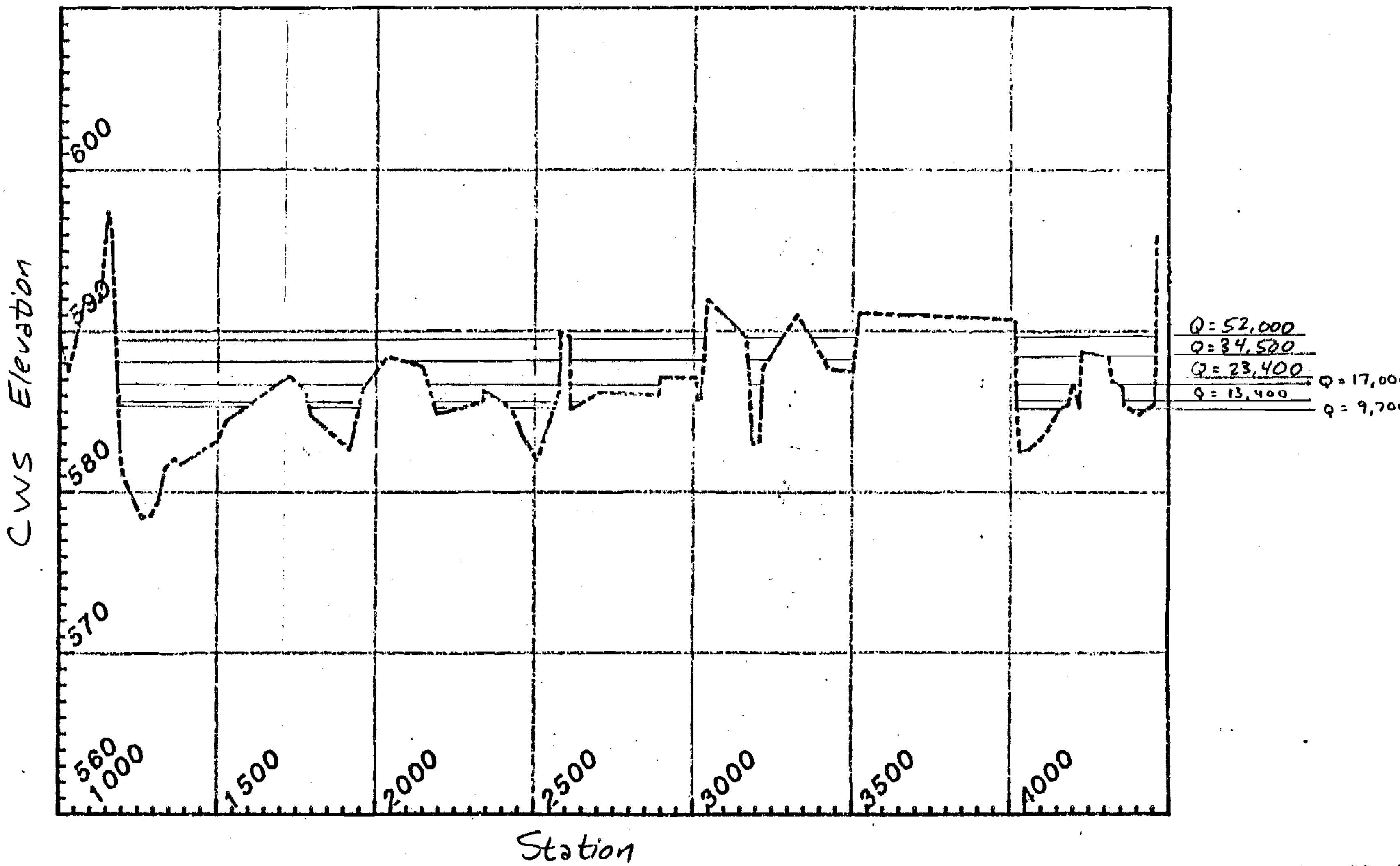

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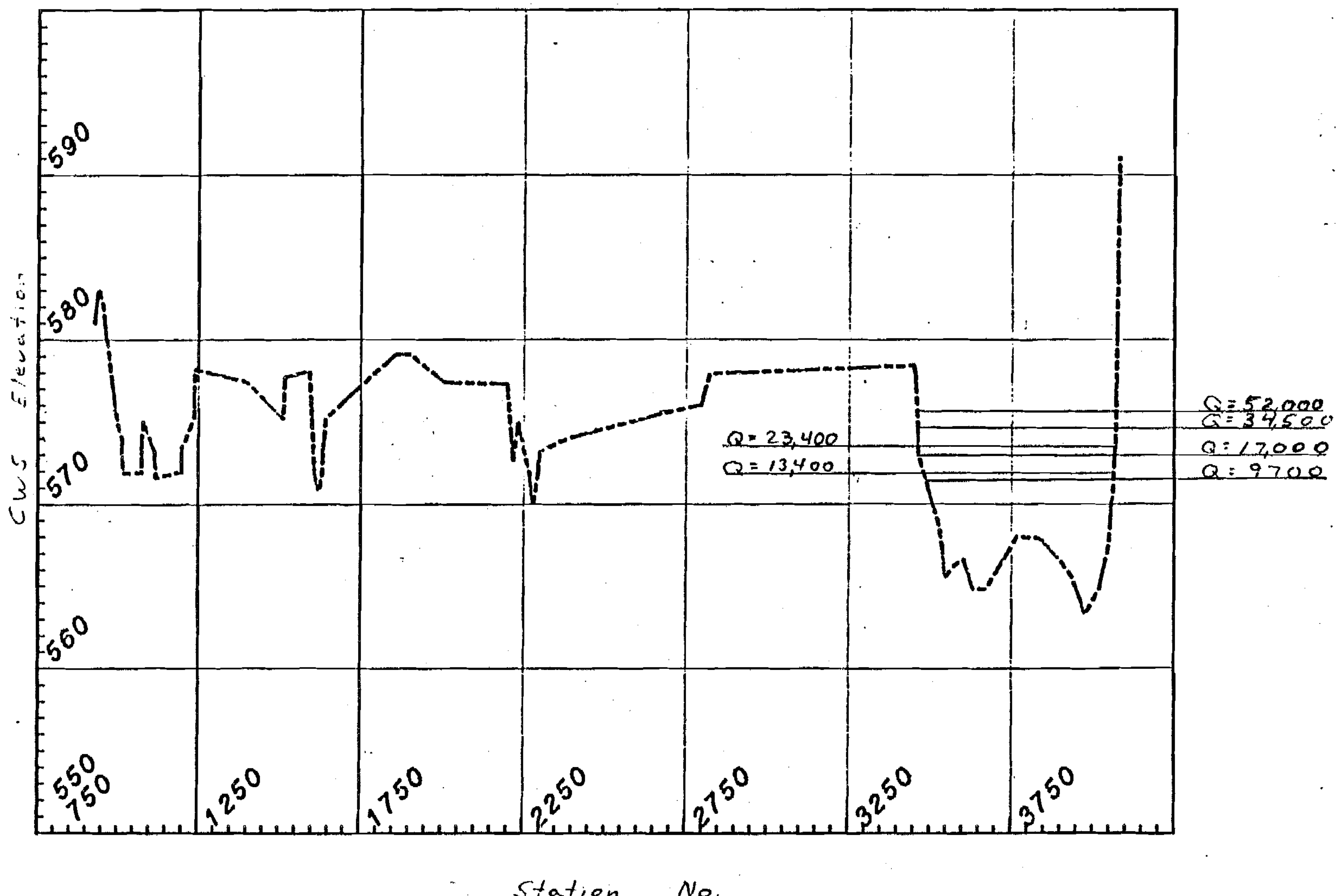

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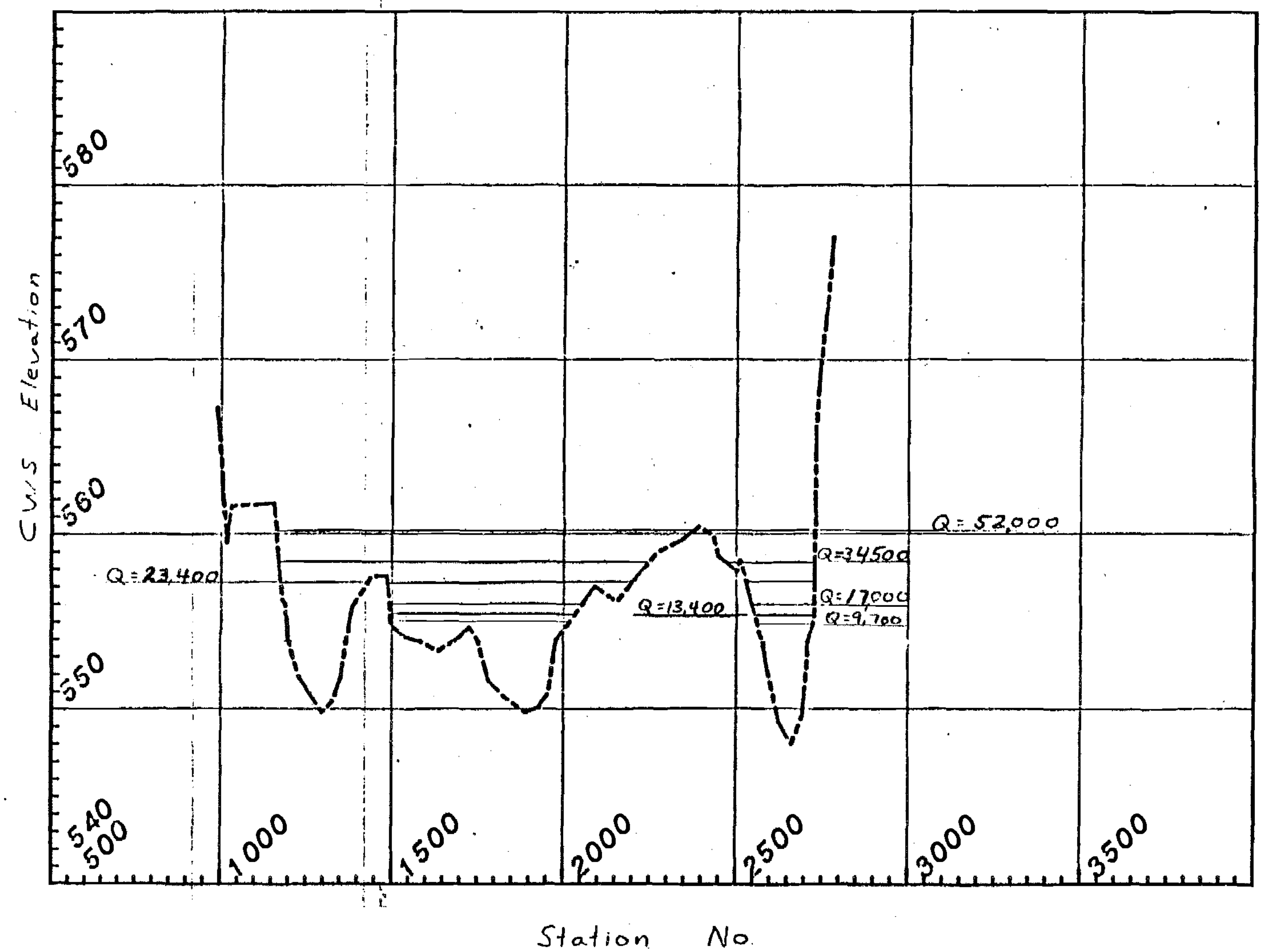

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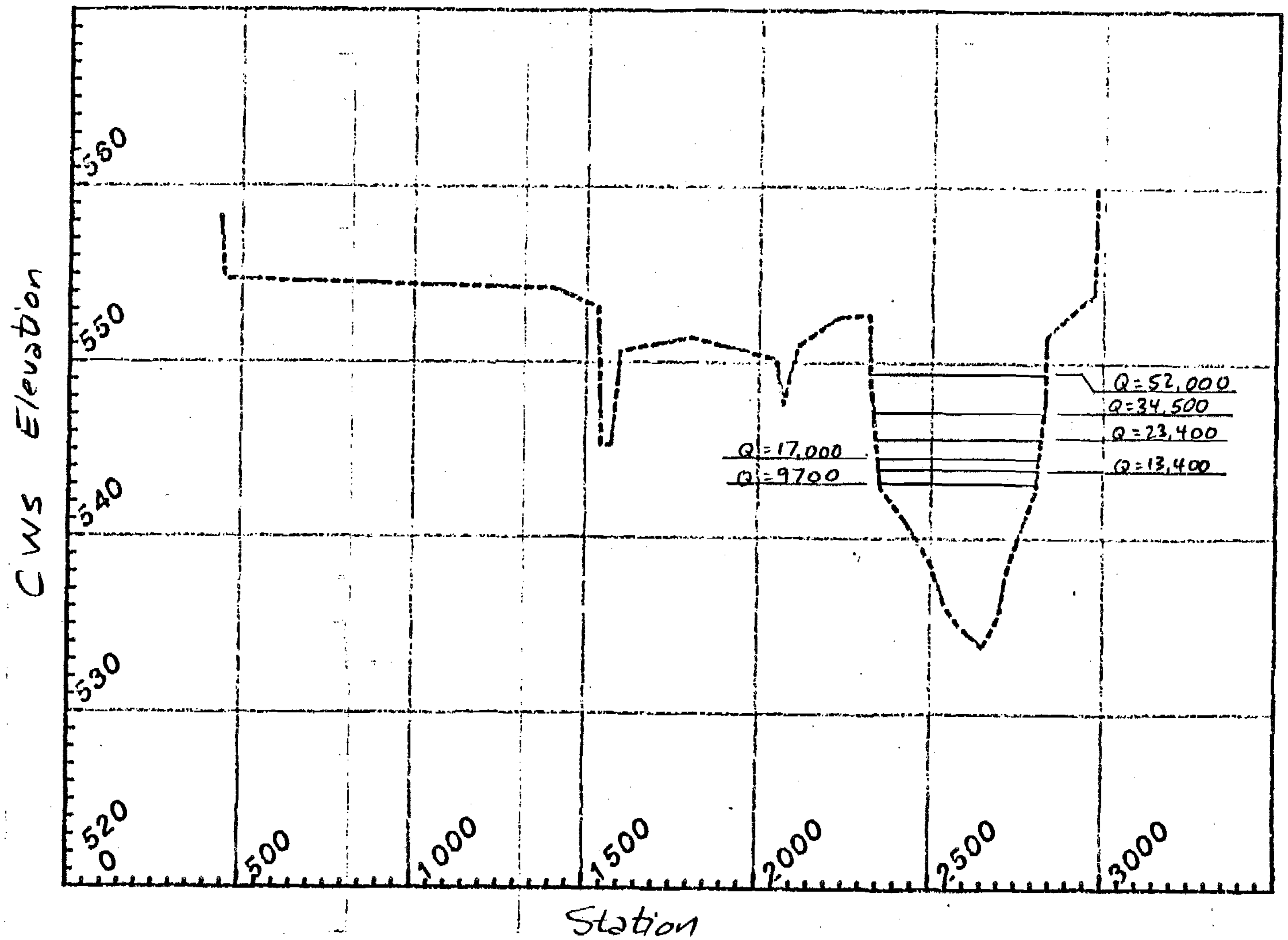

