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River discharge study, Laughlin, Nevada: Colorado River model and diffusion study

B. Dennis Hugh

David L. Stringfield

Jill C. Bicknell

Robert A. Ryder

Clark County Sanitation District, Nevada

Paulsen

River Discharge Study

Laughlin, Nevada

Colorado River Model
and
Diffusion Study

C.C.S.D. Project No. 163

Clark County Sanitation District

January 1988

Prepared by

Kennedy/Jenks/Chilton

Consulting Engineers
3233 West Charleston Boulevard, Suite 110
Las Vegas, Nevada 89102

K/J/C 8834

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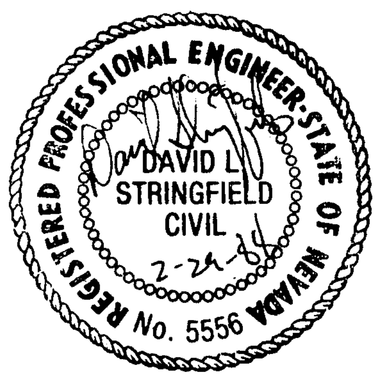

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Clark County Sanitation District

Kennedy/Jenks/Chilton

Consulting Engineers

Principal-in-Charge

B. Dennis Hugh

Project Manager

David L. Stringfield

Project Engineers

Jill C. Bicknell
Robert A. Ryder

Consultants

Dan Szumski
John List

Kennedy/Jenks/Chilton

Consulting Engineers
3233 West Charleston Boulevard, Suite 110
Las Vegas, Nevada 89102
702-870-7502

22 February 1988

Mr. E. James Gans
Clark County Sanitation District
5857 East Flamingo Road
Las Vegas, NV 89122

Subject: Laughlin River Discharge Study
CCSD Project No. 163
Phase 3: River Model
K/J/C 8834

Dear Mr. Gans:

Transmitted herewith is the Clark County Sanitation District's Phase 3 report titled "Colorado River Model and Diffusion Study". We are most appreciative of the support that you and your staff provided us in preparation of this report, especially your Project Manager Mr. David Paulsen.

In addition, I would like to acknowledge the contributions of our Project Manager Mr. David Stringfield, our water resources engineer Mrs. Jill Bicknell, water quality specialist Mr. Robert Ryder, modeling consultant Mr. Dan Szumski and Diffuser Model Consultant Mr. John List. Their dedication and expertize made the successful completion of this report possible.

We thank you for allowing us to serve you on this project. Following your review of the report, we will be available to discuss the details with you and your staff.

Sincerely,

KENNEDY/JENKS/CHILTON

B. Dennis Hugh, P.E.
Regional Manager

BDH/dah

To Dave
Best Wishes
from
Dennis & Dave

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SECTION I

EXECUTIVE SUMMARY

A water quality modeling study of the Mohave Reach of the Lower Colorado River (from Davis Dam to the Nevada/California Stateline) was conducted to evaluate potential water quality impacts resulting from a proposed Laughlin, Nevada wastewater effluent discharge. The study included four major components: (1) review of the current regulatory framework; (2) a field data collection program to document existing water quality conditions in winter, summer, and fall; (3) development and verification of far-field and near-field (mixing zone) water quality models; and (4) application of the models to project future river quality conditions for several treatment-discharge alternatives as well as a no-discharge alternative.

Water quality criteria established by Arizona and California for the Colorado River are less stringent than those established by Nevada. The State of Nevada's "Requirements to Maintain Existing Higher Quality" for the Colorado River below Davis Dam (NAC 445.13495) are based on a strict interpretation of the Federal anti-degradation regulations, which have not yet been addressed by Arizona or California. For example, review of the Arizona and California regulatory framework showed that neither state's water quality criteria would dictate phosphorus removal and only California requires dechlorination of an effluent discharge.

A steady state water quality model of the Mohave Reach was developed using the EPA QUAL-2E program and verified against data from three water quality sampling programs conducted in 1987. The only direct wastewater discharge currently entering the Mohave Reach is the effluent from the River Bend wastewater treatment plant in Bullhead City, Arizona. The discharge from Bullhead City and the proposed discharge from Laughlin were the only point loadings simulated in the model. The major water user in the Reach is the Southern California Edison Mohave Generating Plant which has an average withdrawal rate of 18 cfs.

A mixing zone model was also developed to estimate dilutions downstream of the proposed outfall at Laughlin, for various diffuser configurations. The model was calibrated for lateral mixing conditions in the river using data collected during a dye diffusion test (1987). It was assumed that the location of the discharge would be on the Nevada side of the River, just below the Laughlin Bridge.

The study demonstrated that existing water quality in the Mohave Reach is usually in compliance with the State of Nevada and Federal regulatory requirements, and that the proposed discharge at Laughlin, with additional treatment beyond secondary, will not cause river quality to exceed these requirements for discharges up to 7 MGD. The treatment processes recommended are phosphorus removal and dechlorination. Under these conditions, adequate assimilative capacity is available for equivalent wastewater loadings from Arizona without measurably affecting compliance with water quality objectives.

Specific findings of the study are summarized below:

1. The lower Colorado River flows are regulated at Davis Dam to satisfy storage/release schedules, power requirements, and downstream water demands. From 1968 through 1982, the annual mean discharge below the dam was approximately 11,500 cfs. The monthly releases for downstream demands average 17,000 cfs during summer months and 5,000 cfs during winter months. However, release rates during the day typically vary from 2,000 cfs to more than 20,000 cfs. The minimum monthly discharge based on current downstream demand projections is about 5,000 cfs and is assumed to be the minimum operating flow in the future.

2. The 1987 water quality sampling program for the Mohave Reach and a historical data review found the existing and historical river quality to be within Nevada and Arizona regulatory limits. It appears that total phosphorus is the only regulated characteristic that influences allowable effluent quality (beyond secondary treatment) from the Laughlin wastewater treatment plant.

3. The QUAL-2E river quality model of the Mohave Reach was found to be a satisfactory planning tool for evaluating changes in nutrient concentrations, phytoplankton productivity, oxygen balances, and other quality characteristics resulting from loadings to the Colorado River. The model results were dominated by headwater loadings at Davis Dam. Advective transport and dilution had more effect on water quality in the model simulation than biological or chemical processes, due to high river velocities and therefore short travel times within the main channel of the reach. The model showed no significant increase in biological activity in the reach resulting from the proposed discharge, and dissolved oxygen levels generally remained close to saturation levels during all conditions evaluated by the model.

4. The model results for the future "baseline" (no project) condition showed compliance with all regulatory requirements. The baseline condition assumed: 1) warm water, low flow (5,000 cfs) conditions indicative of late summer/early fall; 2) no discharge from the Laughlin treatment plant; and 3) a discharge of 0.16 MGD from the River Bend treatment plant (the maximum discharge currently allowed by permit). These assumptions were intended to represent a "worst case" condition upon which the Laughlin treatment-discharge alternatives were superimposed.

5. Modeling analyses of alternative discharge conditions superimposed on the baseline condition indicated that, during river flows of 5,000 cfs, a 7 MGD discharge from Laughlin without additional treatment beyond secondary is estimated to increase total phosphorus concentrations in the river downstream of the discharge by 0.013 mg-P/l (i.e., a phosphorus loading of approximately 350 pounds/day). Given historical average concentrations of total phosphorus in the river below Davis Dam of 0.018 mg-P/l, this discharge alone would cause the Nevada annual average standard for total phosphorus (0.02 mg-P/l) to be exceeded. The total average annual phosphorus load to downstream reservoirs (e.g., Lake Havasu) would increase by an estimated 28 percent under these conditions.

6. By imposing an effluent phosphorus limitation of 0.5 mg-P/l on the Laughlin discharge (reducing the phosphorus loading to approximately 29 pounds/day for a 7 MGD discharge), the downstream phosphorus concentration during river flows of 5,000 cfs is estimated to increase by 0.001 mg-P/l, an incremental increase which is within current standards. Under these conditions, it is estimated that the total average annual phosphorus load below the Mohave Reach would increase by approximately 2 percent over current loadings. Phosphorus loading from a 4 MGD treated discharge (approximately 17 pounds/day) would not cause a detectable increase in phosphorus concentrations in the river; the total average annual phosphorus load to downstream reservoirs would increase by less than 1 percent.

7. Residual chlorine in the proposed discharge is a concern due to the potential toxicity of chlorine to aquatic life in the mixing zone and downstream. With dechlorination of the discharge to a maximum of 0.1 mg/l total chlorine residual, the mixing zone analysis showed that total chlorine concentrations in the river would be below EPA acute and chronic toxicity requirements within 50 to 200 feet downstream of the discharge with the recommended diffuser structure in place. This analysis considered the lowest expected hourly discharge rate at Davis Dam, 2,000 cfs.

8. The recommended diffuser structure for a 7 MGD discharge consists of four 20-foot diffuser sections oriented parallel or perpendicular to the river flow and anchored to the two westerly bridge piers at Laughlin. This configuration will provide a mixing zone which is contained entirely within the Nevada side of the river. The utilization of the four sections would be staged to correspond to expansions of the treatment plant and associated increases in discharge rates.

Section II
Task 4.0 Colorado River Model

SECTION II

COLORADO RIVER MODEL

DAVIS DAM

TO

NEVADA/CALIFORNIA
STATELINE

SECTION II

INTRODUCTION

PLANNING OBJECTIVES

A water quality planning study for the Mohave Reach of the Lower Colorado River was conducted to provide the Clark County Sanitation District with a concise technical description of potential water quality impacts resulting from a proposed Laughlin, Nevada wastewater effluent direct discharge. The Mohave Reach extends from Davis Dam to the Nevada/California Stateline, and forms the boundary between Nevada and Arizona. A location map of the study area is shown on Figure 1.

The District's current plans call for expansion of the existing treatment plant capacity from 1.0 million gallons per day (MGD) to 4.0 MGD, with possible future expansions to 7.0 MGD. In addition, the District is considering relocating the final effluent discharge from an existing land-irrigation disposal system to a suitable direct discharge point in the Colorado River. This discharge relocation is expected to have small impacts on existing water quality, which should be quantified in relation to ambient water quality standards for the river. In addition, the Laughlin discharge is planned to utilize no more than Nevada's half of the available assimilative capacity within the river downstream of the discharge point, leaving the remaining capacity for the State of Arizona.

The study program involved development of technical information which satisfies four major planning objectives:

1. Determine existing water quality conditions and historical compliance with water quality objectives within the Mohave Reach of the Lower Colorado River.

2. Develop a water quality model for comprehensive analysis of the proposed Laughlin discharge and other future water quality planning efforts.

3. Examine possible additional treatment requirements at the Laughlin wastewater treatment plant to satisfy regulatory requirements while utilizing the allowable assimilative capacity of the river.

4. Provide probabilistic frameworks for assessing the frequency of extreme events which might cause water quality measurements to exceed numerical limits of the standards.

APPROACH TO MODEL STUDY

In order to accomplish these objectives, Clark County Sanitation District contracted with Kennedy/Jenks/Chilton, with participation by Dan Szumski &

Associates and Flow Science, Inc., to develop a comprehensive mathematical water quality model of the Colorado River Mohave Reach, from Davis Dam to the State Line, so that water quality planning alternatives could be evaluated. This study included three major components. First, a field data collection program was conducted to survey existing water quality conditions within the river, and to provide data for verification of the mathematical model. Three river surveys included physical, chemical, biological, and bacteriological measurements at five locations within the Mohave Reach during different seasonal conditions. A comprehensive review of historical data supplemented the field program and laboratory analysis results by providing information on extreme conditions, water quality variability, and existing compliance with applicable state and interstate standards.

The second phase of the study involved the development of two water quality models for the proposed discharge, using information from the field data collection program, other modeling efforts, and the historical data base. The first of these is a comprehensive steady state river model known as QUAL-2E, which simulates complex kinetic interactions. It incorporates point source loadings, flow dependent channel characteristics, and benthic and meteorological inputs into a framework which computes downstream water quality conditions. The QUAL-2E model of the Colorado River was verified against field survey data assuming complete mixing in the river. The second model is a mixing zone model which was used to assess near-field water quality impacts within the discharge plume. This model provides a basis for determining compliance with operative mixing zone requirements and toxicity limits within the effluent plume. Dispersion characteristics of the river required by the mixing zone model were estimated using the results of a dye test performed as part of the field program.

The third phase of the study utilized the calibrated QUAL-2E model of the river to estimate future water quality conditions within the study area. This included evaluations of future water quality conditions for the no-project alternative as well as several treatment-discharge alternatives. These results were interpreted in a probabilistic framework which looked at both average and extreme water quality occurrences, in order to assess non-compliance with standards due to random and human-induced variations in the environment.

DESCRIPTION OF THE WATER QUALITY MODELING FRAMEWORK

The water quality models employed in this study are descriptive of water quality issues set in two distinctly different time and space scales. The QUAL-2E model is a broad scale, steady state simulator, which computes average water quality conditions in a spatial scale measured in miles and a time scale represented in days. It is assumed that during the time period represented by the calculations, the river discharge rate, wastewater loadings, and environmental conditions are constant. For these idealized conditions, the results are best estimates of average water quality during the day.

In the Mohave Reach of the Colorado River, conditions are less ideal. The discharge is highly regulated at Davis Dam to satisfy storage/release schedules, power requirements, and downstream water demands. Along with these hourly changes in discharge rate, there are variations in both wastewater loadings and environmental conditions (such as light intensity and water temperature) during the day. Thus, river water quality will tend to vary from hour to hour around an average daily condition.

To obtain information on extremes in water quality within the day, this study has employed statistical techniques which can be superimposed on the average daily values computed by QUAL-2E. These methods have been used successfully in studies of other rivers to make comparisons of water quality projections with single value standards such as those that exist in Mohave Reach for total phosphorus and dissolved oxygen.

The time and space scales of a model are important considerations in interpreting the model's results. It would be inappropriate, for example, to use the QUAL-2E model to estimate concentrations of toxicants within a local mixing zone. By simulating complete mixing of the effluent across the Colorado River cross section, the QUAL-2E calculations average out local scale concentration gradients which reflect initial mixing mechanisms and, consequently, local extremes in concentrations.

A technically correct evaluation of mixing zone characteristics requires descriptions of peak concentrations and the downstream dissipation of these peaks resulting from dispersive phenomena. The mixing zone model allows the analysis of spatial variations in water quality within the space scale of one hundred feet or less, and at peak concentrations that may occur within a few minutes or a few hours travel time from the point of discharge. The model can help define the spatial extent of local regions where water quality standards may be exceeded and special mixing zone requirements may apply. It can also be used to examine mixing zone characteristics for alternative diffuser configurations during relatively small time windows of critical hydrologic conditions and peak effluent discharge rates.

This study utilizes both models to address questions which the District and the State of Nevada have raised regarding the Laughlin discharge. A technical description of the QUAL-2E model is provided in the next section. A report on the mixing zone model prepared by Flow Science, Inc., which includes a description of the dye dispersion test, alternative diffuser designs, and associated dilution ratios, is provided as Attachment B to this report.

COLORADO RIVER MODEL DEVELOPMENT

GENERAL DESCRIPTION OF THE QUAL-2E MODEL

The QUAL-2E model was originally developed in 1970 as a steady state mathematical model for evaluating complex water quality interactions in one-dimensional rivers. Since that time, it has been modified and expanded several times by public and private agencies until the National Council on Air and Stream Improvement and the Environmental Protection Agency synthesized these modifications into the current version. The model in its present form consists of a central computational routine for channel characteristics, advective and dispersive transport, point and non-point loadings, and an implicit finite difference solution algorithm. Within this basic framework is a kinetic processor which permits complex interactions among individual water quality constituents, and interactions between these constituents and atmospheric and sediment boundaries.