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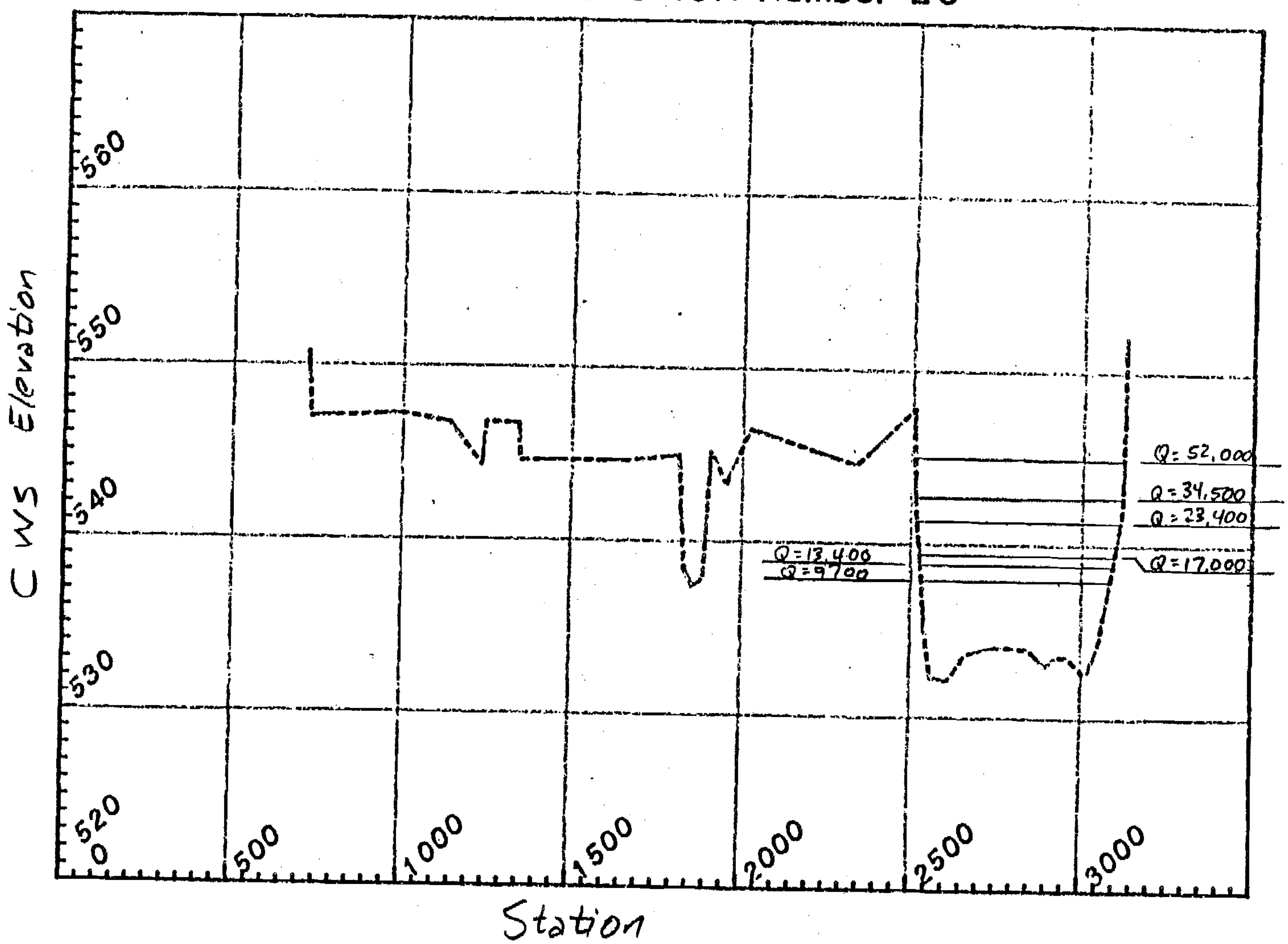

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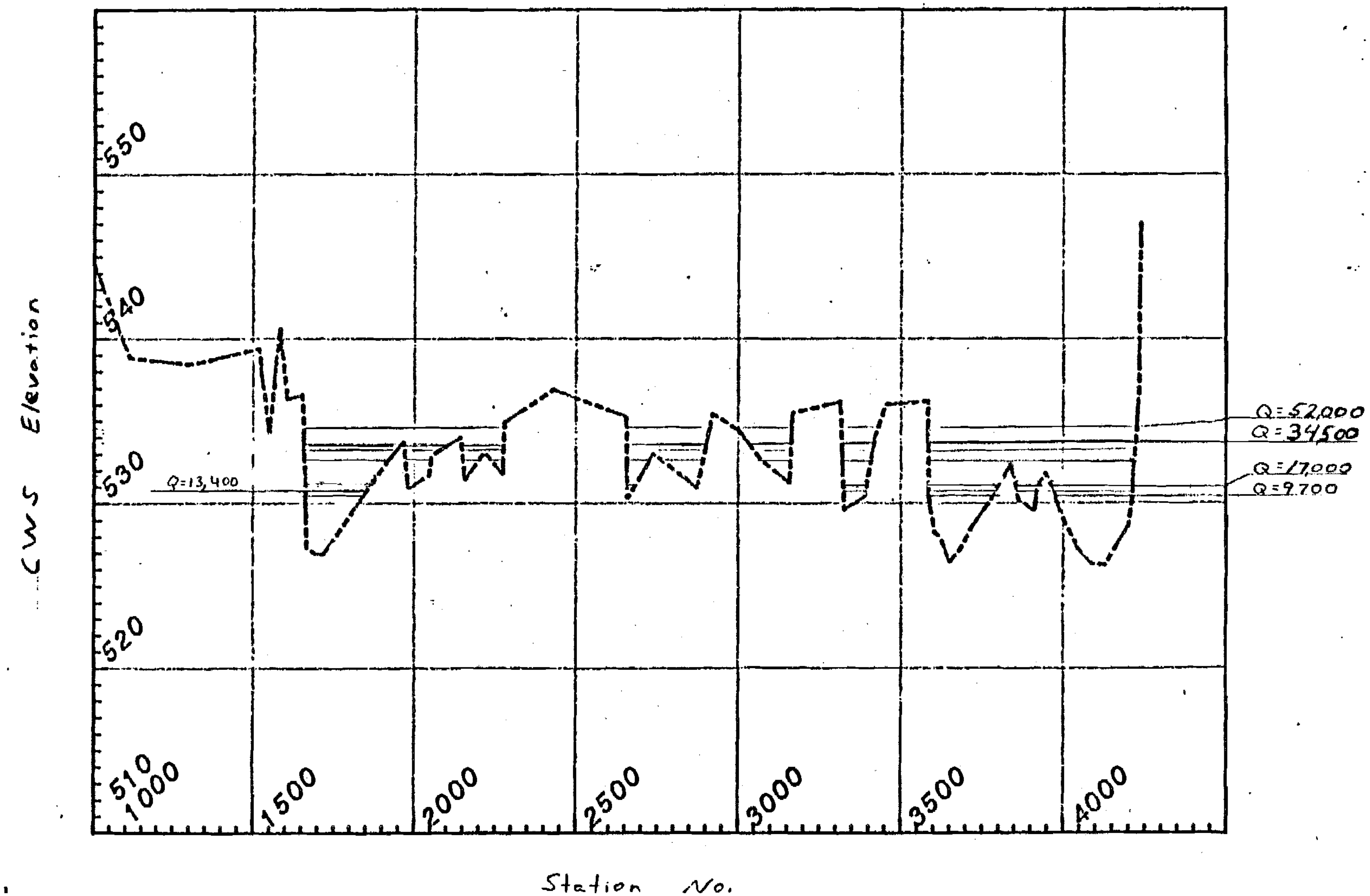

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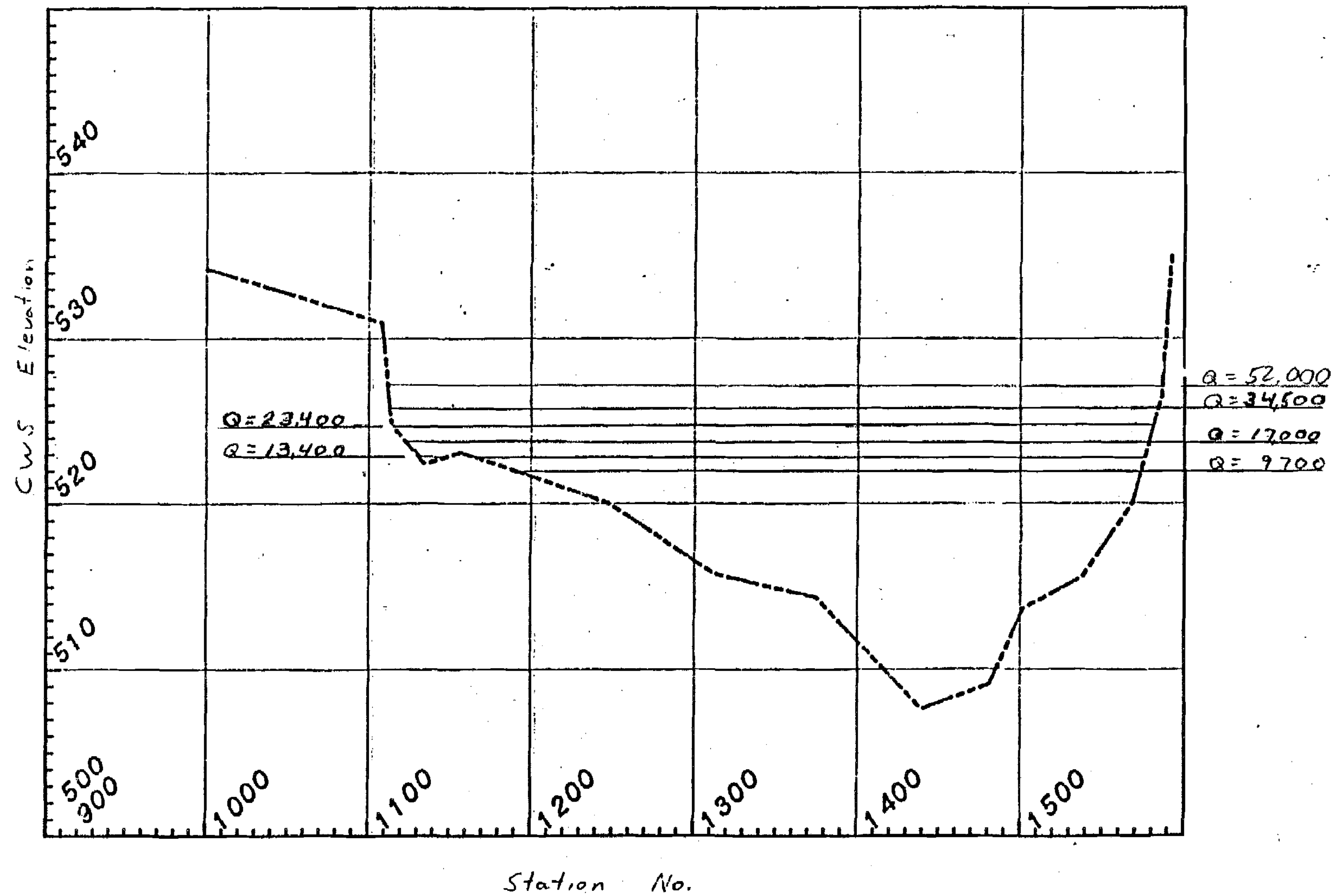