A brief general description of the QUAL-2E model is provided here as a basis for understanding the development of a model specific to the Colorado River system and the model's application. For a more detailed description of the QUAL-2E program, the reader is referred to the program documentation and users manual (Brown and Barnwell, 1985).

To represent the hydraulic properties of a river system in QUAL-2E, the river is divided into reaches for which channel characteristics are then defined. The reaches are further divided into elements of equal length for purposes of computation; however, all elements in a particular reach have the same hydraulic properties. Water quality constituents are transferred into and out of elements via the following mechanisms: advection from one element to the next; point loads and withdrawals specified at certain elements; and exchange with the atmosphere or river bed sediments. Each element is assumed to be completely mixed; that is, the mass of each modeled constituent is distributed equally in the element and the computed concentration of the constituent represents the average concentration in the element.

The QUAL-2E model allows computation of steady state levels of the following water quality characteristics:

- Temperature (°F)
- Biological Oxygen Demand (BOD) (mg/l)
- Dissolved Oxygen (mg/l)
- Organic Nitrogen (mg-N/l)
- Ammonia Nitrogen (mg-N/l)
- Nitrite Nitrogen (mg-N/l)
- Nitrate Nitrogen (mg-N/l)
- Organic Phosphorus (mg-P/l)
- Dissolved Ortho Phosphate (mg-P/l)
- Chlorophyll 'a' (ug/l)
- Fecal Coliforms (no./100 ml)
- Three Conservative Constituents

For the Colorado River Study:
Total Dissolved Solids (TDS) (mg/l)
Chlorides (mg/l)
Sodium (mg/l)

One Nonconservative Constituent
For the Colorado River Study:
Total Chlorine Residual (mg/l)

The model simulates interactions among many of these characteristics in response to biological and chemical conversions and interactions at the atmospheric and sediment boundaries.

Figure 2 illustrates the principle kinetic interactions included in the QUAL-2E model. The figure shows those mechanistic pathways which mediate local concentrations of phytoplankton, dissolved oxygen, nutrient forms, and BOD. The diagram indicates the balance between the sources and sinks of oxygen: dissolved oxygen provided from the atmosphere and algal photosynthesis, and oxygen utilization for BOD stabilization, nitrogen oxidation and algal respiration. The diagram also indicates the sequential conversion of organic nitrogen and phosphorus to inorganic nutrient forms and the mechanism of recycling of organic nutrients from dead algae to the nitrogen and phosphorus pools. The diagram also displays sediment interactions resulting from settling or anaerobic nutrient release. These interactions form the core of the QUAL-2E kinetic routines. In addition to these complex kinetics, QUAL-2E includes provisions for simulating simple first order decay to represent reactions such as coliform die-away, and conservative (non-reactive) substances such as TDS and chlorides.

QUAL-2E contains a number of options for computational algorithms representing different kinetic interactions described in the technical literature. These include eight options for calculating atmospheric reaeration, three options for specifying light and nutrient limitations to phytoplankton growth, three options for calculating available light for photosynthesis, and optional pathways for nutrient reactions. The user selects those options which are believed to most closely represent the kinetics of a particular river system.

Most of the reactions indicated in Figure 2 are influenced by water temperature. To accommodate this requirement, QUAL-2E computes a complete heat balance on the river system to determine temperature conditions resulting from the following heat sources:

- incoming and reflected short wave solar radiation
- incoming and reflected atmospheric radiation
- black body radiation from the water surface
- heat loss by evaporation
- head loss by conduction to the atmosphere
- point and non-point sources of heat

Modeled reaction rates are then adjusted for ambient temperature conditions by applying an Arehenius correction method (Brown and Barnwell, 1985).

In order to accommodate the specific technical requirements in a model of the Mohave Reach of the Colorado River, the study team has conducted a detailed characterization of the river system from historical data and technical reports, and selected computational options in QUAL-2E which are most appropriate to this river system. The methodology and basis for assumptions used in developing a representation of the river system in the QUAL-2E model are described in the following sections.

The QUAL-2E modeling framework has been expanded in one important respect. The study team has incorporated a probabilistic interpretive framework into the analysis to accommodate planning questions related to extreme water quality variations. The historical data base has been analyzed to determine the statistical distribution of water quality measurements around the seasonal average conditions. In this way, it is possible to estimate the frequency with which random (unexplained) variations in water quality may cause observed water quality conditions to depart from those computed in QUAL-2E. This is an important element of the modeling framework in the region below Davis Dam because of the sharp diurnal changes in river flows and the existence of single value extreme standards (which are close to ambient river quality concentrations) for several water quality indicators. This enhancement makes the planning choices clearer when the QUAL-2E model is used to test discharge alternatives.

CHANNEL GEOMETRY AND SEGMENTATION

The Colorado River is highly regulated and exhibits dramatic changes in channel characteristics in response to releases at Davis Dam. These conditions required that a detailed description of channel characteristics (e.g., depth, width, and cross-sectional area) and their variations with flow and with location in the Mohave Reach be provided in the model.

The U.S. Bureau of Reclamation has developed a calibrated HEC-2 model of the Colorado River system to analyze river discharge routing. The HEC-2 model contains information on river cross-sections and slopes at various stations and computes velocity, top width, and conveyance area of each river section for a constant discharge. At the request of the study team, the Bureau provided HEC-2 output for stations in the Mohave Reach at discharge rates of 5,000, 10,000, 20,000, 30,000, 50,000, and 70,000 cubic feet per second (cfs). (The river operating conditions which correspond to these discharges are described in the next section on hydrologic inputs to the model.) The Bureau considers the HEC-2 model calibrated and reliable for a minimum river discharge of 5,000 cfs. The Bureau also provided plots of station cross sections used in the HEC-2 model; these have been reduced and are included in Attachment C to this report.

To represent the Colorado River in the QUAL-2E model, the HEC-2 data were used to divide the river into reaches, from Davis Dam to the California/Nevada state line, based on the the hydraulic characteristics of the Bureau stations. The characteristics of each station at various discharges and the grouping of the stations into reaches are described in Tables 1 and 2.

Graphic display of these data, such as the plot shown on Figure 3, aided the determination of reach divisions.

A schematic diagram of the representation of the river in the QUAL-2E model is illustrated on Figure 4. The reaches and elements are numbered sequentially beginning upstream. Each element is 0.2 miles in length. The reach boundaries were assumed to be midway between HEC-2 stations. The schematic also shows the locations of inputs and withdrawals represented in the model and the locations of river sampling stations.

The average hydraulic characteristics of the reaches were estimated using the HEC-2 data. In Table 1, the average depth of flow at each river station for a given discharge was computed by dividing the conveyance area by the average station width, which was one-half of the sum of the bottom width and top width. The average depth for the model reach was then computed by averaging the depths of the stations in the reach. Similarly in Table 2, the average velocity of the model reach for a given discharge was computed by averaging the velocities of the stations in the reach.

The average hydraulic characteristics of each reach were incorporated into the model in the form of discharge coefficients which represented the depth and velocity of each reach as a function of discharge. The functional form of this relationship is:

$$X_i = a_i Q^{b_i}$$

where

X_i = depth or velocity
Q = river discharge
a_i, b_i = coefficients specific to each river reach

To determine the coefficients for each reach, the average reach depths and velocities from Tables 1 and 2 were plotted versus discharge on log-log paper and connected with a straight line of best fit. The exponent, b_i, was estimated as the slope of the line and a_i was estimated as its intercept. This analysis is illustrated in Figure 5, using data from the cross section at River Mile 271.2 as an example. Plots for all of the fourteen reaches in the model are provided in Attachment D. In several reaches, the data were best approximated by a line with two distinct slopes; the "break point" of the line represented the point at which the channel geometry changed significantly at higher flows. The break point generally occurred at a discharge of 20,000 - cfs; thus, two sets of coefficients were estimated, one set for discharges less than 20,000 cfs, and one set for discharges greater than or equal to 20,000 cfs. The resulting coefficients are listed in Table 3.

HYDROLOGIC INPUTS

River Discharge at Davis Dam

The Colorado River discharge is almost entirely controlled. In the Lower Colorado River Basin, releases from Davis and Parker Dams are scheduled weekly on a daily basis (and revised daily as necessary) to meet downstream requirements for irrigation and for municipal and industrial water supply. Power generation requirements at the dams control the hourly release patterns during the day, in order to meet an efficient power generating schedule, but do not generally affect the daily release quantity. Power is produced for the U.S. Government and marketed by the Western Area Power Authority through a regional power distribution network. Recreational requirements are also considered, if possible, when hourly releases are scheduled.

The highest river flows typically occur during the summer when irrigation and municipal/industrial supply demands are highest; low flows generally occur during the winter when demands are lowest (unless excess water must be released for flood control). The monthly releases for downstream demands average 17,000 cfs during summer months and 5,000 cfs during winter months. The total flow capacity of the power generating facilities is approximately 24,500 to 26,500 cfs. Flows of up to 70,000 cfs may be released from Davis Dam for flood control, depending on the operation of Lake Mead (an upstream flood control reservoir).

Releases from Davis Dam are the primary driving force in the QUAL-2E model. Historical daily discharge data for the Colorado River below Davis Dam were obtained from the U.S. Geological Survey (gaging station 09423000) for the water years 1965 through 1984. (A "Water Year" extends from October 1 to September 30 in the designated year.) More recent daily and hourly discharge data and release projections were obtained from the Bureau of Reclamation, including hourly discharge data for the dates of the three river surveys conducted as part of this study.

To examine the variability of discharges below Davis Dam, a frequency analysis of mean daily flows was conducted for two years of data. The results of the analysis are presented in Table 4. Water year 1971 represents an average year during the period 1968 through 1982; it had a total annual release volume close to the average of the total annual releases during that period. (Water years 1983 and 1984 were extremely wet years and were not included in the average.) Water year 1978 represents a dry year, as it had the lowest total annual release from Davis Dam during the same period of record.

The frequency analysis showed that during an average water year (1971), four percent (or 14 days) of the average daily flows were below 5,000 cfs. In a very dry year such as 1978, 13 percent (or 47 days) of the average daily flows were below 5,000 cfs. For both years, the percent occurrence of average daily flows greater than or equal to 10,000 cfs was roughly the same.

However, there are significant diurnal fluctuations above and below the daily average on a typical day. Daily fluctuations are illustrated on Figure 6, which shows a hydrograph for releases from Davis Dam during the week of

July 12 - 19, 1987. Two Sundays are shown on the hydrograph to illustrate the variability of release patterns on a given day of the week. Power demands have historically been lower on weekends. However, the increase in weekend activities in the area has recently influenced this release pattern.

Based on discussions with the Bureau of Reclamation, these discharge patterns are not expected to change significantly as a result of future development on the river or the completion of the Central Arizona Project (CAP). Maximum CAP diversion from Lake Havasu will be 3,000 cfs, and the normal and projected long term average diversion is expected to be about 2,100 cfs.

According to the Bureau, reservoir releases are not usually reduced below about 2,000 cfs at lower basin dams in order to maintain a live stream for fish and wildlife. A more typical low flow condition has historically been about 5,000 cfs, which is approximately the flow required to operate one generating unit at Davis Dam. This is considered the minimum monthly discharge based on current downstream demand projections, and is assumed for study purposes to be the minimum operating flow in the future. In addition, 5,000 cfs is also the minimum flow for which the Bureau's HEC-2 model results (and consequently the QUAL-2E model hydraulics) are valid.

Point Discharges and Withdrawals

The only wastewater discharge currently entering the Colorado River between Davis Dam and the state line is the effluent from the River Bend Wastewater Treatment Plant in Bullhead City, Arizona. A second discharge from the Laughlin Wastewater Treatment Plant in Laughlin, Nevada, is being considered. These are the only point loadings which were simulated in the model. The locations of the loadings are shown on Figure 4. The proposed Laughlin discharge was assumed to be located at the Laughlin Bridge for the purposes of this study. Data on effluent discharge quantity and quality for the two plants were obtained from NPDES reports and daily operations reports, as well as from measurements and sample analyses performed as part of the river water quality surveys during this study.

Future development of the Fort Mohave Indian Reservation may also contribute wastewater discharge to this reach; however, no specific data are available on this potential source. There are apparently no significant agricultural return flows entering this reach of the river. Stormwater runoff from developed areas of Laughlin and Bullhead City may also be a potential source of pollutants to the river, but no data are available on the quantity and quality of runoff. Stormwater runoff is not included in the model because its effects on water quality, if any, are expected to be sporadic and short-term.

The Southern California Edison Mohave Generating Station is the major water user in the modeled reach of the river, and is the only withdrawal included in the model. The location of the withdrawal point is shown on Figures 1 and 4. According to records of the Colorado River Commission of Nevada, the average pumping rate for the Generating Station during the period 1981-1986 was 18 cfs. The Mohave Indian Reservation has water rights to divert up to 12,500 acre-feet per year from the Colorado; however, no withdrawals by the Reservation were reported during the period 1981-1986.

The Big Bend Water District derives its water supply from infiltration wells which draw water from the river. The current (1987) average annual withdrawal rate from all wells is approximately 2.3 cfs, with the average rate during peak months of July and August totaling 3.4 cfs. (D. Paulson, written communication, January, 1988.) These withdrawals were considered to be insignificant relative to the total river flows. Leakage from the river and evaporation were also considered to be insignificant hydrologic components in this reach of the river.

In general, historical data indicate that present water use and wastewater discharge quantities are very small relative to the average releases from Davis Dam (less than 0.2 percent of the long term average river flow).

KINETIC INTERACTIONS

The selection of options for modeling various kinetic interactions within QUAL-2E and the appropriate reaction coefficients was based on a review of technical literature, recommendations of the QUAL-2E Users Manual (Brown and Barnwell, 1985) and a companion document on model development (Bowie et al, 1985), and knowledge of this particular river system. A summary of the kinetic methodologies selected for the Colorado River model and the rationale employed in deriving many of the important kinetic coefficients is presented in the following sections.

Dissolved Oxygen and Oxygen Demand

Biological oxygen demand and dissolved oxygen kinetics are modeled by using a carbonaceous BOD_5 decay rate of 0.2 day^{-1} which approximates the results of first stage oxidation observed in laboratory measurements of 1, 3, 5, 7, 10, 15, 20 and 30-day BOD. Because of the high river velocities which generally exceed 1 foot per second (fps) even at low flow conditions (5,000 cfs), no BOD settling has been included in the model. The long term BOD analyses yielded an ultimate to 5-day BOD_5 ratio of 1.6. This result has been included in the model by setting the 5-day to ultimate BOD decay coefficient to 0.19 day^{-1}.

Atmospheric reaeration is simulated using the O'Connor-Dobbins formula for the reaeration coefficient (O'Connor and Dobbins, 1958):

$$K_a \text{ (at 20°C)} = \frac{(D_m\bar{U})^{0.5}}{d^{1.5}}$$

where: $\bar{U}$ = mean channel velocity (ft./day)
d = average channel depth (ft.)
D_m = molecular diffusivity of oxygen (ft^2/day)

Samples of bottom sediments indicated that the channel bottom is composed of sandy materials and stones with small quantities of organic residues and filamentous algae. Thus it was assumed that sediment oxygen demand was negligible in the river system.