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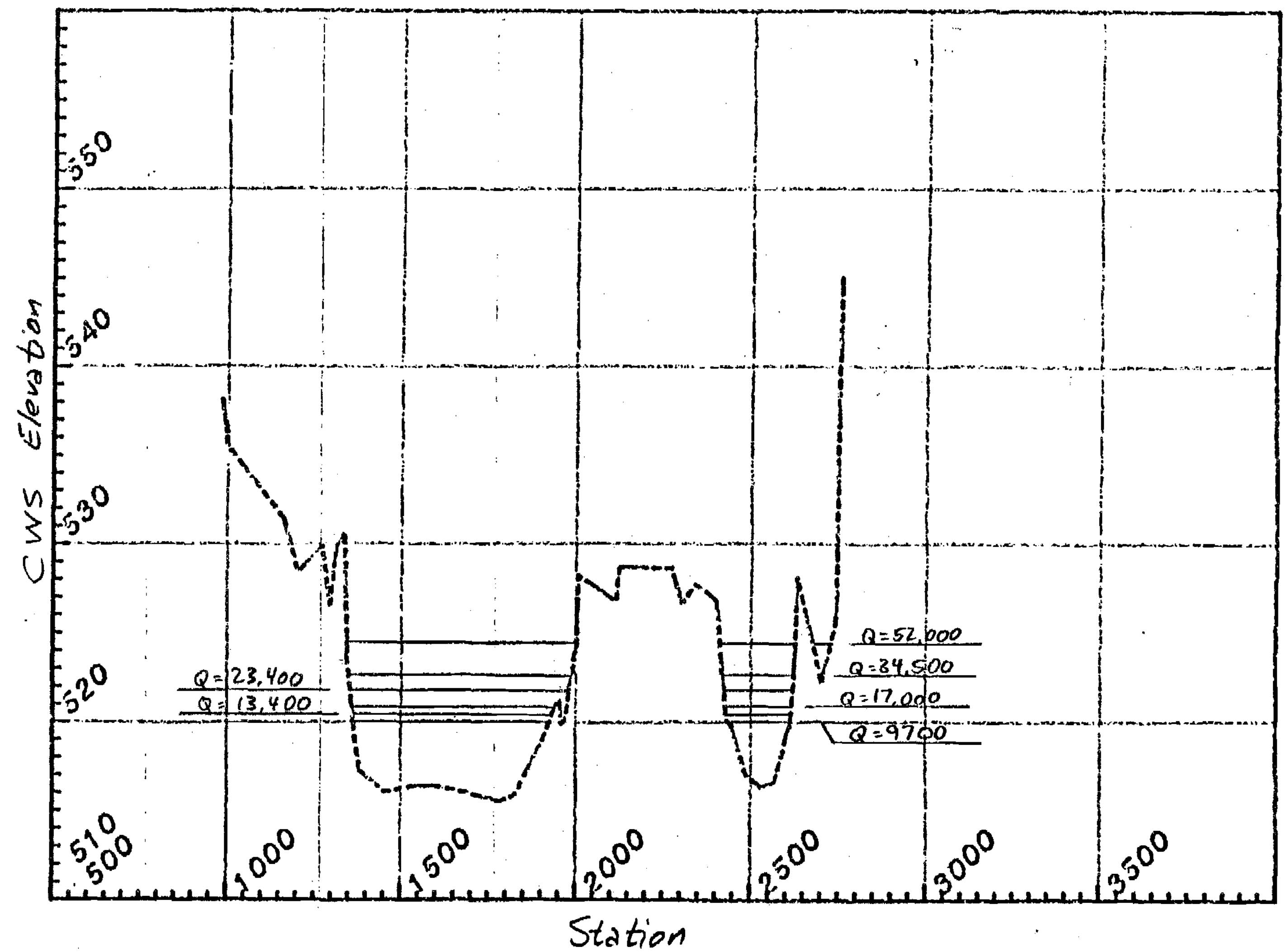

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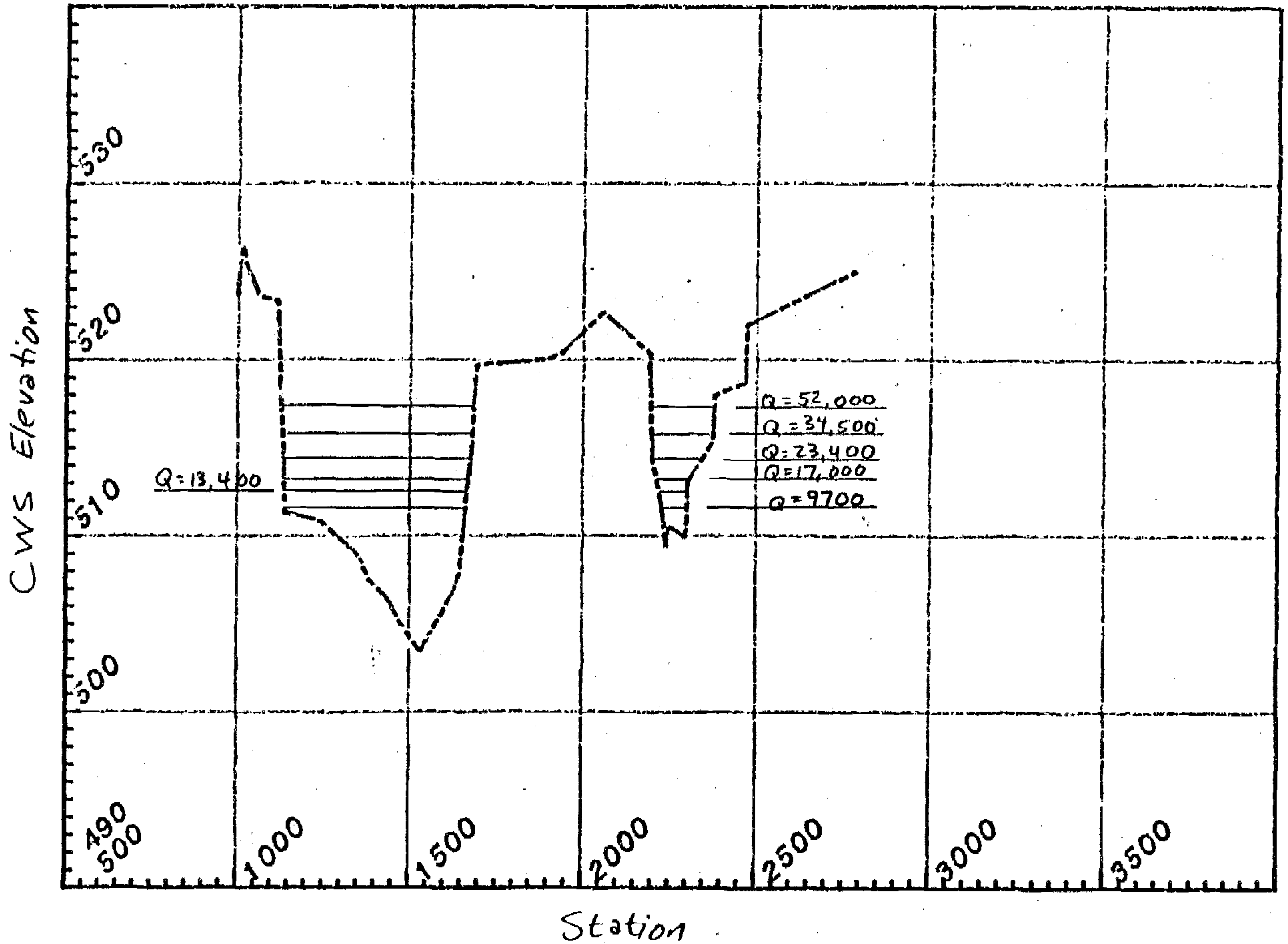

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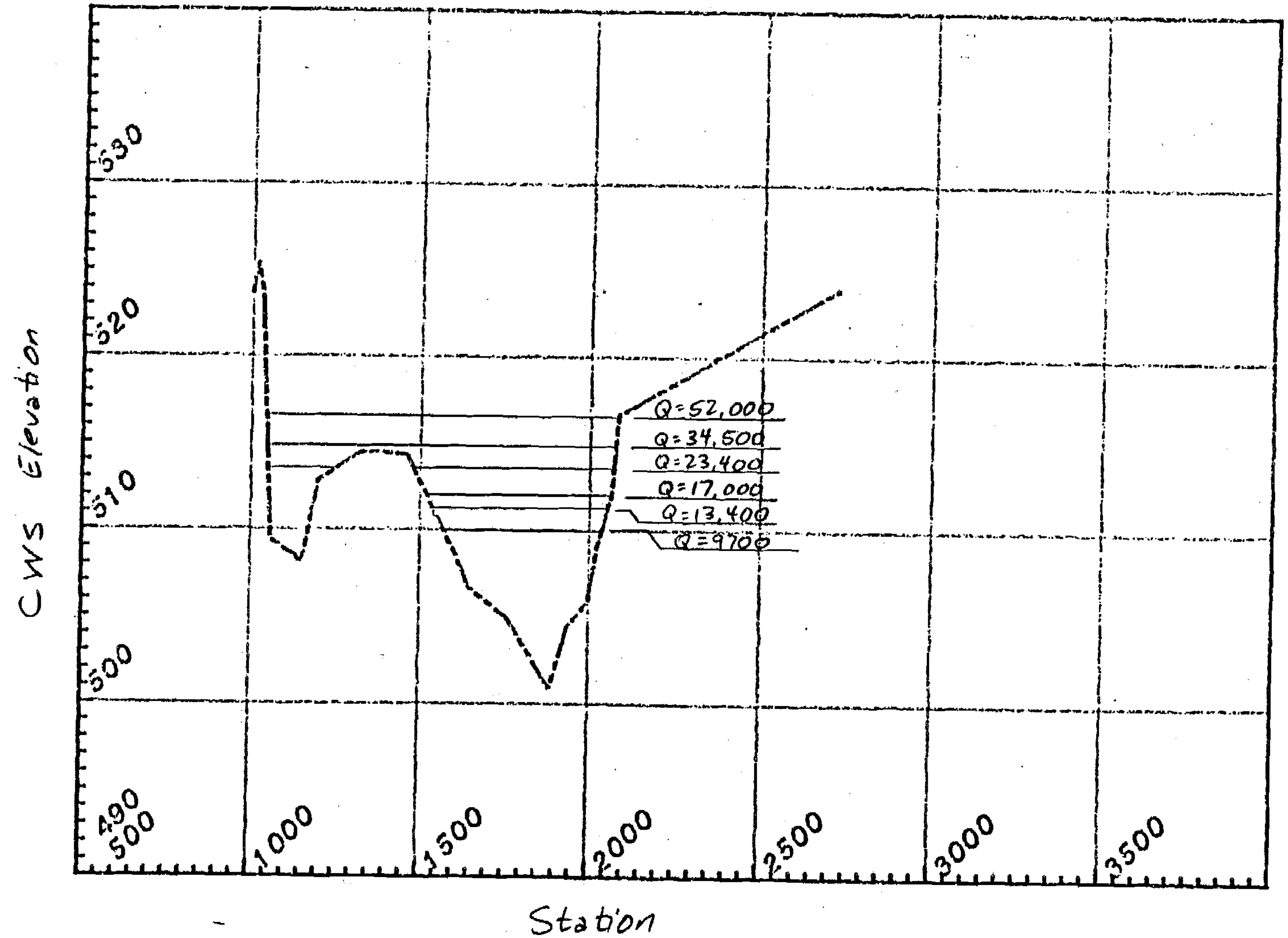

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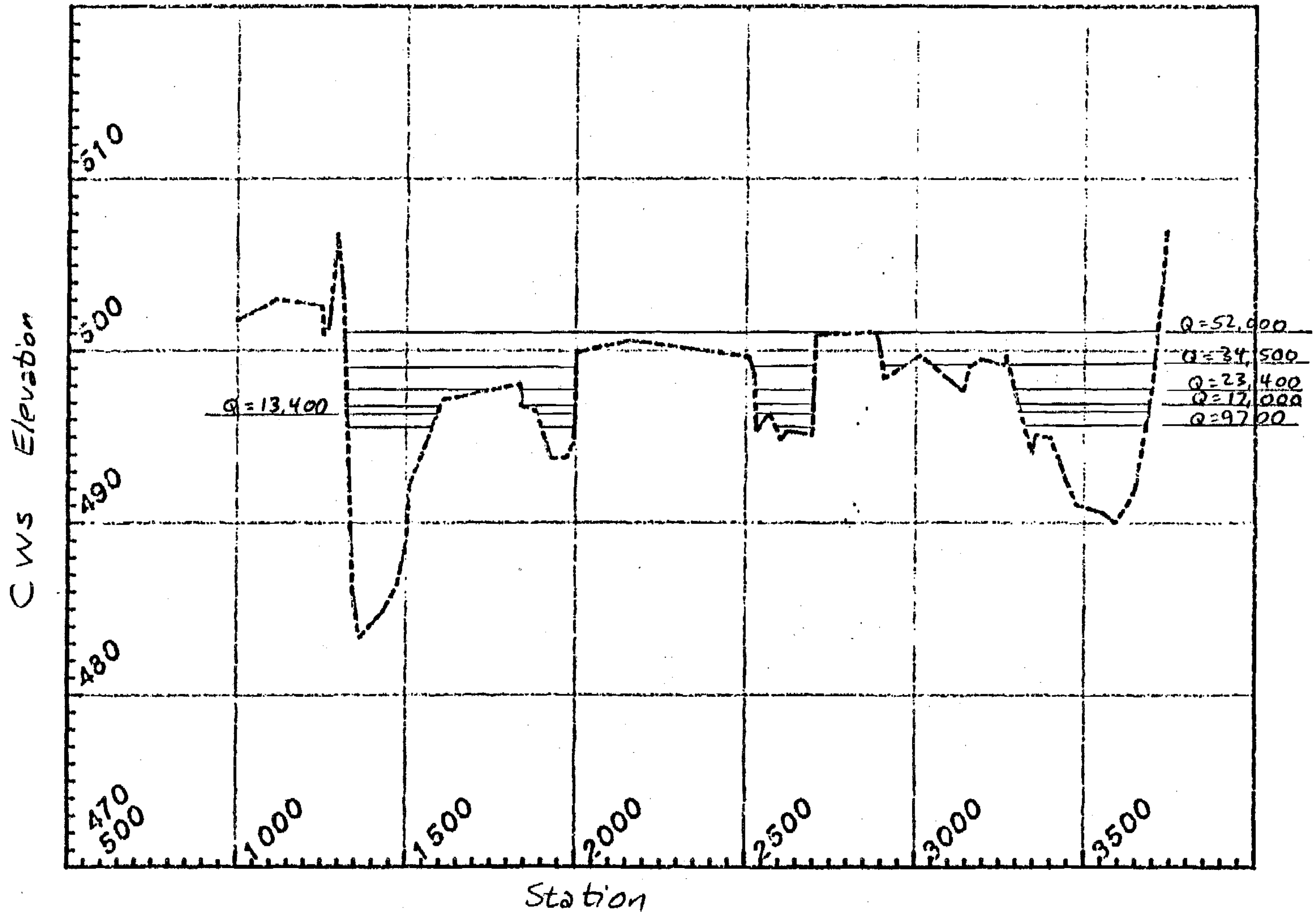

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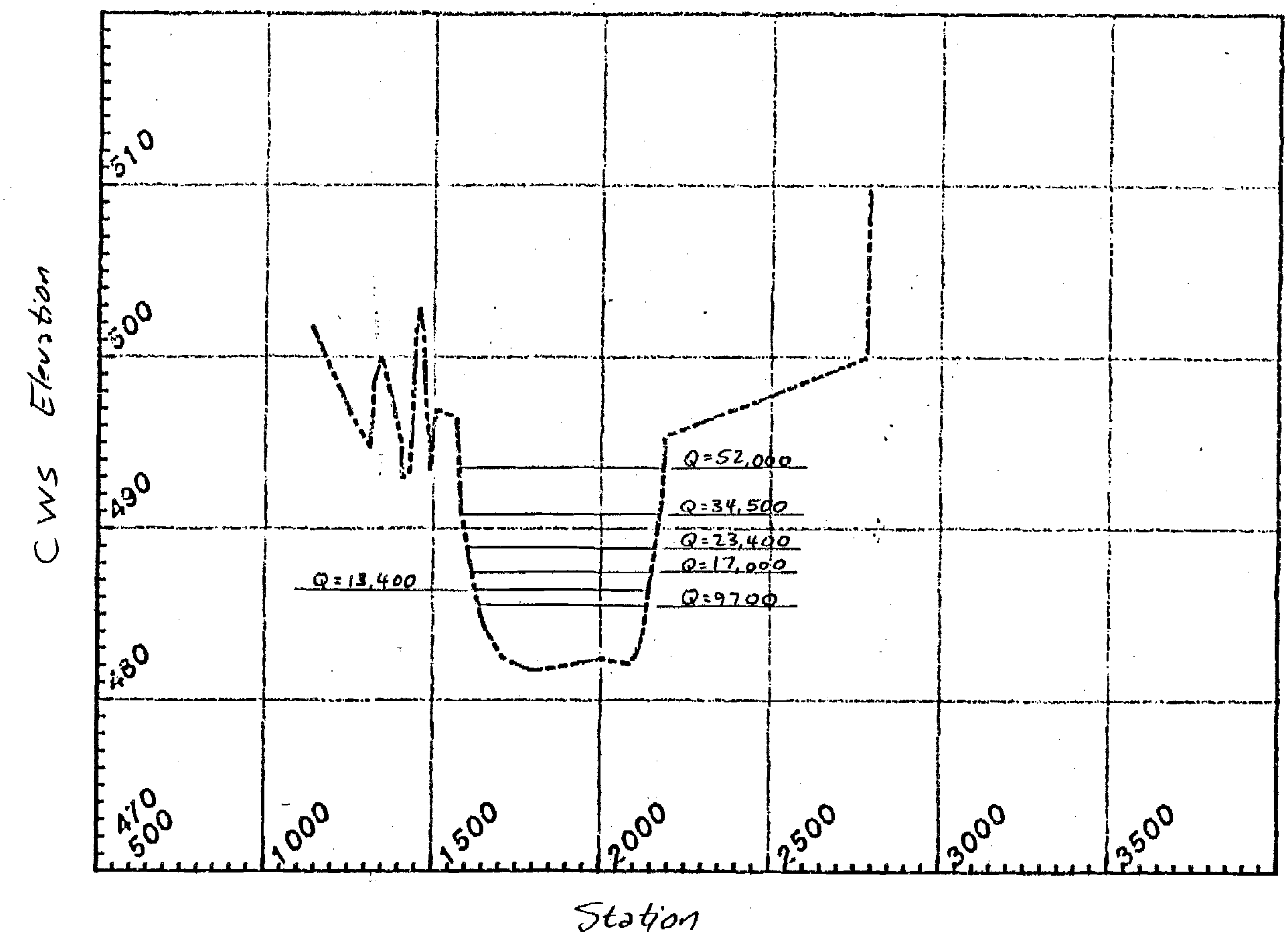
CROSS-SECTION Number 19



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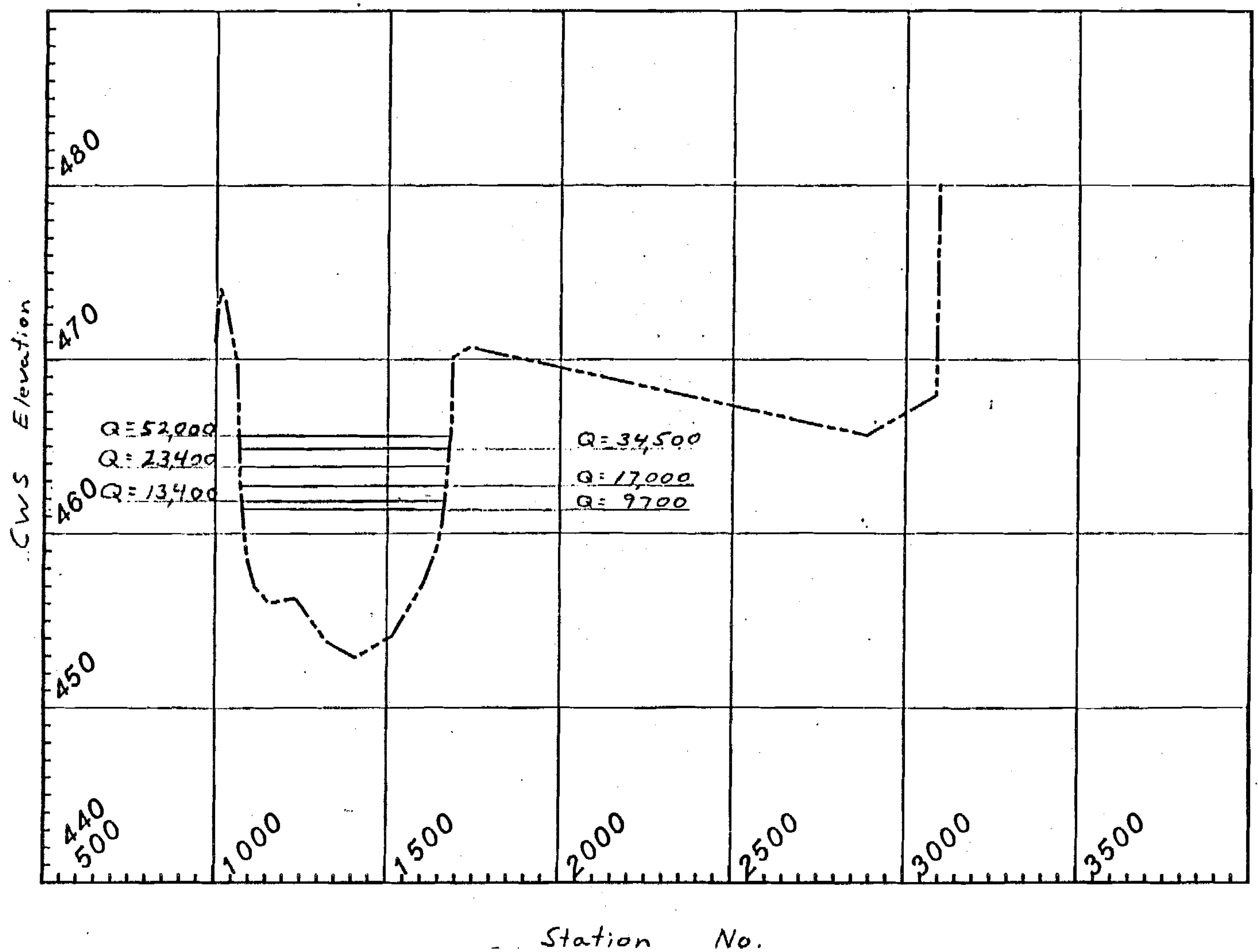

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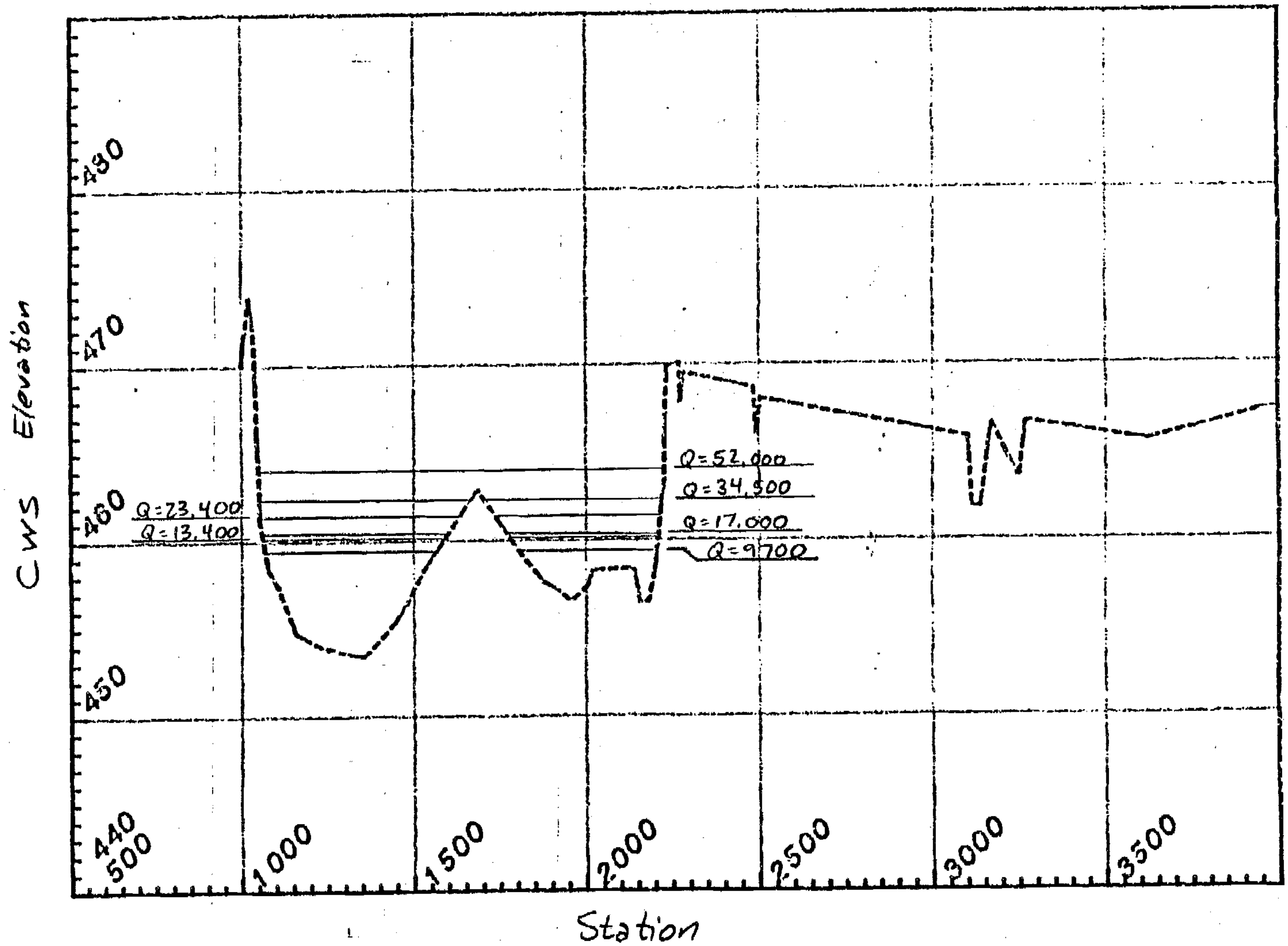
CROSS-SECTION Number 17