<u>Nutrients and Phytoplankton</u>

Phytoplankton dynamics were modeled using a multiplicative equation for light and nutrient limitations to the saturated growth rate.

$$u = u_{max}\ (FL)\ (FN)\ (FP)$$

where: u = local specific growth rate (day^{-1})
u_{max} = saturated phytoplankton growth rate (day^{-1})
FL = light limitation factor for algal growth attenuation
FN,FP = nitrogen and phosphorus limitation factors for algal growth attenuation

This equation determines the local specific growth rate resulting from light and temperature limitations imposed by ambient conditions. A maximum specific growth rate of 3.0 day^{-1} is a reasonable value for mixed algal populations, while accommodating the need for a high growth constant in the toxicant-free environment below Davis Dam. This growth rate is modified for light limitations according to the equation developed by Steel (1956). The formulation reflects the widely-held scientific observation that growth proceeds at a rate which is non-linearly related to light intensity, exhibits a peak rate at an intensity that saturates processes that control photosynthesis, and declines at higher light intensities. The Steele equation is modified within QUAL-2E to reflect other physical laws and technical constraints imposed by modeling the water system as completely mixed in the vertical direction.

First, the model obtains an estimate of the depth-averaged light intensity in the water column by integrating the Beer-Lambert Law for light extinction. Field measurements show that the secchi depth, an estimator of the 10 to 20 percent light depth, is approximately 17 feet or greater in the study area. This value has been converted to a light extinction coefficient using the relationship developed by Beeton (1958):

$$K_e = \frac{1.7}{S.D.}$$

where: K_e = light extinction coefficient (ft^{-1})
S.D. = Secchi Depth (ft.)

The results yield an extinction coefficient of 0.1 ft^{-1}. Using this coefficient, the model computes the depth and light limitation factor using the form given in Reference 2. The saturated light intensity for this calculation was assumed to be 1.02 BTU/ft^2-min, or 200 Langleys/day.

Nutrient limitations are computed in accordance with Monod kinetics, wherein the limitation factors for nitrogen and phosphorus have a value of 0.5 when the ambient available nutrient concentrations are at the Michaelis-Menton half-saturation concentrations. The half-saturation constants have been assigned as 0.025 mg-N/l and 0.01 mg-P/l for nitrogen and phosphorus, respectively, which are within the ranges reported in the literature for mixed phytoplankton populations (Bowie et al, 1985). The phytoplankton preference for ammonia over nitrate nitrogen has been set to 0.5 to reflect preferential ammonia uptake when ammonia concentrations are high.

The phytoplankton endogenous respiration rate is set to 0.1 day^{-1} which is consistent with literature values (Bowie et al, 1985).

Nutrient kinetics permit both the assimilation of inorganic nutrients by phytoplankton and the biologically mediated transformation of organic forms to photosynthetically available nutrients. In particular, the hydrolysis reaction rates for the organic nitrogen and phosphorus conversions to ammonia and ortho-phosphate are 0.03 day^{-1} and 0.05 day^{-1} respectively. The ammonia is then oxidized to nitrite at a rate of 0.15 day^{-1}, and then to nitrate at a rate of 0.50 day^{-1}. These kinetics are consistent with values reported in the literature (Bowie et al, 1985). No organic nutrient settling is included in the model because of the high main channel velocities. Some settling may occur in shallower nearshore areas; however, hand calculations show that losses due to settling will be insignificant in the model results.

It should be noted that phaeophyten organisms were observed in river sediments, but the effects of these organisms on dissolved oxygen and nutrient levels in the river system were not modeled with QUAL-2E.

Coliform Organisms

Fecal coliform densities within the study area are low and do not appear to cause water use impairment. However, the downstream concentration profiles measured during this study were anomolous in that they exhibited minimal decay. The assigned fecal coliform decay rate of 2.0 day^{-1} is a balance between the low observed rate and the fact that high light intensities and cold river temperatures tend to increase fecal coliform die-away.

Chlorine Residual

Total chlorine residuals (including free and combined forms) are toxic to both plant and animal forms and constitute the largest potential hazard to the biology of the study area. This concern is related to both acute toxic effects within the effluent mixing zone, and chronic inhibitory effects downstream. Since it is difficult to model the site specific rate at which chlorine residual and its toxic effects are removed from the river system, it has been analyzed as a conservative substance by setting the chlorine decay rate to 0.0 day^{-1} (i.e., no decay).

TDS, Chloride and Sulfate

Total dissolved solids, chloride, and sulfate concentrations in the river have been analyzed by modeling the impacts from loadings measured at the two wastewater treatment plants during this study. Within the model, each constituent is treated as a conservative parameter (i.e., no decay or transformation of the constituent is modeled).

CONSTITUENT LOADINGS TO THE COLORADO RIVER

Upstream Boundary Conditions

The water quality of the entire Mohave Reach is dominated by upstream boundary conditions (also referred to as headwater loadings), namely the quality of water released from Davis Dam. Typically, releases consist of deep Lake Mohave water discharged through penstocks at the dam; as a result, waters immediately below Davis Dam tend to have lower temperatures, lower dissolved oxygen levels, and slightly higher nutrient concentrations than downstream waters or lake surface waters.

Estimates of present upstream boundary conditions for model verification simulations were based on results of water quality analyses of samples collected below Davis Dam during the river surveys. Where quantities of constituents were below laboratory detection limits, estimates were based on historical STORET and Bureau of Reclamation data at stations below Davis Dam. The upstream boundary conditions in the model have a significant influence on the water quality conditions computed at downstream locations.

Loadings From Wastewater and Other Sources

Wastewater effluents from the River Bend and Laughlin treatment plants were the only sources of constituent loads represented in the model other than the releases from Davis Dam. Concentrations of wastewater effluent constituents were primarily estimated using data collected during the river surveys.

As discussed earlier, there are currently no other known point loads to the Mohave Reach. Non-point source loads, although they could not be quantified, were believed to be infrequent and insignificant relative to the long term average loadings from point sources. River bottom sediments were assumed not to contribute or remove constituents from the river system.

MODEL VERIFICATION

Description of River Surveys

As mentioned earlier, three river surveys were conducted on the Mohave Reach of the Colorado River which provided water quality data for verification of the river quality model. Field measurements and sampling of river water were performed during the periods of February 18-19, June 23, and October 16-17, 1987. Composite samples of wastewater effluent and local climatological data were also obtained during these periods. The field conditions, sample collection methodology, and laboratory analysis results for the surveys are described in a separate report to the District titled "River Discharge Study, Field Survey Data, 1987".

Field measurements and water samples were collected at five stations on the river, as described below:

Station Designation	Location (River Mile)	Description
C1. Davis Dam	275.80	1/4 mile downstream of dam, near boat ramp
C2. Bullhead City	272.35	South of Bullhead City near proposed discharge location
C3. Big Bend	265.78	West end of the river bend downstream of gas pipeline crossing
C4. Fort Mohave	261.30	Just below northern boundary of Mohave Indian Reservation
C5. State Line	257.45	At Nevada/California state line

The location of each station as it is represented in the model is shown on Figures 1 and 4.

At each station, samples were collected near the Nevada side, at midchannel, and near the Arizona side, during three sampling runs within a 24-hour period, and composited for analysis. A summary of the results of the three surveys is presented in Table 5.

Hydrologic Assumptions for Verification Runs

Three verification runs were performed with the river model, and the results of each run were compared with the water quality data collected during each of the three river surveys. The average flow released from Davis Dam during each survey period was assumed as the constant river discharge for each simulation. These discharges were approximately 20,700 cfs during the February survey, 16,600 cfs during the June survey, and 9,900 cfs during the October survey, based on Bureau of Reclamation reports on Davis Dam releases.

The discharge from the River Bend Wastewater Treatment Plant was represented by the average effluent flow rate during each river survey, according to plant operations records. No discharge from the Laughlin Wastewater Treatment Plant was simulated during the model verification runs. Withdrawals from the Mohave Generating Station were assumed to be 18 cfs for all model runs.

Development of Input Data

The input data for the model verification runs are summarized in Table 6. The water quality data obtained at Station C1 (Davis Dam) were used to establish the headwater loadings (upstream boundary conditions) for the verification runs. Loadings from River Bend and climatological data input to the model were taken directly from information collected during the surveys. Values of biological and chemical kinetics coefficients input to the model were the same for all three survey conditions and are listed in Table 7. Many of these were discussed in the previous section on model development.

The methodology for estimating the input data for model parameters which were not measured directly or for which data were missing is described below for each parameter.

Solar Radiation

Solar radiation data were needed for the algal growth and temperature computations in the model. Global radiation measurements were recorded in Las Vegas (Station 23169) during 1977-1980; these records were obtained from the National Climatic Data Center. Global radiation includes direct radiation from the sun, taking into account the angle of incidence of the sun's rays, and diffuse radiation reflected from clouds, dust, etc.

To transfer this information to the project site, the relationship between global radiation trends during a typical year and cloud cover were investigated. Global radiation values (in kilojoules per square meter and in BTU's per square foot) were plotted for the year 1978 on Figure 7, and an envelope constructed to show the variability of the measurements. The lower boundary of the envelope (i.e., minimum radiation values) represents maximum cloud cover conditions, and the upper boundary represents minimum cloud cover (maximum radiation). Cloud cover reports obtained from Bullhead City Airport for each survey period were used to estimate solar radiation for a particular time of year by interpolation of the radiation envelope. The resulting estimates for each survey (in $BTU/ft.^2$, as required by the model) are presented in Table 8.

Phosphates

The model required input data for dissolved ortho-phosphate and organic phosphorus loadings at the Davis Dam headwater. Samples from the river surveys were analyzed for total phosphates and ortho-phosphates, and the difference between the two concentrations in each sample was assumed to represent organic forms of phosphorus.

However, for the February survey, concentrations of both total and dissolved ortho-phosphates were below detection limits in samples from all five sampling stations. (Analyses with lower detection limtis were used in subsequent surveys.) Therefore, concentrations of phosphates in the headwater loading were estimated based on historical data for the river below Davis Dam. A summary of the historical phosphate data is presented in Table 9. Based on these data, the headwater concentrations of dissolved ortho-phosphate and organic phosphate were assumed to be 0.008 and 0.012 mg-P/1, respectively, which represents a total phosphate concentration of 0.020 mg-P/1. The model cannot be verified for phosphates in the February verification run because no downstream concentrations are available for comparison. The historical phosphate concentrations were used to simulate algae growth for the verification period.

In the June and October surveys, total phosphates were present in detectable concentrations, but dissolved ortho-phosphates were not. The input headwater concentrations for organic and dissolved forms were estimated assuming the same ratios of one form to another as that reflected in the historical data.

Nitrogen

In both the June and February surveys, organic nitrogen and nitrite nitrogen were undetected in analyses of samples collected below Davis Dam. It was assumed that, for the verification runs, concentrations of organic nitrogen and nitrite nitrogen in the model would be set equal to half the detection limit if those forms were not detected at the headwater. When these estimates were combined with measured concentrations of ammonia and nitrate nitrogen, the resulting values for total nitrogen concentrations were consistent with historical nitrogen data collected below Davis Dam. This assumption does not significantly impact the model verification results for February and June because the predominant forms of nitrogen measured in the river were ammonia and nitrate nitrogen. In the October river samples, all forms of nitrogen were detected.

Chlorophyll-a

No chlorophyll-a was detected in any of the river samples from the February and June surveys. The detection limits were 10 ug/l for the February analyses and 1 ug/l for June and October analyses. There is little historical data available on chlorophyll-a concentrations below Davis Dam. Recent sampling studies of Davis Dam tailwater by the Bureau of Reclamation (1986-1987) reported the following data:

Date		Chlorophyll-a (mg/m^3)
10-20-86		3.04
12-1-86		1.71
1-5-87		1.55
2-9-87		1.05
3-16-87		1.14
	Average	1.70

Minckley (1979) observed concentrations of 2.77 mg/m^3 (ug/l) below Davis Dam during "autumn to winter", 1975. Based on these data, chlorophyll-a concentrations at the headwater in the model were assumed to be equal to 1.0 ug/l for the February verification run and 2.0 ug/l for the June and October verification runs.

Initial conditions in the model reaches, including initial temperatures and concentrations of modeled constituents, were set based on the data collected at each sampling station (and on historical data when survey data were not available). These conditions serve only as an efficient starting point for the model computations, which proceed toward a steady state solution, and have no effect on the final model output.

Results of Verification Runs

The results of the verification runs for February, June and October are presented graphically in Figures 8, 9 and 10, respectively. The plots for each water quality characteristic display the discrete survey data and the model results for each river reach element. In most cases where survey data are not plotted, the concentration of a constituent was below detection limits at that location. Output data from the model verification runs, upon which Figures 8 through 10 are based, are provide in detail in Attachment E.

The model results indicate that only minor changes from the upstream boundary condition occur for many of the water quality parameters. Total dissolved solids, chlorides, sodium and chlorophyll-a concentrations calculated by the model show essentially no variation along the reach. Temperature remains constant for the February run, but increases by about 3 percent through the reach for the June and October runs.

Among the nutrient species, all three seasonal runs indicate little changes in the parameters along this reach. The February run indicated some reduction in ammonia, with corresponding increases in nitrite and nitrate. The phosphorus species exhibited very little change. The model results for nutrients calibrated reasonably well with the survey results, given the low levels and variability of the river data.

During the February verification run, the dissolved oxygen level along the reach decreased from 10.4 to 10.34 mg/l, as upstream boundary conditions were above saturated levels. Conversely, during the June and October runs, the dissolved oxygen level increased along the reach, from 8.46 to 8.54 mg/l in June and from 7.3 to 7.86 mg/l in October. The model results for dissolved oxygen correlated well with survey data along the reach.

The fecal coliform counts calculated by the model along the reach decreased for all three runs. However, the survey data seemed to indicate some aftergrowth occurring in June and October, which could not be matched with simulated results.

The model results for 5-day biological oxygen demand indicated decreases along the reach. The values decreased from 1.5 to 1.43 mg/l in February, from 1.5

to 1.4 mg/l in June, and from 2.0 to 1.84 in October. The survey values showed more variability around the model results for BOD_5 than for other parameters.

Final Model Coefficients

Field data collected during this study were used to obtain final verification of the QUAL-2E model coefficients. The river system's physio-chemical characteristics were found to be dominated by boundary conditions imposed by the Davis Dam release rather than by kinetic interaction occurring within the water column. In particular, the combination of high river discharge rates and short travel times through the modeled reach (about 7 hours at 5,000 cfs) permitted relatively little reaction to occur, and most water quality indicators showed little longitudinal variation. This impeded efforts to "fine tune" the model kinetics through comparison of verification runs with field observations. Therefore, model coefficients were selected largely on the basis of laboratory tests, literature values, and professional judgement in modeling similar river systems.

The model can be considered verified for the Colorado River Mohave Reach in that the kinetic processes and coefficients selected for the verification runs produced model results which were in reasonable agreement with the prototype water quality conditions. In the judgement of the study team, none of the kinetic coefficients or options presented in Table 7 needed to be changed to achieve a closer representation of the Colorado River system as a result of the verification procedure. These kinetics were assumed to be a valid description of the river system upon which to base projections of water quality under different future discharge scenarios.

MODEL PROJECTIONS

Following verification of the Colorado River model for these seasonal water quality conditions, a series of projection runs were made incorporating the proposed discharge from the Laughlin Wastewater Treatment Plant and a set of realistic future conditions for the river. These projections were designed to quantify the impacts of a point discharge at Laughlin on existing water quality in the river and to evaluate whether existing ambient water quality standards will be violated under alternative treatment and discharge scenarios. This section describes the projection conditions and assumptions, the projection run results, and the sources of variability in the projections.

Basis for Projections

In order to provide a basis for comparison of water quality impacts from alternative treatment and discharge situations, a projection "baseline case" was formulated describing estimated future river conditions without any additional discharges; i.e., the no-project alternative. The baseline case represents the river at low flows (5,000 cfs) during late summer/early fall, when environmental conditions encourage chemical reactions and biological growth and dilutions are lowest. Effluent discharge was simulated from the

River Bend Treatment Plant, which was assumed to be operating at capacity (0.16 MGD), but no discharge from the Laughlin plant was included in the baseline case. From discussions with various agencies involved in management of the river, there are no major additional point loads or withdrawals anticipated in the Mohave Reach of the Colorado in the near future, nor are river operations expected to change significantly.

The water quality characteristics of the Davis Dam headwaters and the effluent from River Bend were based on the data collected during the October river survey, after verifying that the data were consistent with historical records for that season. These characteristics were assumed to represent reasonable estimates of future water quality conditions during the late summer/early fall season. The input data used in the baseline case run are listed in Table 10. The data used to represent headwater loadings in the baseline case were collected at Station C1, which is approximately 0.1 miles downstream of Davis Dam.

On the basis of previous preliminary analyses, it was expected that any negative water quality impacts from wastewater discharges to the Colorado River would be primarily related to total phosphorus loading and total chlorine residual. Therefore, the projection runs focused on simulation of treatment and discharge alternatives which addressed these two constituents. The formulation of the projection runs involved the following assumptions.

1. The total phosphorus concentration at the headwater (i.e., background condition in the river) for the baseline case and the projection runs was assumed to be 0.02 mg-P/l, which is equal to the Nevada annual average standard for phosphorus. The historical average of total phosphorus concentrations measured below Davis Dam is 0.018 mg-P/l; therefore, this represents a conservative estimate which allows for slightly higher background concentrations in the future. The estimated total phosphorus concentration was divided into organic phosphorus and ortho-phosphate concentrations based on historical ratios of these forms to total phosphorus.

2. The total phosphorus concentration in the Laughlin effluent was assumed to be 6.0 mg-P/l (all in the form of ortho-phosphate), based on recent measurements during the river surveys. It was assumed that with the addition of a phosphorus removal process at the plant, the total phosphorus concentration in the effluent could be reliably reduced to 0.5 mg-P/l.

3. The total phosphorus concentration in the River Bend effluent was measured at 5.3 mg-P/l in October; this value was used in the baseline case and the projection runs. No phosphorus removal was simulated at River Bend.

4. The concentration of chlorine in the river at the headwater was assumed to be 0.0 mg/l. This characteristic was not measured during the river surveys and no historical data exist on chlorine in the

river below Davis Dam; however, there are no known sources of chlorine near the dam.

5. The Laughlin treatment plant effluent is currently not chlorinated because it is disposed of through land application. It is expected that chlorination will be required at the plant to meet fecal coliform standards if a river discharge is allowed. A typical level of chlorine residual maintained in wastewater treatment plant effluent is 3.0 mg/l. Therefore, it was assumed that the Laughlin effluent would contain 3.0 mg/l of total residual chlorine and, furthermore, that this level could be reduced to 0.1 mg/l through a dechlorination process at the plant if necessary.

6. The River Bend treatment plant does chlorinate its effluent. Operations records during the period 1978 through 1986 indicated that a typical peak chlorine residual in the effluent was 3.0 mg/l. Therefore, this value was assumed for the total chlorine concentration in the River Bend discharge in the model, and that no dechlorination would occur.

7. Future flows at the Laughlin Wastewater Treatment Plant are expected to range from 1.0 to 7.0 MGD. The projection runs simulated the maximum flow from Laughlin, 7.0 MGD, so that the maximum impacts on river water quality could be observed.

Based on these assumptions, the following projection run conditions were formulated:

Projection 1: Maximum discharge from Laughlin (7.0 MGD) and River Bend (0.16 MGD) treatment plants, with no treatment for phosphorus removal or dechlorination.

Projection 2: Maximum discharge from the Laughlin and River Bend treatment plants, with both phosphorus removal and dechlorination processes at Laughlin.

Projection 3: Maximum discharge from Laughlin and discharge of 0.6 MGD from River Bend, with both phosphorus removal and dechlorination at Laughlin.

The purpose of the scenario in Projection 3 was to simulate equal phosphorus loadings from Nevada and Arizona to determine if these loadings would exceed the assimulative capacity of the river. Under these conditions, the discharge from Laughlin would utilize half of the river capacity.

The changes made to the input data for the baseline case to represent each of the three projections are shown in Table 10. A summary of the assumed values for effluent discharge, total phosphorus, and chlorine residual for the base case and projection runs is presented below:

Treatment Plant Effluent Characteristics

	Discharge, mgd		Total Phosphorus, mg-P/l		Chlorine Residual, mg/l	
Run	Laughlin	River Bend	Laughlin	River Bend	Laughlin	River Bend
Baseline	0	.16	0	5.3	0	3
1	7	.16	6	5.3	3	3
2	7	.16	.5	5.3	.1	3
3	7	.6	.5	5.3	.1	3

Results of Projections

Complete listings of the results of the model runs for the baseline case and all projection conditions are provided in Attachment F. The results of the model runs for the baseline case and Projection 1, for the model element which receives the Laughlin discharge, are summarized in Table 11, along with river water quality standards where applicable. The standards listed represent the average annual values and single values specified in the Nevada NAC 445.13495. These standards are equal to or more stringent than the Arizona Standards (R9-21-101 to 304) for the same characteristics.

The results in Table 11 indicate that most water quality characteristics in the river are not significantly impacted by the maximum expected discharge (7.0 MGD) from the Laughlin plant. This is due to the tremendous dilution provided by the river, even at low flows (approximately 460:1 at a river flow of 5,000 cfs). For all characteristics except phosphorus, increases resulting from the effluent discharge do not cause applicable standards to be exceeded downstream. As mentioned earlier, the QUAL-2E model results are computed based on the assumption that the discharge is completely mixed within the river element. Estimated dilutions in the mixing zone of the discharge and the length of the mixing zone for different discharge conditions are discussed later in this report.

The largest estimated increases in concentrations of river characteristics resulting from the effluent discharge were observed for the nitrogen and phosphorus forms. Nitrate concentrations in the river increased by 0.045 mg-N/l (about 19 percent), although levels were still below the annual average nitrate standards. Total phosphorus concentrations in the river increased by 0.0129 mg-P/l (64 percent), causing both the average annual and single value standards to be exceeded. Chlorine residual levels in the river rose to 6.5 ug/l; although there is no specific Nevada standard for chlorine residual, these results must be evaluated with respect to acute and chronic toxicity levels established to protect aquatic life.

Because of specific concerns raised regarding the potential impacts of phosphorus and chlorine loadings from the Laughlin discharge, Projection Runs 2 and 3 were made to calculate impacts of two additional loading conditions for these characteristics. The results of model runs for the baseline case and all three projections for total phosphorus and total chlorine residual at three locations in the river are summarized in Table 12. Results are also displayed graphically for the entire reach on Figures 11 and 12, for total phosphorus and total chlorine residual, respectively. Again, the values shown for phosphorus and chlorine reflect the concentrations downstream of the mixing zone, i.e., a completely mixed condition.

The results clearly indicate the effects of loadings from each of the treatment plants on concentrations of phosphorus and chlorine in the river, and the reduced effects following phosphorus and chlorine removal from the Laughlin discharge. Phosphorus concentrations downstream of the Laughlin discharge decrease from 0.0329 mg-P/l in Projection 1 to 0.0210 mg-P/l in Projection 2, when total phosphorus in the effluent is reduced to 0.5 mg-P/l. This concentration in the river is only 0.001 mg-P/l above background phosphorus levels, which is approximately equal to the detection limit for phosphorus, and would be difficult to measure with certainty. Given that historical background phosphorus levels average 0.018 mg-P/l, a 0.001 mg-P/l increase would be acceptable under the Nevada standard of 0.02 mg/l for total phosphorus. In Projection 3, with equal phosphorus loadings from both plants, the total phosphorus concentration in the river reaches 0.0219 mg-P/l.

As a result of dechlorination at the Laughlin plant (Projection 2), the total chlorine residual in the river downstream of the discharge is reduced from 0.0065 mg/l to 0.0020 mg/l. This reduction is illustrated clearly on Figure 12. Chlorine loadings from River Bend increase this concentration to 0.0040 mg/l. The critical impacts of chlorine loading, however, are those which may occur in the mixing zone of the discharge where local concentrations of chlorine are much higher and associated toxic effects more severe. These impacts will be evaluated later in this report.

Another potentially toxic substance in wastewater treatment plant effluents is un-ionized ammonia. Model results for ammonia nitrogen indicate baseline concentrations of 0.04 mg-N/l in the river downstream of the proposed discharge (which increase to 0.0405 mg-N/l under Projection 1 with 0.26 mg-N/l ammonia in the proposed discharge). Un-ionized ammonia concentrations in the river were estimated using a method described by Emerson, et al (1975), and conservatively assuming ambient pH and temperature conditions within the Mohave Reach to be 8.5 and 20°C, respectively. With these assumptions, the un-ionized fraction of the ammonia concentration in the river was estimated to be 11.2 percent, resulting in a downstream concentration of un-ionized ammonia of 0.0045 mg-N/l. The un-ionized fraction in the Laughlin effluent, assuming a pH of 7.5 and a temperature of 25°C, is estimated to be 1.8 percent or .0047 mg-N/l, which becomes insignificant when diluted by the river. These concentrations do not pose either an acute toxicity threat or a chronic bioinhibitory effect in the Mohave Reach of the Colorado River.

Sources of Variability

The QUAL-2E model is a steady state simulator of average daily water quality conditions resulting from hydrologic and wastewater loading conditions imposed by planning alternatives. As such the model provides realistic estimates of average daily water quality conditions. However, several State water quality standards for the Colorado River, such as those for dissolved oxygen and total phosphorus, also contain extreme value limits that are not to be violated in any single measurement. Ensuring compliance with standards of this type requires quantitative knowledge of the frequency and magnitude of random variability that occur in measurements of these variables within the study area.

There are many factors that affect the variation about an average value. These factors include both natural and human-induced phenomena, such as local scale anomalies in water quality and diurnal fluctuations in constituents such as temperature and dissolved oxygen due to solar radiation, dam operations, and wastewater treatment plant load variability. A third source of variability is introduced by measurement error. Observed variability may also be affected by long-term trends in water quality parameters and cyclic seasonal variation.

In aggregate these sources of variability contribute to extreme measurements which may cause apparent violations of single value standards. If these sources of variability can be described in a quantitative manner, this knowledge, tempered by professional judgement, can be used to test future compliance with the standards. This task requires a data base of reliable historical measurements. It also requires good estimates of the probability distribution for extreme values, and techniques for relating these extremes to the average values computed by the QUAL-2E model.

The initial step in analyzing variability issues in the Mohave Reach of the Colorado River was to determine the degree to which historical variability was truly random. To do this, the historical data for various water quality characteristcs were compared to known probability distributions for random events. These included the normal (Gaussian) distribution and the log normal distribution.

First, the available historical records for several water quality parameters were examined to determine the adequacy of the assumption that the data are normally distributed about a mean value. Records from the STORET Data Files from 1967 to 1981, supplemented by river survey data, were ranked in ascending order. The ranked data were plotted on normal probability paper by calculating the percentage of data less than or equal to the value in question. If the data fit a normal distribution, the plot should be approximately linear. Parameters that exhibited a curvilinear plot were log-transformed and replotted to see if the data fit a lognormal distribution. From these plots, the sample mean and standard deviations were estimated. The plots are included as Attachment G and a summary of the estimated statistics is given in Table 13.

The plots indicate that the data for most of the water quality constituents are approximately normally distributed, except for chlorides and fecal coliform which appear to be log normally distributed. Thus it can be said that the variability in the data is randomly distributed. In addition, there appears to be no appreciable skewness in the distributions that would tend to overestimate the probability of observing extremely high values. It is acceptable, then, to apply standard measures of variability to the QUAL-2E model results to estimate the probability of violating single value quality standards.

Table 14 summarizes the adjustments that can be superimposed on the QUAL-2E average concentrations to compute extreme values for a given probability of exceedance. As an example, if it is necessary to estimate the probability of exceeding the Nevada total phosphorus single-value standard of 0.03 mg-P/l, and the model results indicate an average downstream concentration of 0.014 mg-P/l, the probability of exceedance would equal 5 percent (0.030 - 0.014 = 0.016; the 0.016 adjustment corresponds to a 5 percent probability of exceeding the standard).

COMPARISON OF ALTERNATIVES

Treatment Criteria

Water quality modeling analyses of wastewater discharge alternatives for the Laughlin Wastewater Treatment Plant indicate that phosphorus removal and dechlorination are required treatment processes to achieve ambient water quality standards.

Other standards for dissolved oxygen, temperature, pH, nitrogen, suspended solids, turbidity, and fecal coliform are satisfied with existing treatment processes for discharge rates up to 7.0 mgd.

The criteria upon which this evaluation of additional treatment requirements has been made include the following:

Water Quality Characteristic	Requirements for Existing Higher Quality in the Colorado River
Total Phosphorus	Annual average : <0.02 mg-P/l Single value : <0.03 mg-P/l
Total Chlorine Residual	Mixing zone concentration : 0.038 mg/l Downstream concentration : 0.011 mg/l

The criteria for total phosphorus are those required by NAC (445.13495) to maintain existing higher quality, while the total chlorine residual concentration limits are EPA's national water quality criteria (EPA, 1980). The states of Arizona and Nevada require that mixing zone concentrations of total chlorine residual not exceed the LC50 concentration for the most sensitive species (0.038 mg/l) and that downstream concentrations not exceed the chronic bioinhibitory effect concentration (0.011 mg/l). In addition, the Nevada requirements specify that the mixing zone boundary be established such that it occupies no more than one third of the river cross section and maximizes the zone of passage dimensions.

The following sections describe the rationale employed in estimating treatment requirements for total phosphorus and chlorine at the Laughlin Wastewater Treatment Plant.

Treatment Requirements for Total Phosphorus

The total phosphorus concentrations below Davis Dam have an historical average of 0.018 mg-P/l which is just slightly below the average annual standard of 0.02 mg-P/l. However, the single value standard, 0.03 mg-P/l, has been exceeded on at least two occasions when total phosphorus concentrations were measured at 0.04 mg-P/l (as reported in the STORET data base).

The water quality projection base case utilizes a total phosphorus concentration of 0.02 mg-P/l at Davis Dam to simulate a conservative situation which allows for slightly higher background concentrations in the future. This approach is reasonable even for low flow projections since our analysis of historical data indicates that there is no correlation between total phosphorus concentrations and Davis Dam releases.

The modeling analyses of alternative treatment and discharge conditions at low flows result in average and extreme concentrations of total phosphorus in the river as follows:

	Total Phosphorus Concentrations, mg-P/l (River Flow = 5,000 cfs)		
	Downstream Average	Percentile Extremes 85%	95%
Baseline Case - Existing Loads	0.020	0.030	0.036
No phosphorus removal at Laughlin (7 MGD)	0.033	0.043	0.049
Phosphorus removal at Laughlin (7 MGD)	0.021	0.031	0.037
Phosphorus removal at Laughlin and equal phosphorus load from River Bend	0.022	0.032	0.038

The results of the analysis of the baseline case indicate that, for river flows of 5,000 cfs and no Laughlin discharge, approximately 85 percent of the measurements of total phosphorus are expected to be at or below 0.03 mg-P/l. In other words, the 0.03 mg-P/l single value standard for "existing" higher quality corresponds to the 85th percentile value in the the historical data base. This is a reasonable interpretation of the standard since there is a finite probability of obtaining measurements of 0.04 or 0.05 mg-P/l due to random occurrences.