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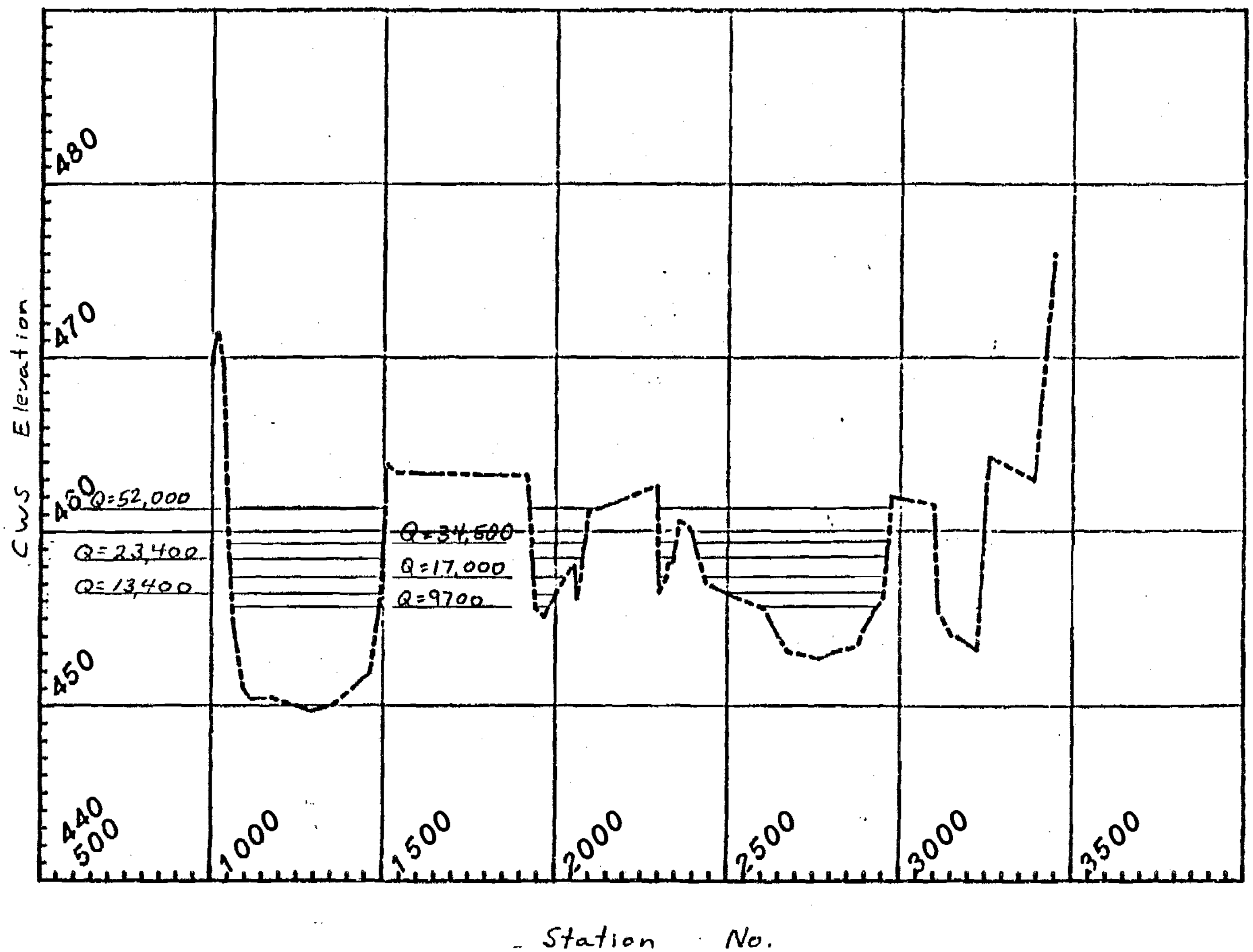

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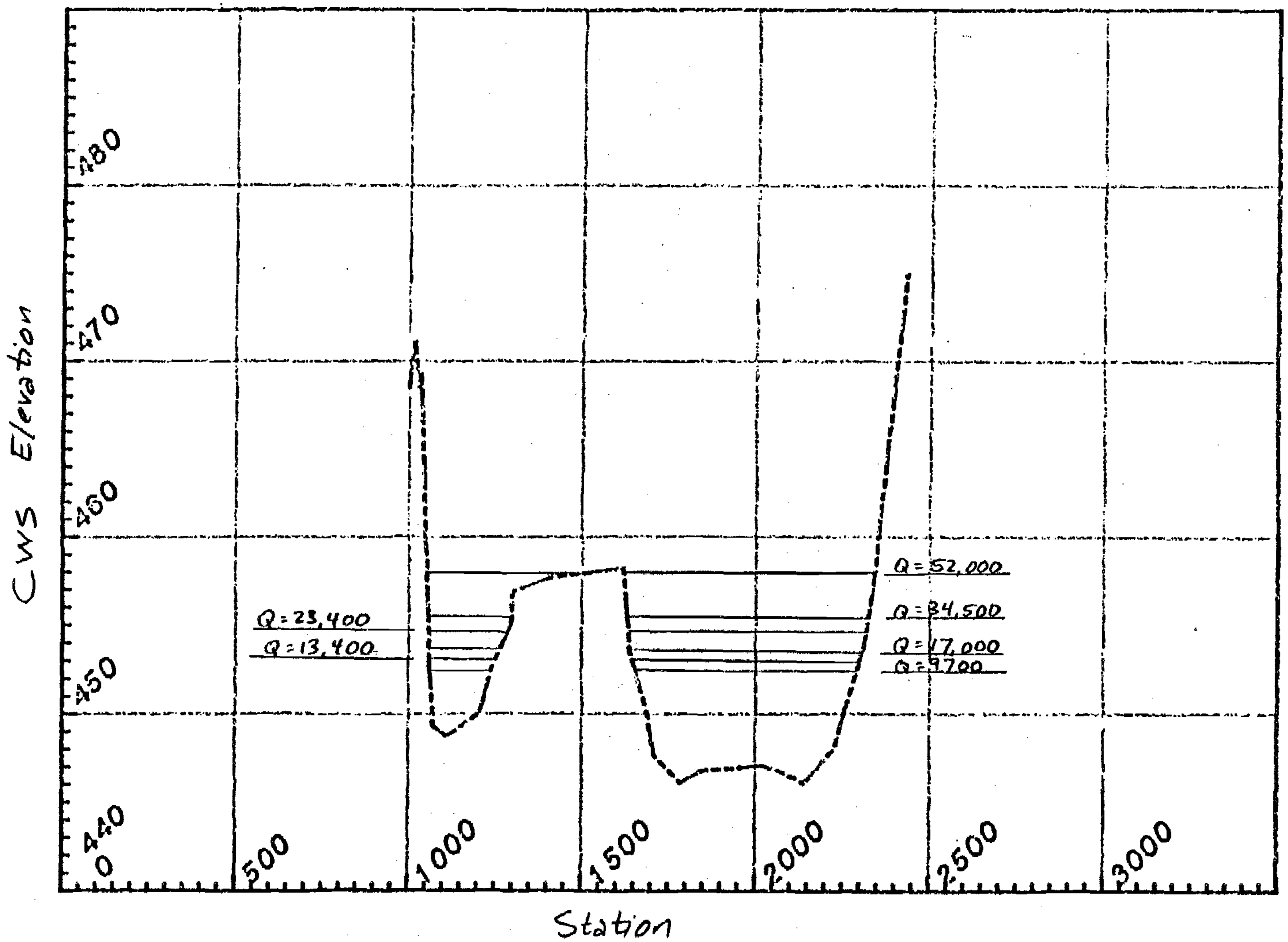

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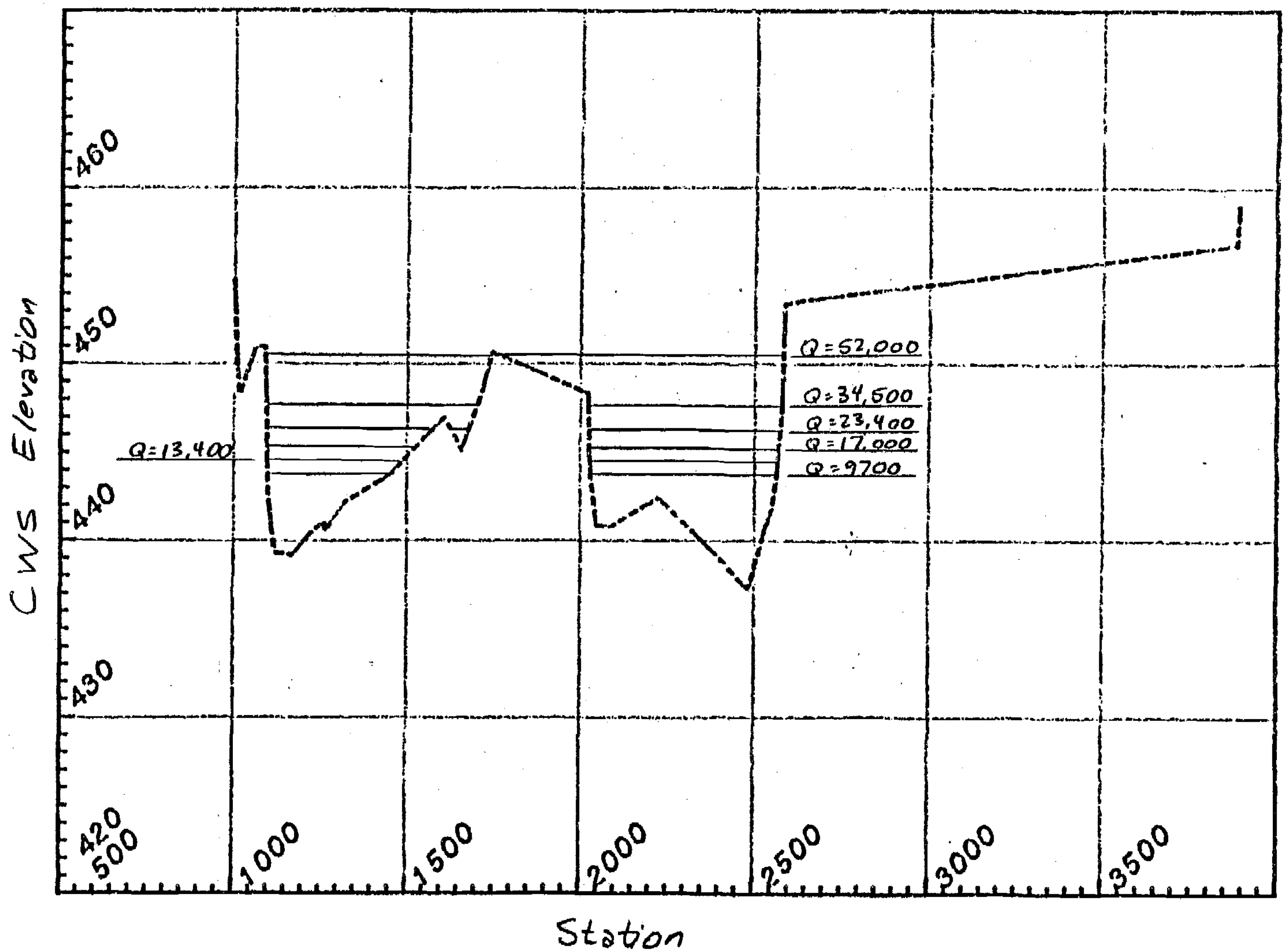
CROSS-SECTION Number 1 4



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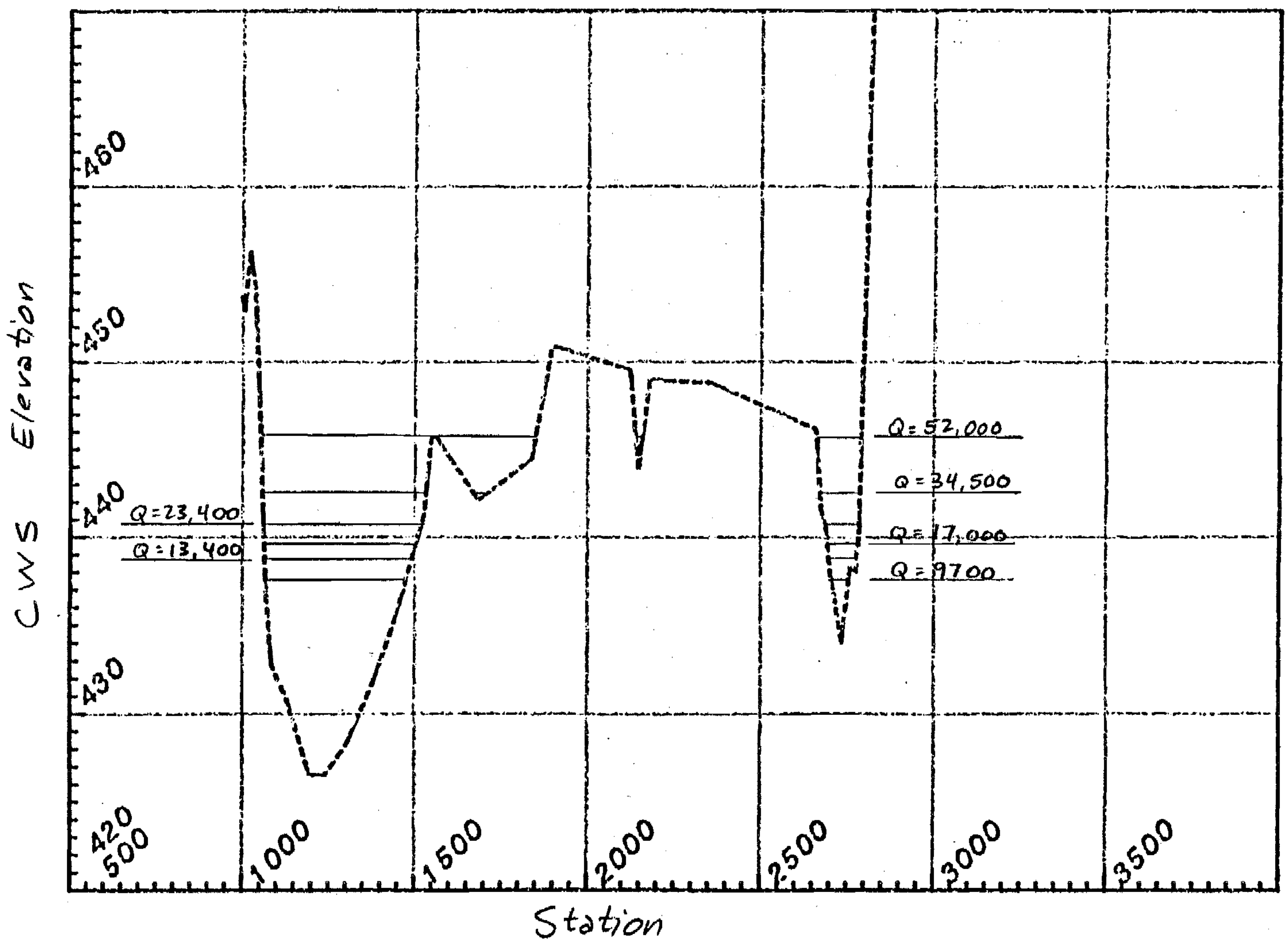