The modeling results indicate that effluent discharge from Laughlin with no treatment for phosphorus removal could produce extreme (85 percentile) concentrations of 0.043 mg-P/l in the river at 5,000 cfs, which violates the single value objective. In addition, the average phosphorus concentration under these conditions is above the annual average standard by 0.013 mg-P/l. By contrast, phosphorus removal at Laughlin to 0.5 mg-P/l yields downstream average and extreme value concentrations which are only 0.001 mg-P/l above the concentrations for the baseline case for an effluent discharge rate of 7.0 MGD and river flows of 5,000 cfs. This average is small, and certainly within the uncertainty allowance provided by using a 0.02 mg-P/l headwater concentration at Davis Dam. If the Laughlin effluent discharge rate is limited to 4.0 MGD rather than 7.0 MGD under the same conditions, the downstream total phosphorus concentration is equivalent (within analytical limits) to the base case condition. If necessary, future expansions at the Laughlin plant could utilize more restrictive effluent total phosphorus objectives, such as 0.2 mg-P/l, to attain best practical treatment (BPT) loadings. This level of phosphorus removal has proven to be achievable.

A summary of the estimated impact of the proposed Laughlin discharge on phosphorus concentrations in the Colorado River is presented on Figure 13. The plot illustrates the increase in total phosphorus concentration in the river projected to result from different effluent discharge rates as a function of river flow. The shaded area of the plot represents the range of expected allowable increases in phosphorus, based on the historical range in background river concentrations of 0.016 - 0.020 mg-P/l and the Nevada annual average standard for total phosphorus of 0.020 mg-P/l. Figure 13 clearly illustrates the conditions under which effluent discharges cause allowable increases in phosphorus in the river, and the fact that a 7 MGD discharge with phosphorus removal to 0.5 mg-P/l is well within the acceptable limits even for low river flows.

Another way of viewing these results is to consider the impacts of a discharge on the total phosphorus loading to downstream reservoirs and water users. Assuming an average annual river flow of 11,400 cfs, the existing total phosphorus load is computed to be approximately 1,233 pounds/day (on an average annual basis) with no Laughlin discharge; 1,583 pounds/day with an untreated 7.0 MGD Laughlin discharge; and 1,262 pounds/day with a 7.0 MGD Laughlin discharge and phosphorus removal to 0.5 mg-P/l. Thus, a 7.0 MGD discharge at Laughlin would produce a 350 pound/day (28 percent) increase in downstream total phosphorus load without phosphorus removal, but only a 29 pound/day (2 percent) increase in downstream total phosphorus load if phosphorus removal is implemented. A 4.0 MGD discharge at Laughlin with phosphorous removal would produce correspondingly lower loading increases to downstream users (approximately 1 percent or 17 pound/day increase over existing conditions).

Treatment Requirements for Total Chlorine Residual

Modeling analyses of total chlorine residual concentrations show that without dechlorination, instream concentrations will exceed acute toxicity requirements within a mixing zone of acceptable dimensions for a broad range of mixing zone dilutions, and approach but not exceed chronic bioinhibitory limits in the downstream region. These results are summarized as follows:

	Total Chlorine Residual (mg/l)			
	Effluent Concentration	Initial Dilution	Mixing Zone Concentration	Downstream Concentration (below River Bend)
Baseline Case - Existing Loads		--	--	0.0002
No Dechlorination at Laughlin (7 MGD)	3.0	10:1	0.30	0.0065
		20:1	0.15	
		50:1	0.062	
		79:1	0.038	
Dechlorination at Laughlin (7 MGD)	0.1	2.6:1	0.038	0.0004
		10:1	0.010	
		20:1	0.005	
		50:1	0.002	
EPA Criteria			0.038	0.011

Thus, at river flows of 5,000 cfs, mixing zone chlorine concentrations exceed the 0.038 mg/l acute toxicity limit for initial dilutions less than 79:1 if dechlorination is not implemented; however, downstream (completely mixed) concentrations do not exceed the 0.011 mg/l chronic toxicity threshhold. Therefore, the primary concern with potential effects of chlorine residual is in the mixing zone.

The calculated receiving water concentrations based on a 0.1 mg/l effluent chlorine residual following dechlorination indicate compliance with both acute and chronic toxicity criteria, provided that initial dilutions exceed 3:1. It is likely that initial dilutions of the proposed discharge will exceed this requirement. Although Nevada does not have specific requirements for either chlorine toxicity or effluent chlorine residuals, the analysis presented here shows that effluent dechlorination is desirable, but not necessarily a prerequisite for the safe operation of the proposed discharge for discharge rates between 1.0 and 7.0 MGD, as long as high initial mixing through an engineered diffuser structure can be achieved.

In order to refine these results into mixing zone requirements, the mixing zone model was used to further define dilution estimates in the region immediately downstream of alternative diffuser configurations.

Mixing Zone Analysis for Total Chlorine Residual

Sections 445.187 to 445.194 of the Nevada Administrative Code establish requirements to ensure a zone of mixing in any stream. The application for the mixing zone must be submitted with the application for the discharge permit and must demonstrate that "no violation of water quality standards occurs at any point designated by the director and no appreciable harm to beneficial uses, either designated or actual, will result from the proposed zone of mixing..." (NAC 445.188). The zone of mixing is established on a case-by-case basis. A "zone of passage" outside the mixing zone must be provided but no specific dimensions are set (NAC 445.191).

The mixing zone model described in Attachment B was used to estimate the size of the mixing zone for the Laughlin discharge, and also the wastewater dilutions within that mixing zone. Five diffuser design alternatives were analyzed:

1. Four individual discharge ports, one on each side of the two westerly piers of the Laughlin Bridge;

2. Four 20-foot long diffuser sections replacing the ports in Alternative 1 and running parallel to the river flow:

3. An 80-foot long diffuser in the center of the main river channel (on the Nevada side), running perpendicular to the river flow.

4. A 120-foot long diffuser in the same orientation as Alternative 3.

5. A 240-foot long diffuser in the same orientation as Alternative 3.

Results of this analysis for the alternative discharge configurations are summarized as follows:

Mixing Zone Dilutions for Laughlin Diffuser Alternatives
(Davis Dam Discharge = 5,000 cfs)

Alt. No.	Diffuser Configuration	Dilution	Downstream Distance (ft)	Total Chlorine Residual(mg/l) With Dechlorination	Without Dechlorination
1	4 ports (2/pier)	26:1	200	0.0038	0.1154
		84:1	2,000	0.0012	0.0357
2	4 20-ft diffuser sections parallel to flow	19:1	~50	0.0053	0.1579
		30:1	200	0.0033	0.1000
		84:1	~2,200	0.0012	0.0357
3	80-ft diffuser perpendicular to flow	77:1	50	0.0013	0.0390
		>120:1	200	<0.0008	<0.0250
4	120-ft diffuser perpendicular to flow	97:1	50	0.0010	0.0309
		>160:1	200	<0.0006	<0.0188
5	240-ft diffuser perpendicular to flow	175:1	50	0.0006	0.0171
		>280:1	200	<0.0004	<0.0107

These results demonstrate that, with dechlorination, total chlorine residual concentrations will be less than the EPA acute toxic limit within 200 feet downstream of the discharge for all five diffuser alternatives at flows of 5,000 cfs or greater. In fact, with dechlorination, initial mixing is adequate to satisfy mixing zone requirements. However, without dechlorination, the water quality objectives are satisfied within 200 feet of the diffuser only for diffuser alternatives 3 through 5. Thus, for the 5,000 cfs discharge condition and no dechlorination, the mixing zone length is estimated to be about 2,000 feet for diffuser alternatives 1 and 2; and about 50 to 200 feet for diffuser alternatives 3, 4, and 5.

The mixing zone created by Alternatives 1 through 4 will occupy less than one quarter of the river flow width (which is approximately 500 feet near the Laughlin Bridge), leaving more than three quarters of the flow width as a zone of passage for aquatic life. The mixing zone created by Alternative 5 will occupy almost half of the flow width, but achieves much greater initial dilutions in the mixing zone, resulting in a shorter mixing zone length.

Recognizing that over a 24-hour period river flows may drop below 5,000 cfs, a second analysis of mixing zone dilutions was completed for the minimum anticipated hourly flow of 2,000 cfs. The results are summarized as follows:

Mixing Zone Dilutions for Laughlin Diffuser Alternatives
(Davis Dam Discharge = 2,000 cfs)

				Total Chlorine Residual	
Alt. No.	Diffuser Configuration	Dilution	Downstream Distance (ft)	With Dechlorination	Without Dechlorination
1.	4 ports (2/pier)	19:1	200	0.0053	0.1579
2.	4 20-ft diffuser sections parallel to flow	13:1	0	0.0076	0.2308
		18:1	200	0.0056	0.1667
3.	80-ft diffuser perpendicular to flow	52:1	200	0.0019	0.0577
4.	120-ft diffuser perpendicular to flow	78:1	200	0.0013	0.0385
5.	240-ft diffuser perpendicular to flow	157:1	200	0.0006	0.0191

Again, for the case of dechlorinated effluent, the results show compliance within 200 feet of the diffuser with mixing zone requirements (0.038 mg/l) for all five alternatives with dechlorination. Without dechlorination, downstream concentrations during a river flow of 2,000 cfs are approximately double those computed for river flows of 5,000 cfs. However, should dechlorination facilities be inoperative, maximum total chlorine residual concentrations at the downstream end of the mixing zone will be less than four times the acute toxicity limit for the short periods of time when river flows drop to 2,000 cfs.

From this analysis, it appears that to satisfy mixing zone requirements for total chlorine residual, the treatment process should include dechlorination to a level of about 0.1 mg/l total residual. Also, the District should obtain permits for a mixing zone extending at least 200 feet downstream of the diffuser structure and 50 feet wider than the maximum horizontal dimension of the selected structure.

Another possibility that can relieve the chlorine residual toxicity concern at low flows is to either pond the effluent and not discharge during low flows or dechlorinate to a zero chlorione residual, as is practiced by many dischargers by utilizing an excess of dechlorination chemicals.

Preliminary Criteria for Diffuser Structure

The following criteria were used in the development of the five alternative diffuser configurations discussed in the previous section and in Attachment B. In order to accommodate mixing zone requirements and other operational considerations, these criteria are recommended as guidelines for design of the Laughlin outfall and diffuser:

1.	Outfall velocity at minimum hourly flow:	0.5 fps
2.	Outfall velocity at maximum 10-minute flow:	10.0 fps
3.	Port velocity for diffuser parallel to river flow:	25.0 fps
4.	Port velocity for diffuser perpendicular to river flow:	15.0 fps
5.	Height of diffuser above river bottom:	2.0 feet
6.	Uniform flow distribution from ports	
7.	Anchorage to withstand flood discharges at Davis Dam	

QUAL-2E MODEL SENSITIVITY ANALYSIS

The QUAL-2E model results form the technical basis for several wastewater planning decisions at the Laughlin Wastewater Treatment Plant. As such it is important to know how the decision making process is influenced by inaccuracies in model coefficients which could alter water quality projections. Thus, a model sensitivity analysis was conducted to test a wide range of model coefficients which influence the key decision making variables, such as total phosphorus concentration, total chlorine residual concentration, treatment plant discharge rate, and Davis Dam discharge. Selected coefficients were varied within a reasonable range to examine the effects of the variations on computed concentrations of water quality characteristics of the river.

The results of this analysis are displayed in Table 15. In aggregate these results show that the model results are relatively insensitive to most model coefficients; the primary factor effecting downstream concentration is the headwater loading at Davis Dam. The only significant factors adversely effecting downstream total phosphorus concentration are the saturated growth rate and the phosphorus half saturation coefficient. Changing the saturated growth rate to 1.0 day^{-1} and the phosphorus half saturation coefficient to 0.05 mg-P/l increases the total phosphorus concentration downstream of River Bend to 0.0212 and 0.0213 mg-P/l, respectively, from the 0.0209 mg-P/l concentration computed for the recommended treatment alternative. However, within the accuracy limits of total phosphorus laboratory determinations, the estimated downstream concentration is still approximately 0.021 mg-P/l.

A 50 percent increase or decrease in chlorine residual in the Laughlin treatment plant effluent results in a downstream concentration change of less than half a part per billion. This implies that the downstream concentrations are still less than half of the chronic bioinhibitory limit of 0.011 mg/l for effluent concentrations as high as 0.15 mg/l.

This analysis lends credibility to the model's ability to provide reasonable evaluations of alternative treatment scenarios at Laughlin.

SUMMARY AND CONCLUSIONS

Water quality modeling studies of Clark County Sanitation District's proposed discharge of treated wastewater effluent from the Laughlin, Nevada facility to the lower Colorado River have demonstrated that State and Federal regulatory requirements for river quality can be satisfied. In particular, the studies demonstrate that existing water quality is generally within limits imposed by Nevada and Arizona, and the proposed discharge at Laughlin, with additional treatment requirements, will maintain existing good water quality for discharges up to 7 MGD. Adequate assimilative capacity reserves exist to permit an equivalent wastewater loading from Arizona without measurably affecting compliance with water quality objectives.

The specifics of these broad conclusions are summarized as follows:

1. Three comprehensive water quality monitoring surveys of the Mohave Reach of the Lower Colorado River found the existing water quality conditions to be within regulatory limits established by the States of Nevada and Arizona. This water quality was verified by a detailed technical review of historical river quality data. Based on this work, it appears that the total phosphorus limitation is the only parameter that influences effluent quality from the Laughlin Wastewater Treatment Plant.

2. A comprehensive steady state QUAL-2E river quality model of the Colorado River between Davis Dam and the state line was developed for analyzing a broad range of water quality issues. The model was verified against data from three water quality monitoring surveys and found to be a satisfactory planning tool for addressing planning questions related to phytoplankton productivity, nutrient concentrations, sanitary water quality, and toxicity dilution. Sensitivity testing of the model shows that its response is dominated by headwater loadings at Davis Dam. Advective transport and dilution had more effect on water quality in the model simulation than biological or chemical processes, due to high river velocities and therefore short travel times within the main channel of the reach. The model

showed no significant increase in biological activity in the reach resulting from the proposed discharge, and dissolved oxygen levels generally remained close to saturation levels during all conditions evaluated by the model. Short travel times and low levels of pollutant discharges tend to minimize wastewater impacts within this study area.

3. The model was employed to develop estimates of future "baseline case" water quality conditions without a discharge at Laughlin and full capacity utilization at the River Bend treatment plant. Warm water, low flow conditions indicative of late summer/early fall were chosen as the critical case for this analysis. The model results show compliance with all applicable regulatory requirements for the future baseline condition. Total phosphorus concentrations were conservatively estimated to be 0.02 mg-P/l, on the basis of a review of historical phosphorus data for the Davis Dam headwater and allowance for some increase in background phosphorus levels in the future.

4. Modeling analyses of alternative discharge scenarios for the Laughlin Wastewater Treatment Plant were then imposed on this baseline condition to test compliance with water quality standards. The results indicated that if the Laughlin plant discharges 7 MGD of secondary treated effluent during river flows of 5,000 cfs, the limiting water quality characteristic is total phosphorus; this discharge is estimated to increase river concentrations of total phosphorus to 0.033 mg-P/l, 0.013 mg-P/l above the average annual concentration limit of 0.02 mg-P/l. In addition, the expected single sample value for this condition (estimated to be the 85th percentile exceedence level) is 0.043 mg-P/l, which is above the single value standard of 0.03 mg-P/l.

5. By imposing an effluent phosphorus limitation of 0.5 mg-P/l on the Laughlin discharge, the average downstream concentration for a 5,000 cfs release at Davis Dam is 0.021 mg-P/l, which is within the 0.02 mg-P/l requirement. The single sample value for this case is 0.031 mg-P/l, again within the regulatory requirement. At average annual flows, the expected average daily concentrations of total phosphorus are expected to be below 0.021 mg-P/l.

6. Allowances for future assimilative capacity utilization by the State of Arizona were analyzed by imposing a loading equivalent to that from Laughlin at the River Bend treatment plant. The results indicate continued compliance with both the average annual and single value total phosphorus limits, with downstream concentration estimates of 0.022 and 0.032 mg-P/l, respectively.

7. Total chlorine residual concentrations were evaluated for potential acute and chronic bioinhibitory impacts using both the QUAL-2E model and a special mixing zone model developed for this purpose. The results show that, without dechlorination facilities, downstream concentrations exceeded the acute toxicity limit within a mixing zone that is between 50 feet and 2,000 feet in length, depending upon the diffuser design. In all cases, by the time the discharge has traveled about 8,000 feet,

downstream mixing results in concentrations below the chronic toxicity threshold limit. Regardless of diffuser design, complete mixing of the discharge plume occurs at the river bend (about 10,000 feet downstream of the Laughlin bridge) due to natural secondary currents.

With dechlorination at Laughlin, the mixing zone analysis shows that total chlorine residual concentrations are below both acute and chronic toxicity requirements within a 200-foot mixing zone downstream of the diffuser. In addition, if dechlorination facilities are inoperative during periods of minimum hourly discharges from Davis Dam (2,000 cfs), concentrations will not exceed four times EPA's acute toxicity threshold, and will be below the acute toxicity values reported by EPA for most aquatic species.

8. In order to satisfy mixing zone requirements, the recommended diffuser structure appears to be one consisting of four 20-foot diffuser sections oriented perpendicular or parallel to the river flow and anchored to the two westerly bridge piers at Laughlin. The diffuser should be located 2 feet above the river bottom, should have minimum and maximum manifold velocities of 0.5 and 10.0 fps, and port velocities of 25.0 fps and 15.0 fps for diffusers located parallel and perpendicular to the river flow, respectively. Anchorage of this structure should be designed to withstand expected flood stage discharges from Davis Dam.

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TABLE 1

COLORADO RIVER - MOHAVE REACH
AVERAGE CHANNEL DEPTHS (FT) FOR VARIOUS FLOW RATES (CFS)
(DATA FROM USBR HEC-2 RUNS)

			Q=5,000				Q=10,000				Q=20,000				Q=30,000				Q=50,000				Q=70,000			
REACH	RIVER MILE	BOTTOM WIDTH	AREA	TOP WIDTH	DEPTH*	AVE RCH DEPTH	AREA	TOP WIDTH	DEPTH*	AVE RCH DEPTH	AREA	TOP WIDTH	DEPTH*	AVE RCH DEPTH	AREA	TOP WIDTH	DEPTH*	AVE RCH DEPTH	AREA	TOP WIDTH	DEPTH*	AVE RCH DEPTH	AREA	TOP WIDTH	DEPTH*	AVE RCH DEPTH
1	275.6	255	2546	435	7.4	9.0	3677	483	10.0	11.5	5526	501	14.6	15.6	6849	534	17.4	17.9	9478	618	21.7	21.4	11757	633	26.5	25.7
	275.3	300	3409	342	10.6		4230	350	13.0		5552	368	16.6		6477	405	18.4		8465	501	21.1		10289	525	24.9	
2	274.1	335	1997	515	4.7	4.7	3340	591	7.2	7.2	6044	937	9.5	9.5	8446	990	12.7	12.7	12731	1068	18.1	18.1	16658	1083	23.5	23.5
3	273.0	180	2434	505	7.1	7.1	3927	621	9.8	9.8	6197	674	14.5	14.5	8056	720	17.9	17.9	11307	767	23.9	23.9	14230	787	29.4	29.4
4	271.9	285	6390	696	13.0	13.0	8174	734	16.0	16.0	10843	789	20.2	20.2	12942	809	23.7	23.7	16501	840	29.3	29.3	19733	867	34.3	34.3
5	271.2	430	3453	462	7.7	7.7	4572	484	10.0	10.0	6209	512	13.2	13.2	7501	536	15.5	15.5	9755	569	19.5	19.5	11860	583	23.4	23.4
6	270.5	420	2131	421	5.1	5.1	3024	429	7.1	7.1	4305	451	9.9	9.9	5291	464	12.0	12.0	7043	507	15.2	15.2	8950	545	18.5	18.5
7	269.5	495	2280	644	4.0	4.0	3597	681	6.1	6.1	5366	724	8.8	8.8	6753	748	10.9	10.9	9392	776	14.8	14.8	12545	996	16.8	16.8
8	269.0	310	3538	700	7.0	7.0	5127	861	8.8	8.8	7228	883	12.1	12.1	8841	903	14.6	14.6	12001	906	19.7	19.7	15402	940	24.6	24.6
9	268.0	944	3512	944	3.7	3.7	5546	1382	4.8	4.8	9212	1842	6.6	6.6	12596	1961	8.7	8.7	21012	2320	12.9	12.9	30193	2383	18.2	18.2
10	267.2	675	1820	675	2.7	2.8	2826	718	4.1	4.1	4751	834	6.3	6.5	6597	842	8.7	9.1	10144	851	13.3	13.9	13722	856	17.9	18.8
	266.5	986	2840	986	2.9		4223	1065	4.1		7580	1300	6.6		11271	1388	9.5		17925	1482	14.5		24624	1514	19.7	
11	265.3	220	1303	423	4.1	7.2	2302	468	6.7	10.0	4494	574	11.3	13.7	6417	608	15.5	17.0	9497	652	21.8	23.1	12730	737	26.6	28.8
	264.3	100	1562	204	10.3		2180	227	13.3		3432	327	16.1		4653	402	18.5		6817	457	24.5		9168	490	31.1	
12	263.3	270	1695	326	5.7	4.5	2435	341	8.0	6.8	3847	381	11.8	10.8	5267	444	14.8	14.0	7768	467	21.1	20.0	10368	472	27.9	25.4
	262.9	493	1648	493	3.3		2856	509	5.7		5040	539	9.8		6923	559	13.2		10154	581	18.9		13735	704	22.9	
13	262.2	220	2768	351	9.7	8.2	3809	365	13.0	11.3	5505	441	16.7	15.5	7142	478	20.5	19.0	9971	506	27.5	25.6	13113	677	29.2	29.2
	261.2	460	2235	498	4.7		3777	525	7.7		6133	554	12.1		8134	573	15.7		11526	593	21.9		14850	635	27.1	
	260.1	325	2664	367	7.7		3867	411	10.5		5749	459	14.7		7479	503	18.1		10492	527	24.6		13773	686	27.2	
	259.6	220	3268	394	10.6		4498	427	13.9		6391	462	18.7		8099	522	21.8		11318	580	28.3		14746	670	33.1	
14	259.1	270	2248	417	6.5	5.8	3541	447	9.9	8.6	5473	491	14.4	13.3	7237	518	18.4	17.3	10324	536	25.6	23.8	13385	611	30.4	26.9
	258.1	480	2397	487	5.0		3941	502	8.0		6042	517	12.1		7888	529	15.6		11067	606	20.4		14349	970	19.8	
	257.7	250	1745	322	6.1		2926	477	8.0		4991	497	13.4		6814	515	17.8		9918	536	25.2		12768	615	29.5	
	257.1	380	2351	438	5.7		3771	497	8.6		6059	526	13.4		8045	548	17.3		11409	571	24.0		14470	664	27.7	

Note: * Depths computed by dividing conveyance area (ft2) by average width (ft), where average width = (top width + bottom width)/2.

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TABLE 2

COLORADO RIVER - MOHAVE REACH
AVERAGE VELOCITIES (FPS) FOR VARIOUS FLOW RATES (CFS)
(DATA FROM USBR HEC-2 RUNS)

	RIVER	Q=5,000		Q=10,000		Q=20,000		Q=30,000		Q=50,000		Q=70,000	
REACH	MILE	VEL	AVE RCH	VEL	AVE RCH	VEL	AVE RCH	VEL	AVE RCH	VEL	AVE RCH	VEL	AVE RCH
1	275.6	1.96	1.72	2.72	2.54	3.62	3.61	4.38	4.51	5.28	5.60	5.95	6.38
	275.3	1.47		2.36		3.60		4.63		5.91		6.80	
2	274.1	2.50	2.50	2.99	2.99	3.31	3.31	3.55	3.55	3.93	3.93	4.20	4.20
3	273.0	2.05	2.05	2.55	2.55	3.23	3.23	3.72	3.72	4.42	4.42	4.92	4.92
4	271.9	0.78	0.78	1.22	1.22	1.84	1.84	2.32	2.32	3.03	3.03	3.55	3.55
5	271.2	1.45	1.45	2.19	2.19	3.22	3.22	4.00	4.00	5.13	5.13	5.90	5.90
6	270.5	2.35	2.35	3.31	3.31	4.64	4.64	5.67	5.67	7.10	7.10	7.82	7.82
7	269.5	2.19	2.19	2.78	2.78	3.73	3.73	4.44	4.44	5.32	5.32	5.58	5.58
8	269.0	1.41	1.41	1.95	1.95	2.77	2.77	3.39	3.39	4.17	4.17	4.54	4.54
9	268.0	1.42	1.42	1.80	1.80	2.17	2.17	2.38	2.38	2.38	2.38	2.32	2.32
10	267.2	2.75	2.26	3.54	2.96	4.21	3.43	4.55	3.61	4.93	3.89	5.10	3.95
	266.5	1.76		2.37		2.64		2.66		2.84		2.79	
11	265.3	3.84	3.52	4.34	4.47	4.45	5.14	4.67	5.56	5.26	6.30	5.50	6.57
	264.3	3.20		4.59		5.83		6.45		7.33		7.63	
12	263.3	2.95	2.99	4.11	3.81	5.20	4.59	5.70	5.02	6.44	5.68	6.75	5.93
	262.9	3.03		3.50		3.97		4.33		4.92		5.10	
13	262.2	1.81	1.87	2.63	2.52	3.63	3.38	4.20	3.90	5.01	4.64	5.34	4.97
	261.2	2.24		2.65		3.26		3.69		4.34		4.71	
	260.1	1.88		2.59		3.48		4.01		4.77		5.08	
	259.6	1.53		2.22		3.13		3.70		4.42		4.75	
14	259.1	2.22	2.33	2.82	2.86	3.65	3.57	4.14	4.02	4.84	4.70	5.23	5.11
	258.1	2.09		2.54		3.31		3.80		4.52		4.88	
	257.7	2.86		3.42		4.01		4.40		5.04		5.48	
	257.1	2.13		2.65		3.30		3.73		4.38		4.84	

$V = aQ^b$
$d = cQ^d$

TABLE 3

DISCHARGE COEFFICIENTS FOR REPRESENTATION OF COLORADO RIVER IN QUAL-2E MODEL

Reach Number	Q < 20,000 CFS				Q ≥ 20,000 CFS			
	Velocity		Depth		Velocity		Depth	
	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
1	.021	.520	.321	.391	.021	.520	.321	.391
2	.549	.181	.0956	.464	.549	.181	.0065	.734
3	.129	.325	.0794	.527	.129	.325	.0794	.527
4	.0053	.590	.850	.320	.0071	.560	.367	.406
5	.015	.540	.250	.400	.015	.540	.250	.400
6	.040	.480	.088	.477	.040	.480	.088	.477
7	.083	.384	.0417	.540	.083	.384	.0417	.540
8	.022	.488	.224	.402	.022	.488	.0623	.512
9	.123	.290	.105	.418	.762	.106	.0035	.762
10	.254	.264	.014	.617	.953	.130	.0014	.849
11	.547	.225	.159	.449	.547	.225	.096	.515
12	.257	.291	.0192	.640	.572	.210	.0123	.685
13	.073	.384	.131	.486	.073	.384	.131	.486
14	.179	.302	.033	.606	.179	.302	.033	.606

TABLE 4

FREQUENCY ANALYSIS OF COLORADO RIVER DISCHARGE
BELOW DAVIS DAM

Range of Average Daily Flows (cfs)	Percentage of Flows in Each Range: Water Year 1971 (Average Year)	Percentage of Flows in Each Range: Water Year 1978 (Dry Year)
<2,000	0%	0%
2,000 - 4,999	4%	13%
5,000 - 9,999	37%	30%
10,000 - 19,999	59%	57%
≥ 20,000	0%	0%

Note: Data compiled from United States Department of Interior - Geological Survey Records for Station No. 09423000, Colorado River below Davis Dam.

TABLE 5

SUMMARY OF WATER QUALITY DATA FROM RIVER SURVEYS
USED FOR VERIFICATION OF MODEL RUNS

Water Quality Characteristic	Sampling Station Number	February Survey	June Survey	October Survey
Average River Discharge (cfs)	ALL	20,730	16,600	9,870
Temperature (°F)[1]	C1	54.0	63.6	63.7
	C2	53.8	63.2	64.0
	C3	54.1	63.3	63.7
	C4	54.1	63.7	64.2
	C5	54.1	64.0	64.6
Dissolved Oxygen (mg/l)[1]	C1	10.4	8.46	7.30
	C2	10.3	8.57	7.63
	C3	10.3	8.65	7.84
	C4	10.4	8.69	7.92
	C5	10.4	8.75	8.30
BOD, 5-day (mg/l)	C1	1.8	<0.5	2.0
	C2	1.0	2.3	1.4
	C3	1.7	1.3	1.5
	C4	0.6	<0.5	0.7
	C5	0.6	0.5	0.9
Total Dissolved Solids (mg/l)	C1	540.	540.	486.
	C2	530.	530.	524.
	C3	521.	530.	507.
	C4	524.	500.	493.
	C5	514.	520.	504.
Chlorides (mg/l)	C1	53.	56.	57.
	C2	--	56.	56.
	C3	56.	55.	58.
	C4	--	55.	56.
	C5	58.	55.	58.
Sodium (mg/l)	C1	70.	64.	76.
	C2	--	71.	74.
	C3	72.	66.	74.
	C4	--	70.	74.
	C5	74.	68.	75.