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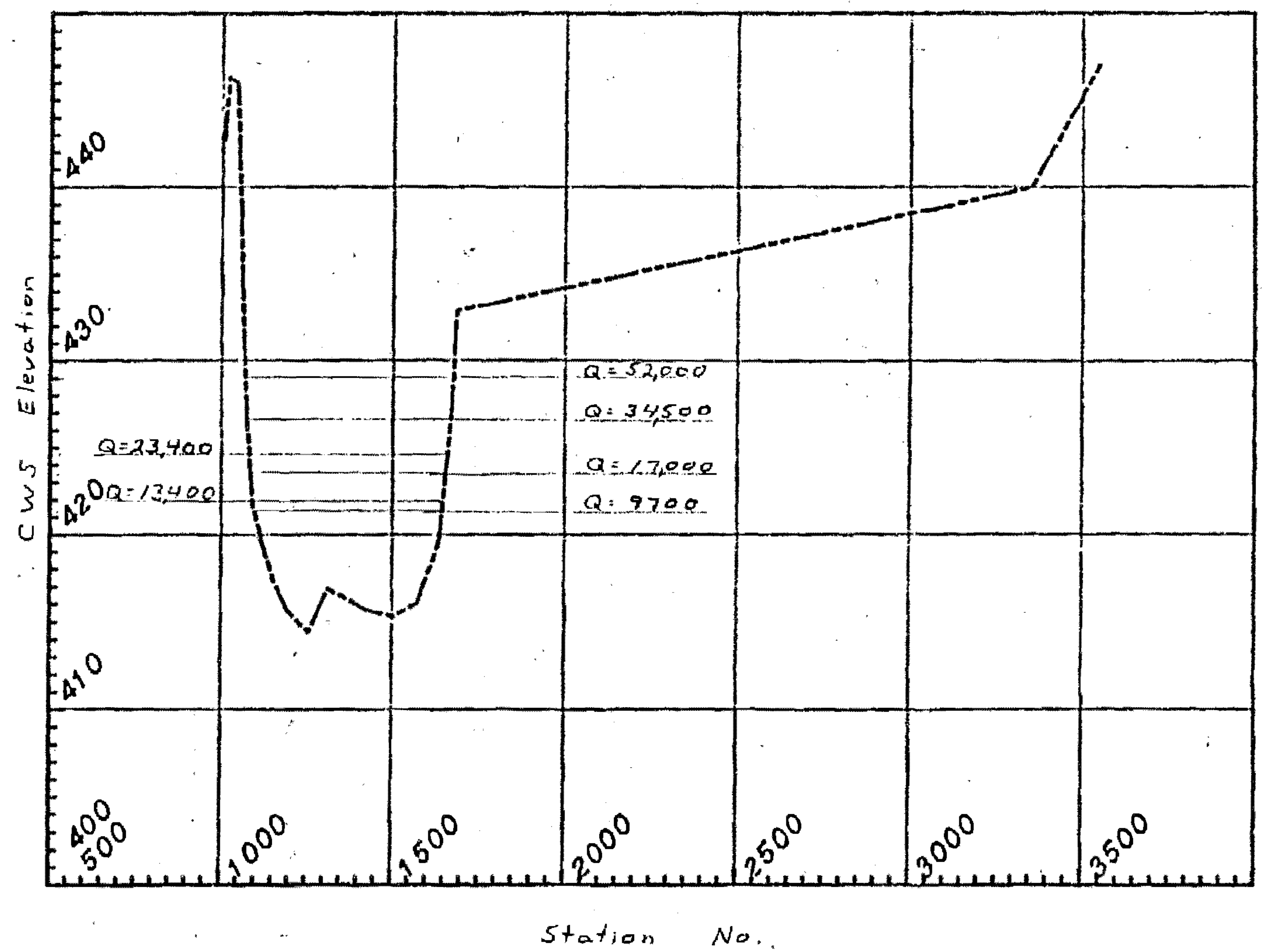
CROSS-SECTION Number 1 2



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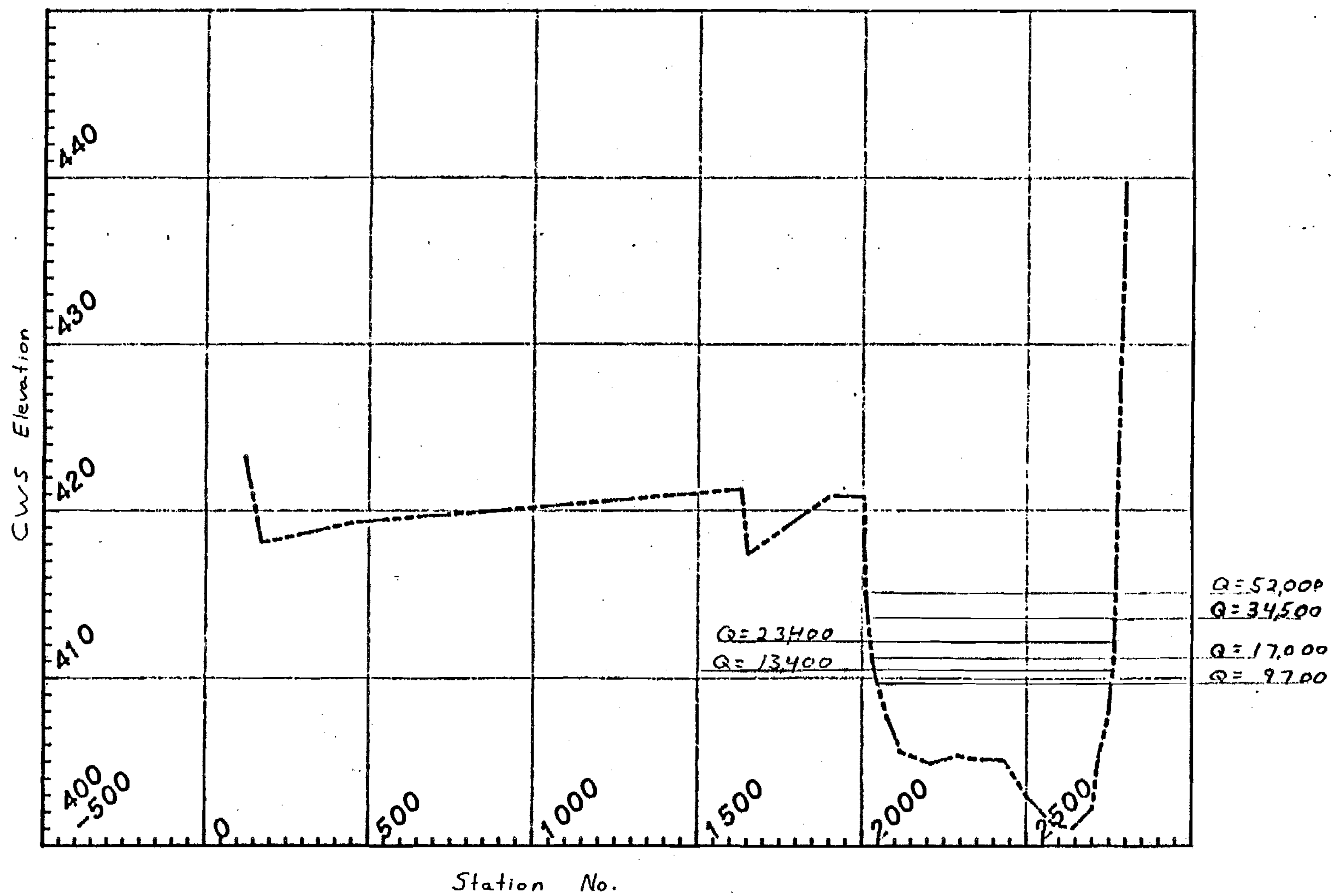

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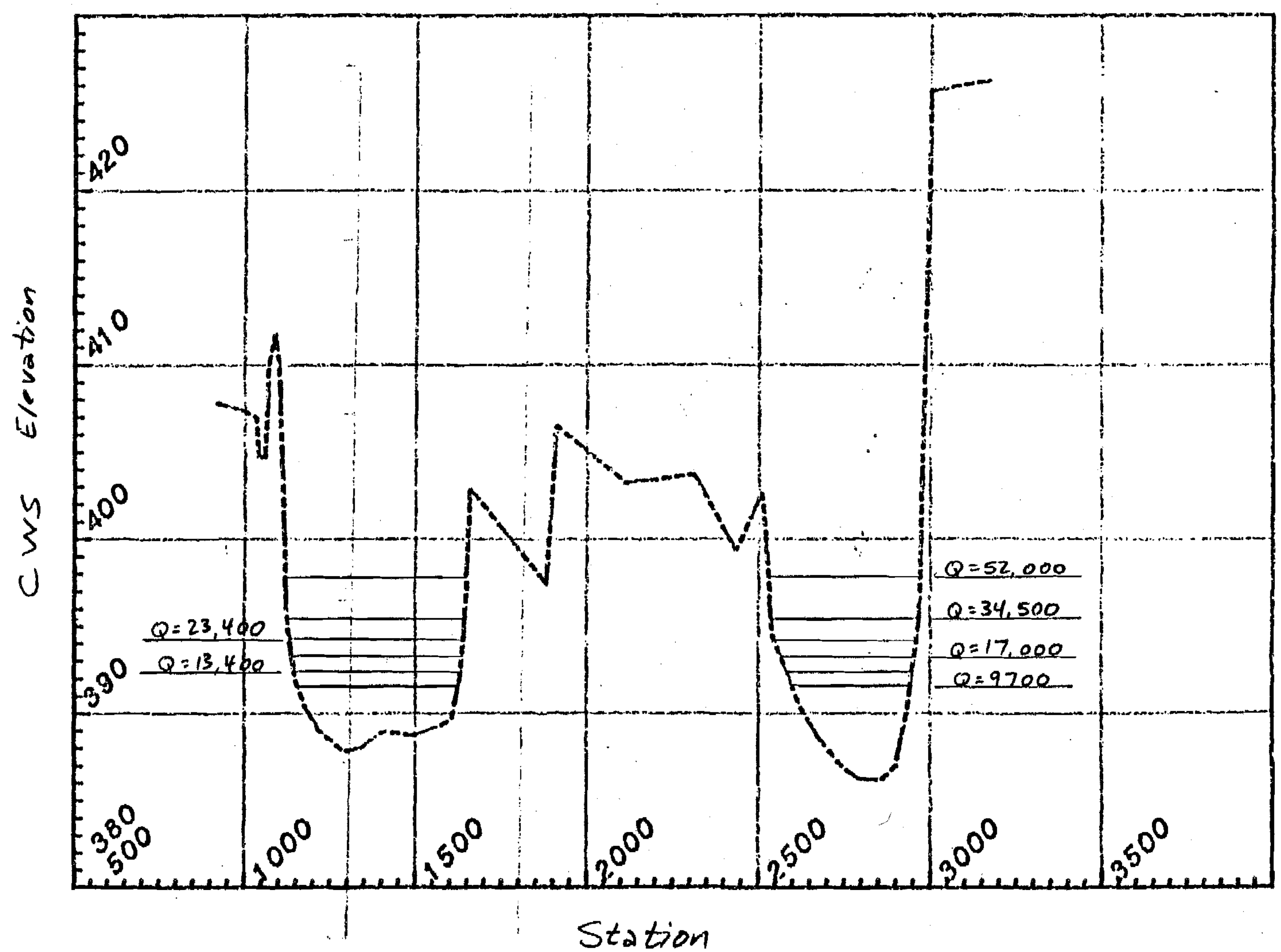

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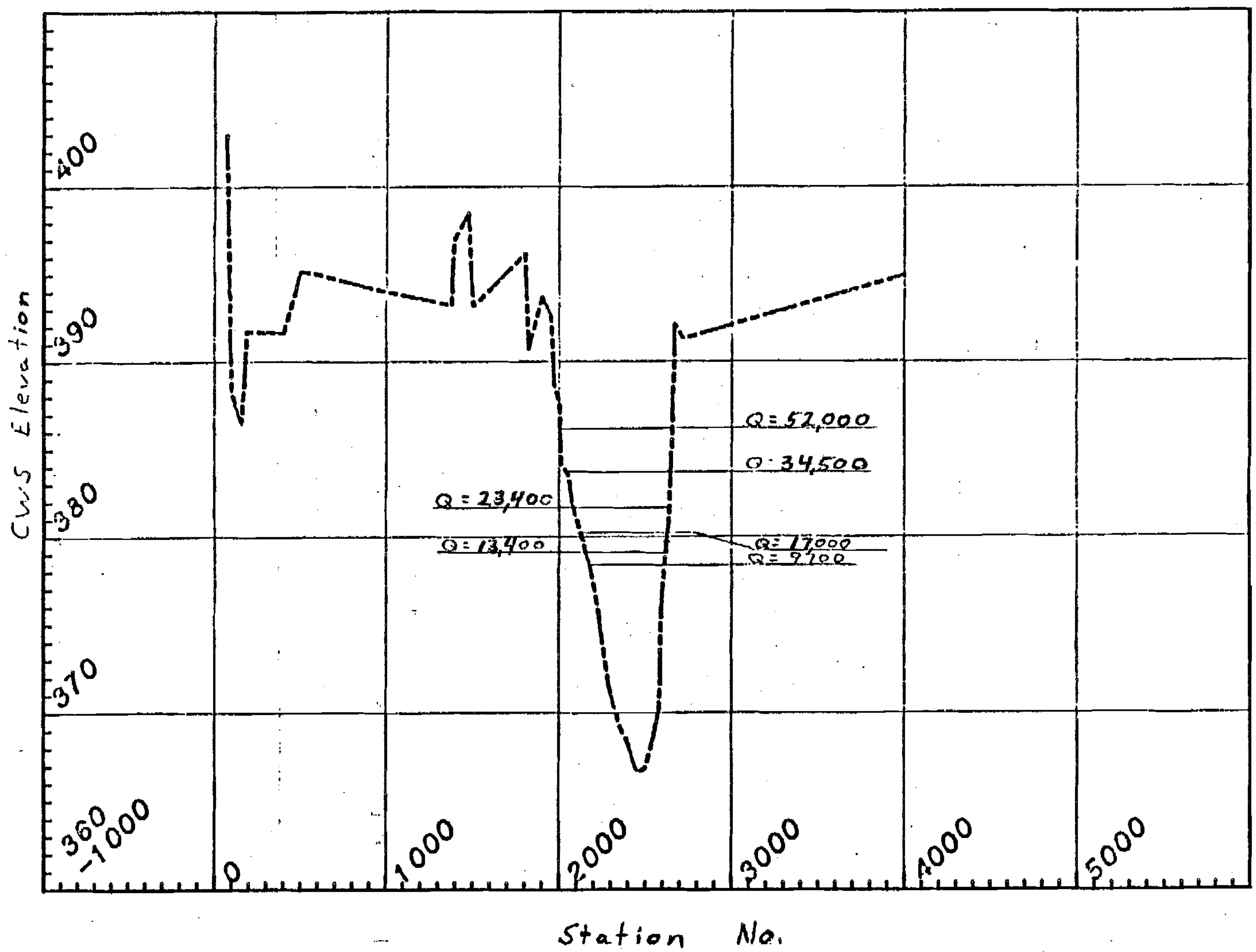

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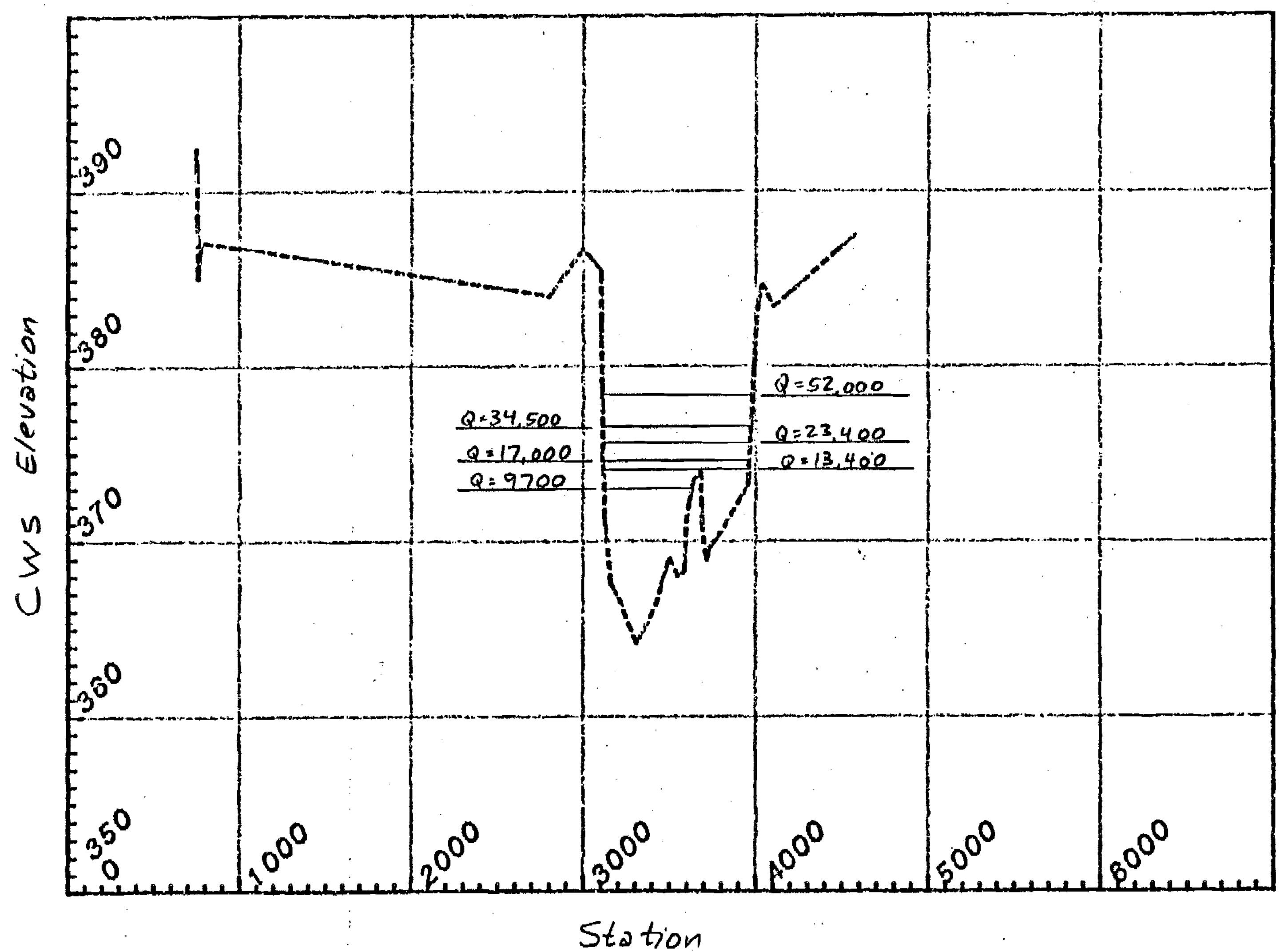

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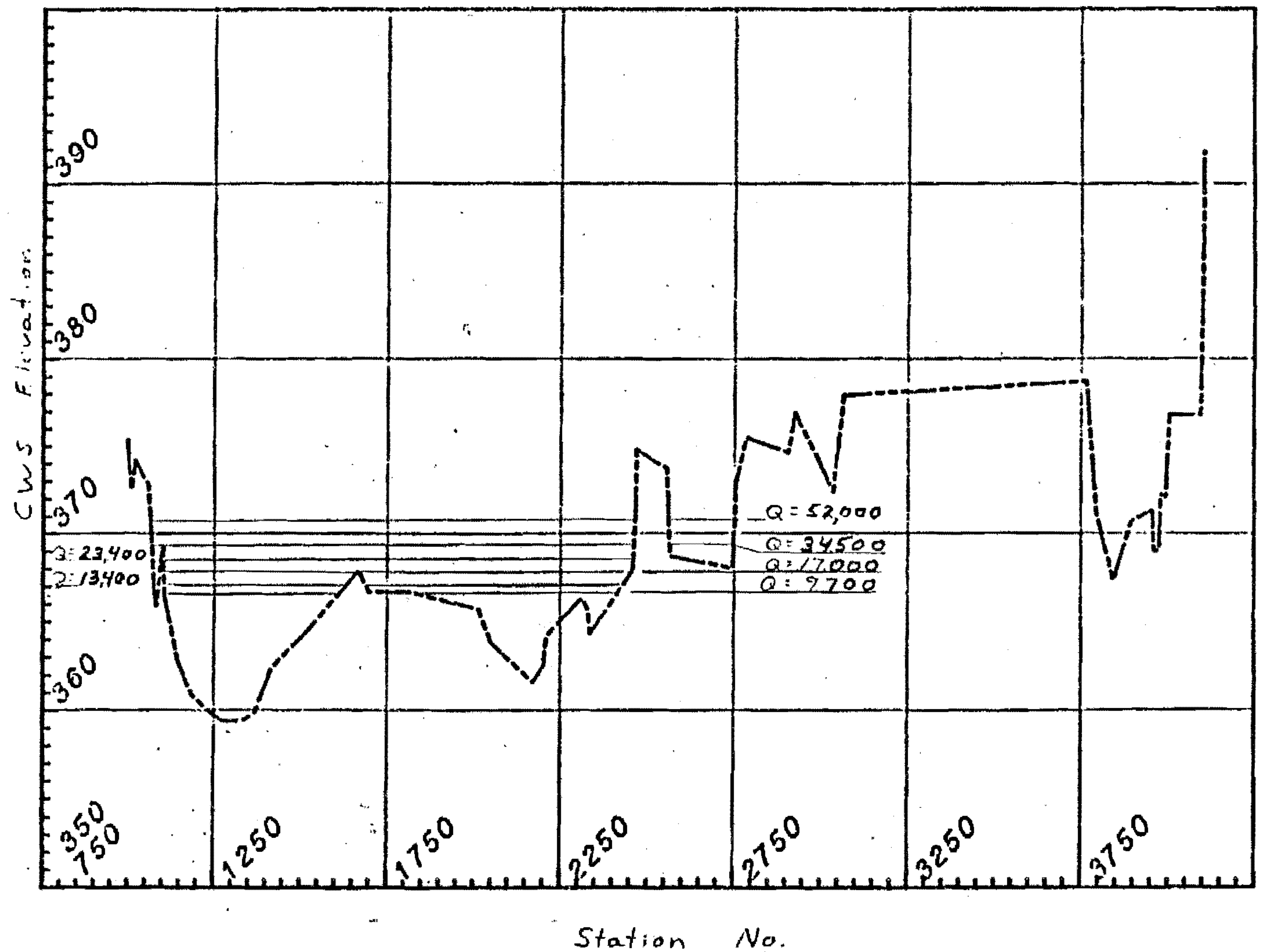

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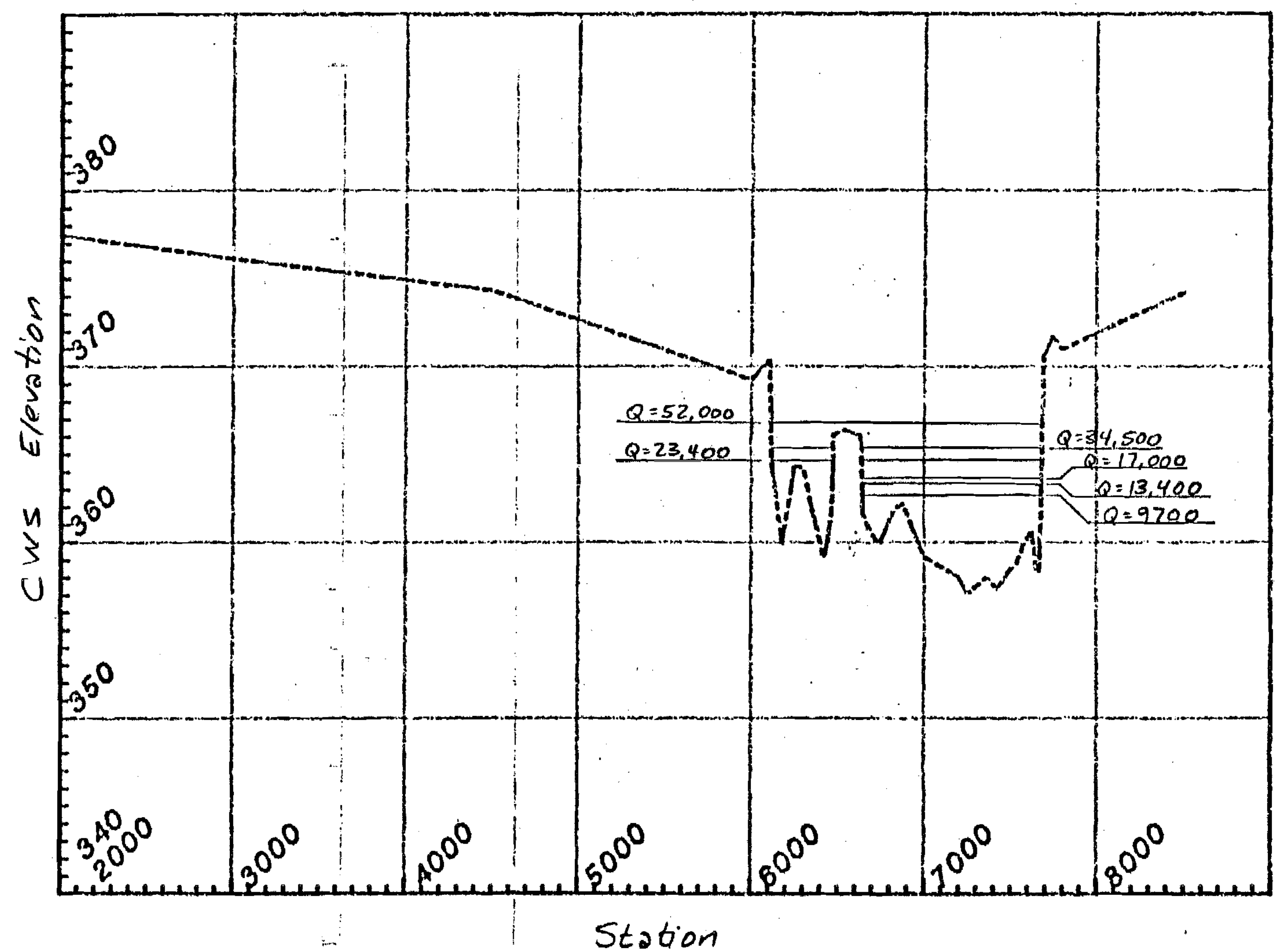