TABLE 5

SUMMARY OF WATER QUALITY DATA FROM RIVER SURVEYS
USED FOR VERIFICATION OF MODEL RUNS

Water Quality Characteristic	Sampling Station Number	February Survey	June Survey	October Survey
Fecal Coliform (No./100 ml)[2]	C1	8	2	25
	C2	4	5	27
	C3	14	13	33
	C4	2	10	19
	C5	8	20	19
Chlorophyll-a (ug/l)	C1	<10	<1.0	<1.0
	C2	<10	<1.0	<1.0
	C3	<10	<1.0	<1.0
	C4	<10	<1.0	<1.0
	C5	<10	<1.0	<1.0
Organic Nitrogen (mg-N/l)	C1	<0.3	<0.01	0.23
	C2	<0.3	1.0	0.23
	C3	<0.3	0.36	0.21
	C4	<0.3	0.34	0.13
	C5	<0.3	0.70	0.12
Ammonia Nitrogen (mg-N/l)	C1	0.20	0.09	0.04
	C2	0.30	0.09	0.05
	C3	<0.15	0.09	0.04
	C4	0.20	0.07	0.03
	C5	0.24	0.07	0.03
Unionized Ammonia (mg-N/l)	C1	0.006	0.006	0.0014
	C2	0.013	0.006	0.0016
	C3	<0.007	0.006	0.0013
	C4	0.008	0.005	0.0010
	C5	0.012	0.005	0.0011
Nitrite Nitrogen (mg-N/l)	C1	<0.2	<0.01	0.01
	C2	<0.2	<0.01	0.01
	C3	<0.2	<0.01	0.01
	C4	<0.2	<0.01	<0.01
	C5	<0.2	<0.01	<0.01
Nitrate Nitrogen (mg-N/l)	C1	0.26	0.29	0.24
	C2	0.25	0.28	0.17
	C3	0.29	0.37	0.26
	C4	0.22	0.27	0.25
	C5	0.28	0.26	0.27

TABLE 5

SUMMARY OF WATER QUALITY DATA FROM RIVER SURVEYS
USED FOR VERIFICATION OF MODEL RUNS

Water Quality Characteristic	Sampling Station Number	February Survey	June Survey	October Survey
Organic Phosphorus (mg-P/l) (calculated)	C1	<0.05	<0.009	0.007-0.017
	C2	<0.05	0.009-0.19	<0.009
	C3	<0.05	<0.005	<0.005
	C4	<0.05	<0.005	<0.005
	C5	<0.05	<0.005	0.009-0.019
Dissolved Ortho Phosphate (mg-P/l)	C1	<0.05	<0.01	<0.01
	C2	<0.05	<0.01	<0.01
	C3	<0.05	<0.01	<0.01
	C4	<0.05	<0.01	<0.01
	C5	<0.05	<0.01	<0.01
Total Phosphate (mg-P/l)	C1	<0.05	0.009	0.017
	C2	<0.05	0.019	0.009
	C3	<0.05	0.005	<0.005
	C4	<0.05	0.005	<0.005
	C5	<0.05	<0.005	0.019

Notes:

1. Data represent averages of field measurements made at three locations at a river cross section during three sampling runs in a 24-hour period.

2. Data represent geometric means of three discrete samples collected during a 24-hour period.

TABLE 6

INPUT DATA FOR MODEL VERIFICATION RUNS

Input Parameter	February Survey	June Survey	October Survey
Day of Year Start Time	49.	174.	290.
Total Daily Solar Radiation (BTU/ft.^{2})	1140	2780	1520
Headwater Loadings			
Flow (cfs	20,730.	16,600.	9,870.
Temperature (°F)	54.0	63.6	63.7
Dissolved Oxygen (mg/l)	10.4	8.46	7.30
BOD_5 (mg/l)	1.5	1.5	2.0
TDS (mg/l)	540.	540.	486
Chlorides (mg/l)	53.	56.	57.
Sodium (mg/l)	70.	64.	76.
Fecal Coliform (No./100 ml)	18.	2.	20.
Chlorophyll-a (ug/l)	1.0	2.0	2.0
Organic Nitrogen (mg-N/l)	0.05	0.005	0.23
Ammonia Nitrogen (mg-N/l)	0.2	0.09	0.04
Nitrite Nitrogen (mg-N/l)	0.01	0.005	0.01
Nitrate Nitrogen (mg-N/l)	0.26	0.29	0.25
Organic Phosphorus (mg-P/l)	0.012	0.0054	.009
Dissolved Ortho Phosphate (mg-P/l)	0.008	0.0036	.008
Mohave Withdrawal (cfs)	18.0	18.0	18.0
River Bend WWTP Loadings			
Effluent Discharge (cfs)	0.30	0.24	0.13
Temperature (°F)	74.	86.	84.
Dissolved Oxygen (mg/l)	2.0	2.7	2.0
BOD_5 (mg/l)	5.1	1.1	21.0
TDS (mg/l)	1,420.	1,400.	1,430.
Chlorides (mg/l)	345.	385.	408.
Sodium (mg/l)	262.	250.	290.
Fecal Coliform (No./100 ml)	63.	34.	131.
Chlorophyll-a (ug/l)	0.0	0.0	0.0
Organic Nitrogen (mg-N/l)	1.7	2.3	0.08
Ammonia Nitrogen (mg-N/l)	0.41	0.24	0.42
Nitrite Nitrogen (mg-N/l)	0.01	0.005	0.04
Nitrate Nitrogen (mg-N/l)	14.	17.	19.
Organic Phosphorus (mg-P/l)	0.01	0.01	0.01
Dissolved Ortho Phosphate (mg-P/l)	6.9	1.8	5.3

TABLE 6

INPUT DATA FOR MODEL VERIFICATION RUNS

Input Parameter	February Survey	June Survey	October Survey
Local Climatological Data			
Month, Day, and Year	02-18-87	06-23-87	10-17-87
Hour of Day	12	13	14
Net Solar Radiation (BTU/ft.^{2}-hr.)	95	200	130
Cloudiness (Fraction of Sky Cover)	0.4	0.1	0.0
Dry Bulb Temperature (°F)	60.	95.	82.
Wet Bulb Temperature (°F)	48.	80.	70.
Barometric Pressure (In. Hg)	30.0	30.0	30.
Wind Speed (ft./sec.)	20.	9.0	6.0

TABLE 7

BIOLOGICAL AND CHEMICAL KINETICS PARAMETERS
USED FOR MODEL VERIFICATION RUNS

Description	Value	Units
Oxygen uptake by NH_3 oxidation	3.43	mg-O/mg-N
Oxygen uptake by NO_2 oxidation	1.14	mg-O/mg-N
Oxygen production by algae	1.4	mg-O/mg-A
Oxygen uptake by algae	1.6	mg-O/mg-A
Nitrogen content of algae	0.085	mg-N/mg-A
Phosphorus content of algae	0.014	mg-P/mg-A
Algal maximum specific growth rate	3.0	1/day
Algal respiration rate	0.10	1/day
Nitrogen half-saturation constant	0.025	mg/l
Phosphorus half-saturation constant	0.01	mg/l
Linear algal self-shading coefficient	0.0	1/ft.-ugCha/l
Nonlinear algal self-shading coefficient	0.0	1/ft.-$(\text{ugCha/l})^{2/3}$
Light function option*	3	
Light saturation coefficient	1.02	BTU/ft.^{2}-min.
Daily averaging option*	2	
Light averaging factor	0.92	
Algal growth calculation option*	1	
Algal preference for NH_3-N	0.5	
Algal/temperature solar radiation factor	0.45	
Nitrification inhibition coefficient	1.0	
5-day to ultimate BOD K coefficient	0.19	
BOD deoxygenation coefficient	0.2	1/day
BOD settling coefficient	0.0	1/day
Sediment oxygen demand rate	0.0	gm/ft.^{2}-day
Reaeration option*	3	
Organic nitrogen hydrolysis rate	0.03	1/day
Organic nitrogen settling coefficient	0.0	1/day
NH_3 oxidation rate	0.15	1/day
Benthal source rate for nitrogen	0.0	mg/ft.^{2}-day
NO_2 oxidation rate	0.50	1/day
Organic phosphorus hydrolysis rate	0.05	1/day
Organic phosphorus settling coefficient	0.0	1/day
Benthal source rate for phosphorus	0.0	mg/ft.^{2}-day
Chlorophyll-a to algae ratio	10.	
Algal settling rate	0.0	ft./day
Non-algal light extinction coefficient	0.1	1/ft.
Coliform decay rate	2.0	1/day

* Computation Option Codes are described in the QUAL-2E documentation and users manual ( ).

TABLE 8

SOLAR RADIATION ESTIMATES FOR LAUGHLIN
DURING THREE RIVER SURVEYS

Date (1987)	Maximum Radiation* (BTU/Ft.^{2})	Minimum Radiation* (BTU/ft.^{2})	Envelope Range	Cloud Cover	Estimated Radiation During Survey (BTU/ft.^{2})
Feb. 18-19	1550	520	1030	40%	1140
June 23	2850	2190	660	10%	2780
Oct. 16-17	1520	650	870	0%	1520

* Estimates obtained from global solar radiation envelope on Figure 6, representing values measured at Las Vegas (Station 23169) during 1978.

TABLE 9

SUMMARY OF HISTORICAL PHOSPHATE DATA
COLLECTED BELOW DAVIS DAM

Station Name	Collection Agency	Time Period	Number of Measurements	Total Phosphate (mg/l) Average	Total Phosphate (mg/l) Range	Ortho Phosphate (mg/l) Average	Ortho Phosphate (mg/l) Range
1.5 miles downstream of Davis Dam	Nevada Dept. of Conservation and Natural Resources	1/69 - 5/78	22	0.016	0.00 - 0.040	0.007	0.00 - 0.040
Boat Ramp at Sportsman's Campground	Univ. of Nevada	12/74 - 11/75	13	0.021	<0.010 - 0.040	0.007	<0.005 - 0.010
Davis Dam Tailwater	U.S. Bureau of Reclamation	8/86 - 1/87	4	0.0163	0.004 - 0.023	0.0028	<0.005 - 0.008
C1 - Davis Dam	Clark County Sanitation District (Kennedy/Jenks/Chilton)	2/87 - 10/87	3	0.013	<0.05 - 0.017	--	<0.01 - <0.05

TABLE 10

INPUT DATA FOR FUTURE PROJECTION RUNS

Input Parameter	Baseline Case	Changes From Projection Baseline Case: Projection Run 1	Projection Run 2	Projection Run 3
Day of Year				
Total Daily Solar	270			
Radiation (BTU/ft^2)	1,520			
Headwater Loadings				
Flow (cfs)	5,000			
Temperature (°F)	64.			
Dissolved Oxygen (mg/l)	7.30			
BODs (mg/l)	2.0			
TDS (mg/l)	540			
Chlorides (mg/l)	56.			
Sodium (mg/l)	70.			
Fecal Coliform (mg/l)	20.			
Chlorophyll-a (ug/l)	2.			
Organic Nitrogen (mg-N/l)	0.23			
Ammonia Nitrogen (mg-N/l)	0.04			
Nitrite Nitrogen (mg-N/l)	0.01			
Nitrate Nitrogen (mg-N/l)	0.24			
Organic Phosphorus (mg-P/l)	0.012			
Dissolved Ortho-Phosphate (mg-P/l)	0.008			
Laughlin WWTP Loadings				
Effluent Discharge (cfs)	0.0	10.8	10.8	10.8
Temperature (°F)	77.			
Dissolved Oxygen (mg/l)	0.5			
BODs (mg/l)	13			
TDS (mg/l)	1,100			
Chlorides (mg/l)	280			
Sodium (mg/l)	240			
Fecal Coliform (No./100 ml)	200			
Chlorophyll-a (ug/l)	0.00			
Organic Nitrogen (mg-N/l)	1.1			
Ammonia Nitrogen (mg-N/l)	0.26			
Nitrite Nitrogen (mg-N/l)	0.14			
Nitrate Nitrogen (mg-N/l)	21			
Organic Phosphorus (mg-P/l)	0.01			

TABLE 10 (CONT'D)

INPUT DATA FOR FUTURE PROJECTION RUNS

	Changes From Projection Baseline Case			
Laughlin WWTP Loadings (Continued)	Baseline Case	Projection Run 1	Projection Run 2	Projection Run 3
Dissolved Ortho-Phosphate (mg/P/l)	6.0	6.0	0.5	0.5
Chlorine Residual (mg/l)	3.0	3.0	0.1	0.1
Mohave Withdrawal (cfs)	18.0			
River Bend WWTP Loadings				
Effluent Dishcharge (cfs)	0.25			0.93
Temperature (°F)	84			
Dissolved Oxygen (mg/l)	2.0			
BODs (mg/l)	21.			
TDS (mg/l)	1430.			
Chlorides (mg/l)	408.			
Sodium (mg/l)	290.			
Fecal Coliform (No./100 ml)	200.			
Chlorophyll-a (ug/l)	0.0			
Organic Nitrogen (mg-N/l)	0.08			
Ammonia Nitrogen (mg-N/l)	0.42			
Nitrite Nitrogen (mg-N/l)	0.04			
Nitrate Nitrogen (mg-N/l)	19.			
Organic Phosphorus (mg-P/l)	0.01			
Dissolved Ortho-Phosphate (mg/P/l)	5.3			
Chlorine Residual (mg/l)	3.0			
Local Climatological Data				
Month, Day, and Year	10-1-00			
Hour of Day	14			
Net Solar Radiation (BTU/ft^2-hr)	130			
Cloudiness	0.0			
Dry Bulb Temperature (°F)	82			
Wet Bulb Temperature (°F)	70			
Barometric Pressure (In.Hg.)	30			
Wind Speed (ft/sec)	6			

TABLE 11

PROJECTED RIVER WATER QUALITY BELOW PROPOSED
LAUGHLIN WASTEWATER TREATMENT PLANT DISCHARGE

SUMMARY OF RESULTS OF MODEL RUNS
FOR BASELINE CASE AND PROJECTION 1

Water Quality Characteristic	Model Results (1) Baseline Case(2)	Projection 1(3)	Increase over Baseline	Percent Increase	River Waster Quality Standard(4)
Temperature, °F	64.22	64.25	0.03	0.05	$\Delta T = 0$
Total Dissolved Solids, mg/l	540.00	541.21	1.21	0.22	≤734 (Goal)
Chlorides, mg/l	56.00	56.48	0.48	0.86	-
Sodium, mg/l	70.00	70.37	0.37	0.53	-
Dissolved Oxygen, mg/l	7.37	7.36	-0.01	-0.14	≥6.0 SV
Biological Oxygen Demand, mg/l	1.98	2.01	0.03	1.5	-
Organic-N, mg/l	0.2298	0.2316	0.0018	0.78	-
Ammonia-N, mg/l	0.04	0.0405	0.0005	1.3	≤0.02
Nitrite-N, mg/l	0.0100	0.0103	0.0003	3.0	≤1.1 AA, ≤1.6 SV
Nitrate-N, mg/l	0.2399	0.2846	0.0447	18.6	≤0.06 SV
Total-N, mg/l	0.5197	0.5670	0.0473	9.1	-
Organic-P, mg/l	0.0120	0.0120	0.00	0	-
Dissolved-P, mg/l	0.008	0.0209	0.0129	161	-
Total-P, mg/l	0.020	0.0329	0.0129	64	≤0.02 AA, <0.03 SV
Fecal Coliform, #/100 mg	18.28	18.67	0.39	2.1	<50.A.G.M.
Chlorine, mg/l	0.00	0.0065	0.0065	-	-
Chlorophyll-'a', mg/l	2.04	2.04	0.00	0	-

Notes:

1) Results represent completely mixed concentrations of characteristics computed for Element 8 at River Mile 274.3 (see Figure 3) which was the assumed location of the proposed wastewater discharge. The river flow for the simulations was 5,000 cfs.
2) The baseline case represents an estimated future condition in the river without the Laughlin discharge.
3) Projection 1 represents the baseline case conditions with the addition of a 7.0 MGD effluent discharge from Laughlin.
4) Nevada Standards (NAC 445.13495).
   SV = single value standard; AA = annual average standard; AGM = annual geometric mean.