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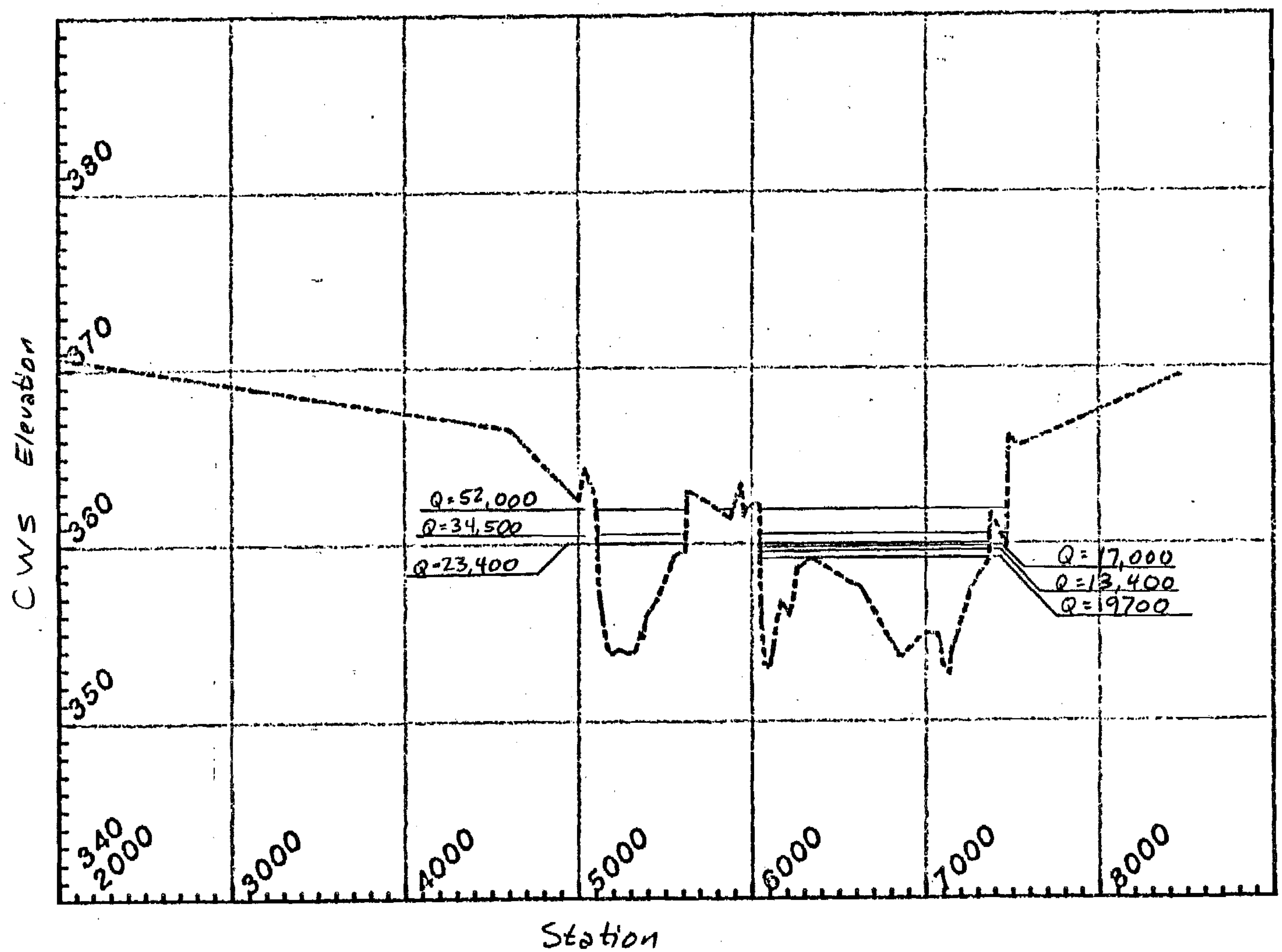

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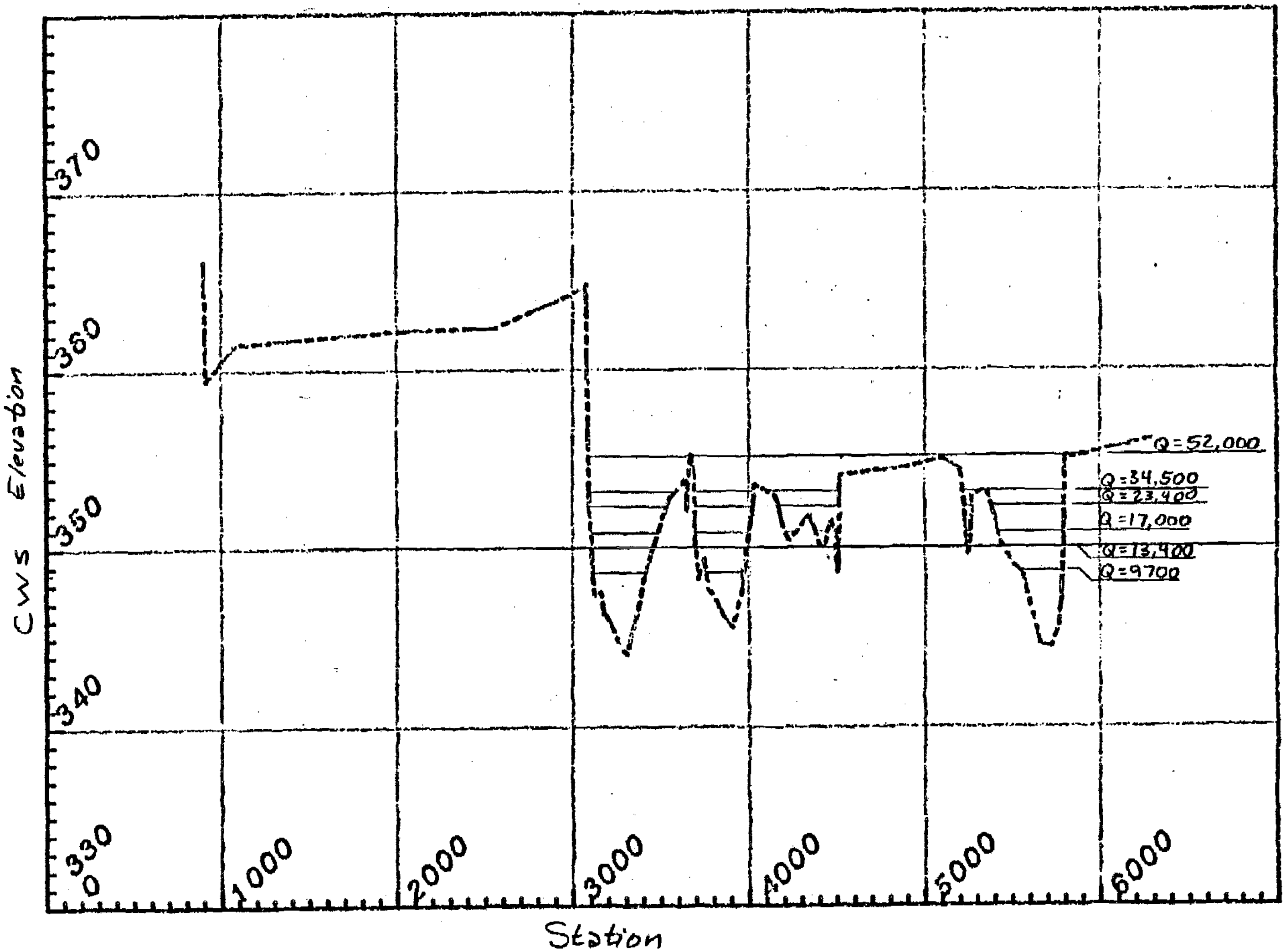
SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 4



C-66

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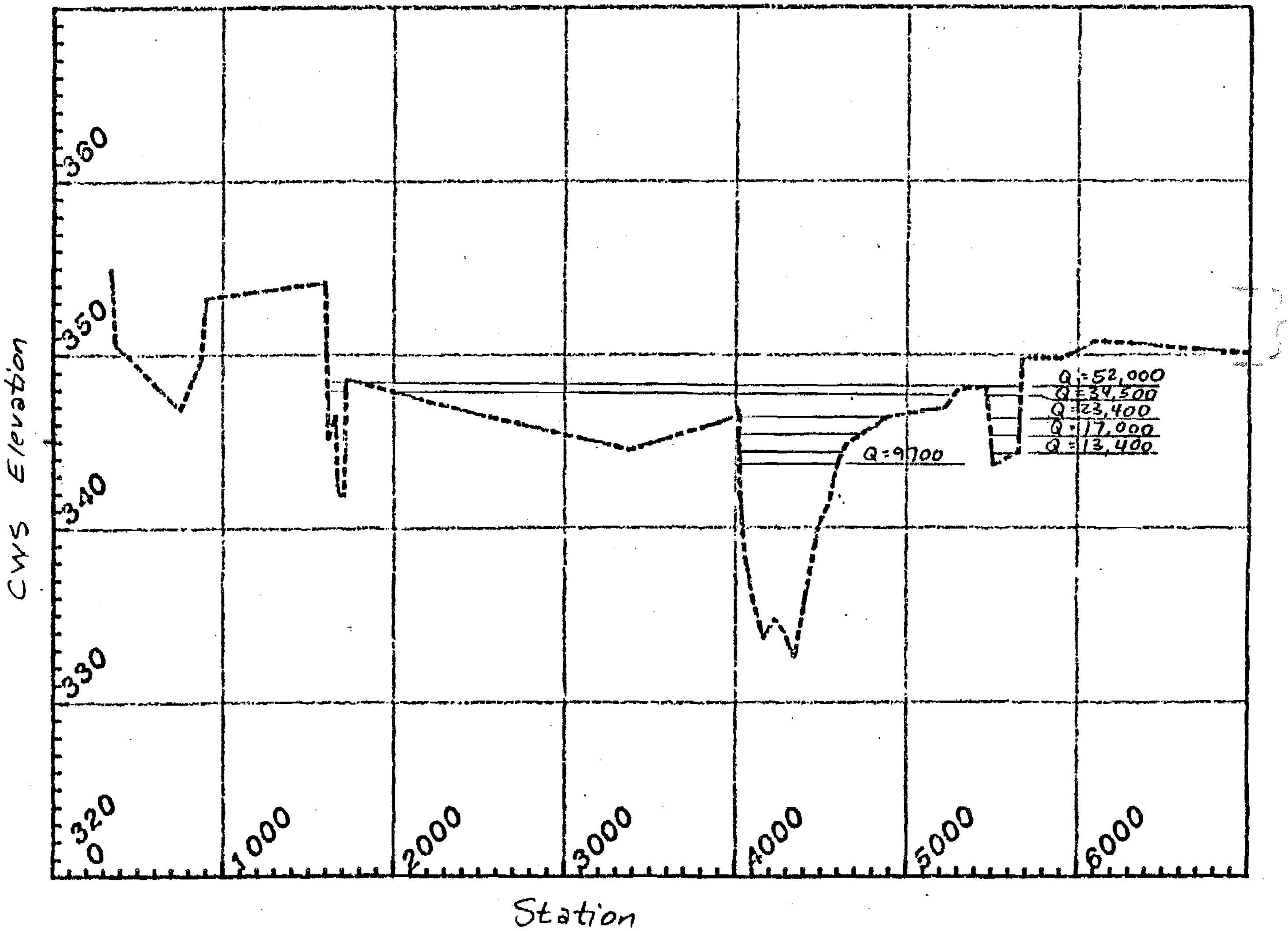
PREPARED FOR:

ACRES

SUSITNA HYDROELECTRIC PROJECT

CROSS-SECTION Number 3



PREPARED BY:

R&M CONSULTANTS, INC.

PREPARED FOR:

ACRES

NOTE :
NUMBERS INDICATE CROSS
SECTION DESIGNATION

ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA RIVER HYDROGRAPHIC SURVEYS

RIVER CROSS SECTION LOCATION MAP

R&M CONSULTANTS INC

DATE JAN. 1981	SCALE 1:250,000		
DEPARTMENT	DRAWING NO	REV	
PROJECT 052216	SHEET 1 OF		

DATE	NO	REVISIONS	CH	APP	APP