TABLE 12

RESULTS OF PROJECTION RUNS
FOR PHOSPHORUS AND CHLORINE

Location in River	Total Phosphorus, mg-P/l			
	Baseline Case	Projection 1	Projection 2	Projection 3
At Davis Dam Headwaters	0.0200	0.0200	0.0200	0.0200
Below Proposed Laughlin WWTP Discharge	0.0200	0.0329	0.0210	0.0210
Below River Bend WWTP Discharge	0.0210	0.0330	0.0212	0.0219

Location in River	Total Chlorine Residual, mg/l			
	Baseline Case	Projection 1	Projection 2	Projection 3
At Davis Dam Headwaters	0.00	0.00	0.00	0.00
Below Proposed Laughlin WWTP Discharge	0.00	0.0065	0.0002	0.0002
Below River Bend WWTP Discharge	0.0020	0.0066	0.0004	0.0008

TABLE 13

PROBABILITY ANALYSIS FOR KEY WATER QUALITY PARAMETERS

Parameter	Sample Size	Mean	Variance of[2] the Mean	Standard Deviation	Distribution Type	Probability That Sample Is Less Than or Equal To Indicated Level: 85%	90%	95%	99%
Total Phosphorus (mg-P/l)	49	0.018	±.00002	0.01	N	0.028	0.031	0.034	0.041
Ortho-Phosphorus (mg-P/l)	54	0.007	±.00002	0.01	N	0.017	0.020	0.023	0.03
Nitrate (mg-N/l)	174	0.27	±.0002	0.18	N	0.45	0.50	0.57	0.69
Ammonia (mg-N/l)	28	0.05	±.0001	0.06	N	0.11	0.13	0.148	0.19
Dissolved Oxygen Deficit (mg/l)	59	0.80	±.003	0.40	N	1.2	1.31	1.46	1.73
Temperature (Winter), °F	115	53.4	±.1	3.43	N	56.8	57.8	59.0	61.4
Temperature (Summer), °F	125	63.7	±.06	2.64	N	66.3	67.1	68.0	69.8
Chlorides[1](mg/l)	180	89	±.007	1.12	LN	100	102	107	117
Fecal Coliform[1] (no./100 ml)	29	2.34	±.4	3.37	LN	7.94	11.22	17.38	39.8
Total Dissolved Solids (mg/l)	167	711	±13	46	N	757	770	786	818
Total Dissolved Solids (mg/l) (1978-1987)	98	680	±20	44	N	724	736	752	782

Notes:

1. The sample mean is used as the minimum variance unbiased estimate of the population mean due to the fact that excessive skewness was not observed.
2. Indicates accuracy of the estimate of the mean.
3. N = Normal distribution
   LN = Log normal distribution

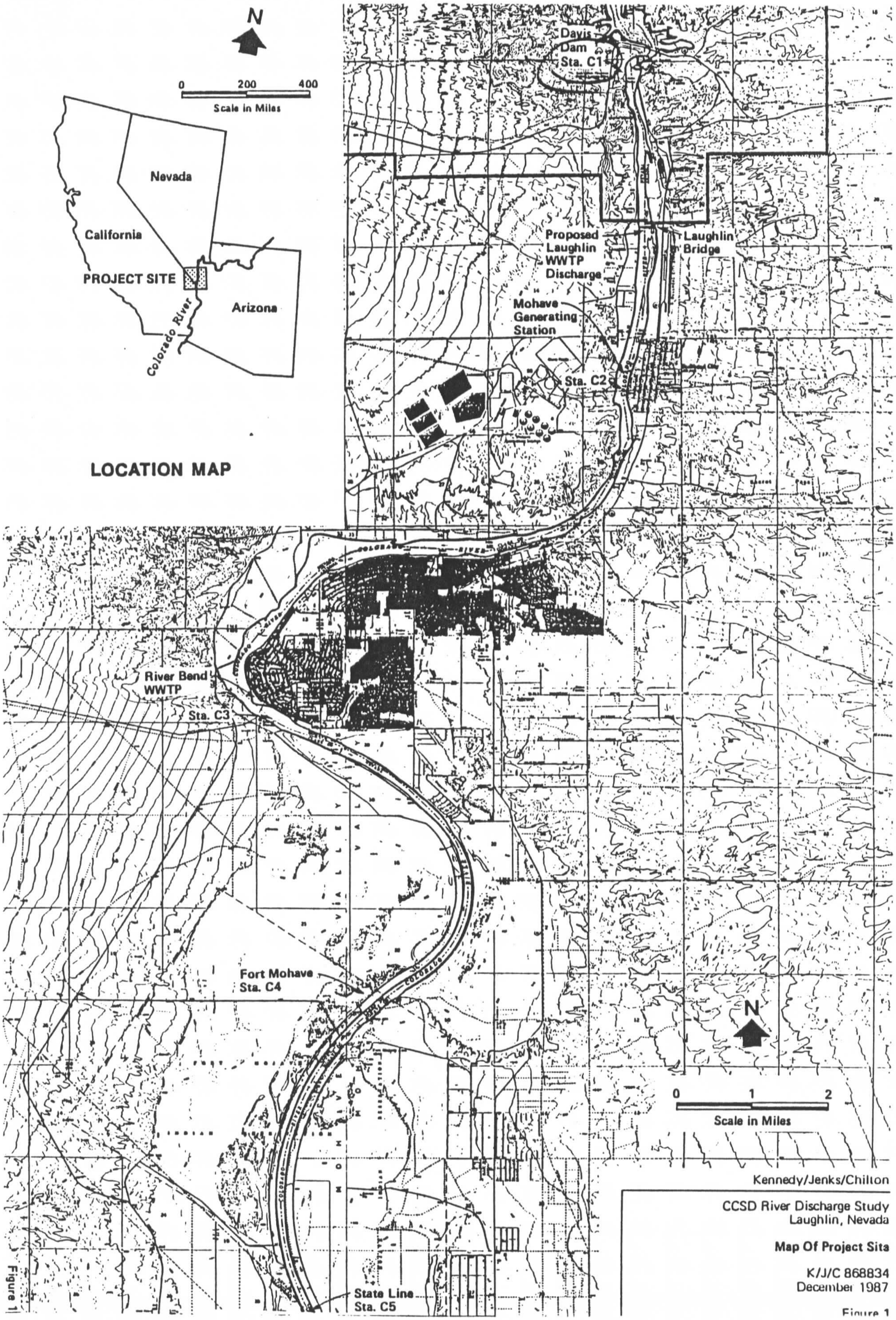
TABLE 14

ADJUSTMENT TO QUAL-2E MODEL RESULTS TO OBTAIN EXTREME VALUES OF GIVEN EXCEEDANCE PROBABILITIES

		85	90	95	99
Constituent	50%	15%	10%	5%	1%
Total Phosphorus	+0.000	+0.01	+0.013	+0.016	+0.023
Ortho-Phosphorus	+0.00	+0.01	+0.013	+0.016	+0.023
Nitrate	+0.00	+0.18	+0.23	+0.30	+0.42
Ammonia	+0.00	+0.06	+0.08	+0.098	+0.14
Dissolved Oxygen Deficit	+0.00	+0.40	+0.51	+0.66	+0.93
Temperature (Winter), °F	+0.00	+3.4	+ 4.4	+ 5.6	+8.0
Temperature (Summer), °F	+0.00	+2.6	+ 3.4	+ 4.3	+6.1
Chlorides	+0.00	+0.11	+0.13	+0.18	+28
Fecal Coliform	+0.00	+10.28	+13.56	+19.72	+42.14
Total Dissolved Solids	+0.00	+46	+59	+75	+107
Total Dissolved Solids (1978-87)	+0.00	+44	+56	+72	+102

Explanation of Table:

The QUAL-2E model results represent average river concentrations of each constituent. There is a 50 percent probability that the average concentration will be exceeded by any single measurement. By adding the adjustment value in Table 14 to the average value, the probability that the adjusted concentration will be exceeded by a single measurement decreases accordingly to Table 14, which is based on statistical analyses of the historical data. For example, if the average nitrate concentration is 0.20 mg/l and the adjustment for the 5 percent exceedance level is 0.30, there is a 5 percent probability that a single measurement of nitrate concentration will exceed 0.50 mg/l.



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CCSD River Discharge Study
Laughlin, Nevada

Map Of Project Site

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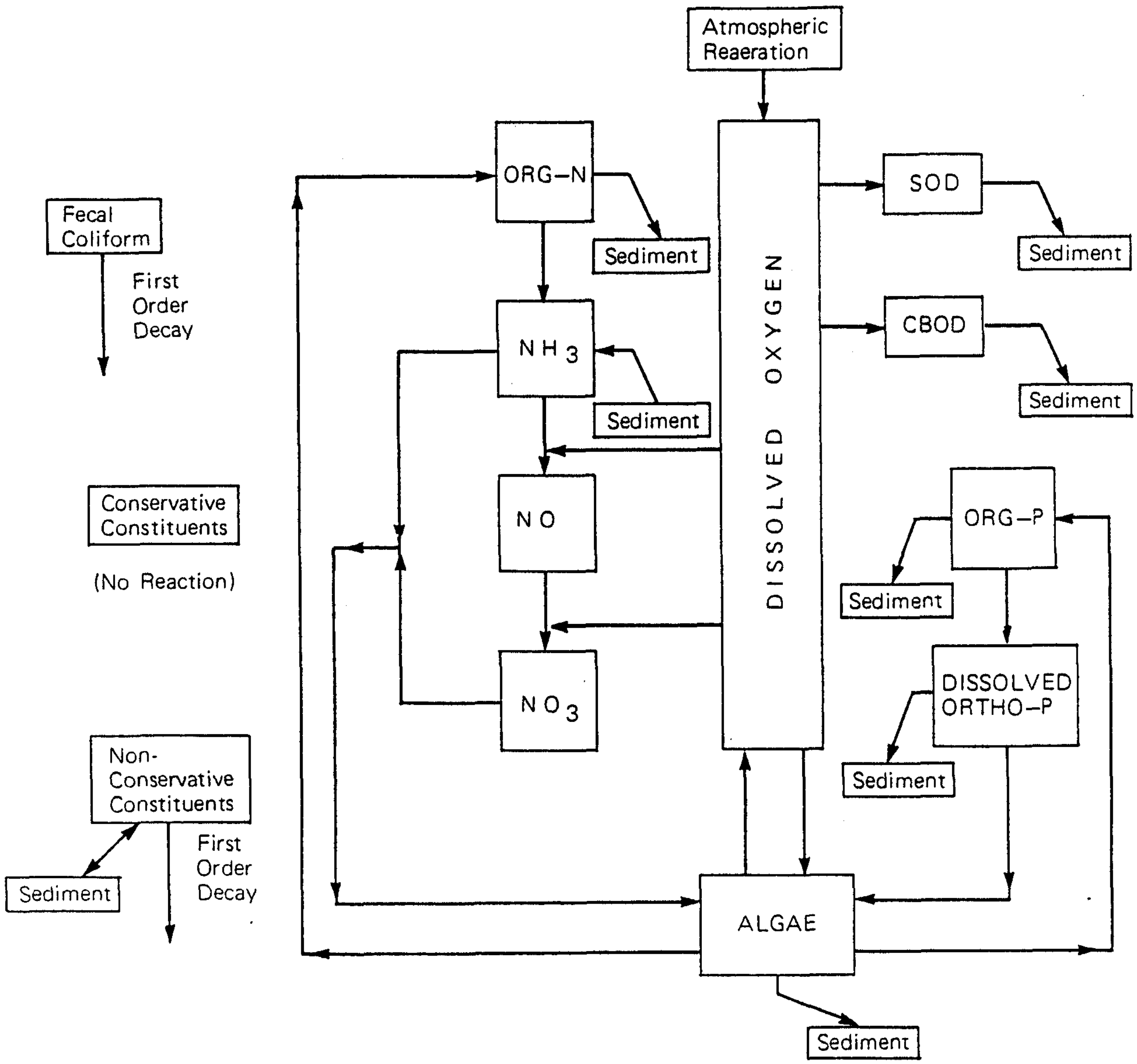
Figure 1



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CCSD River Discharge Study
Laughlin, Nevada

Major Constituent Interactions in the QUAL-2E Model

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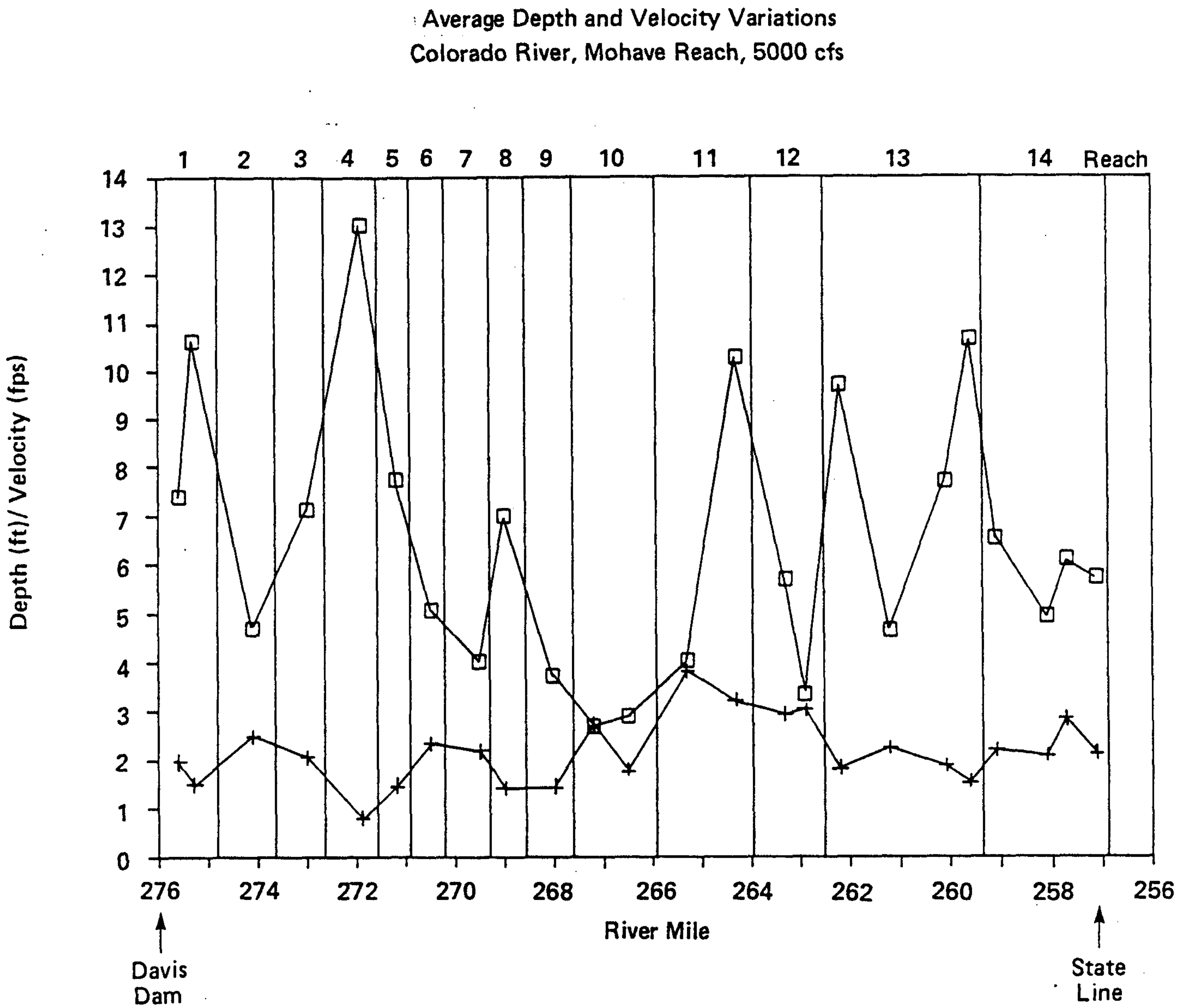
December 1987

Figure 2



Legend

□ Average Depth (ft)

+ Velocity (fps)

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CCSD River Discharge Study
Laughlin, Nevada

Average Depths and Velocities at 5,000 cfs and Reach Divisions, Colorado River

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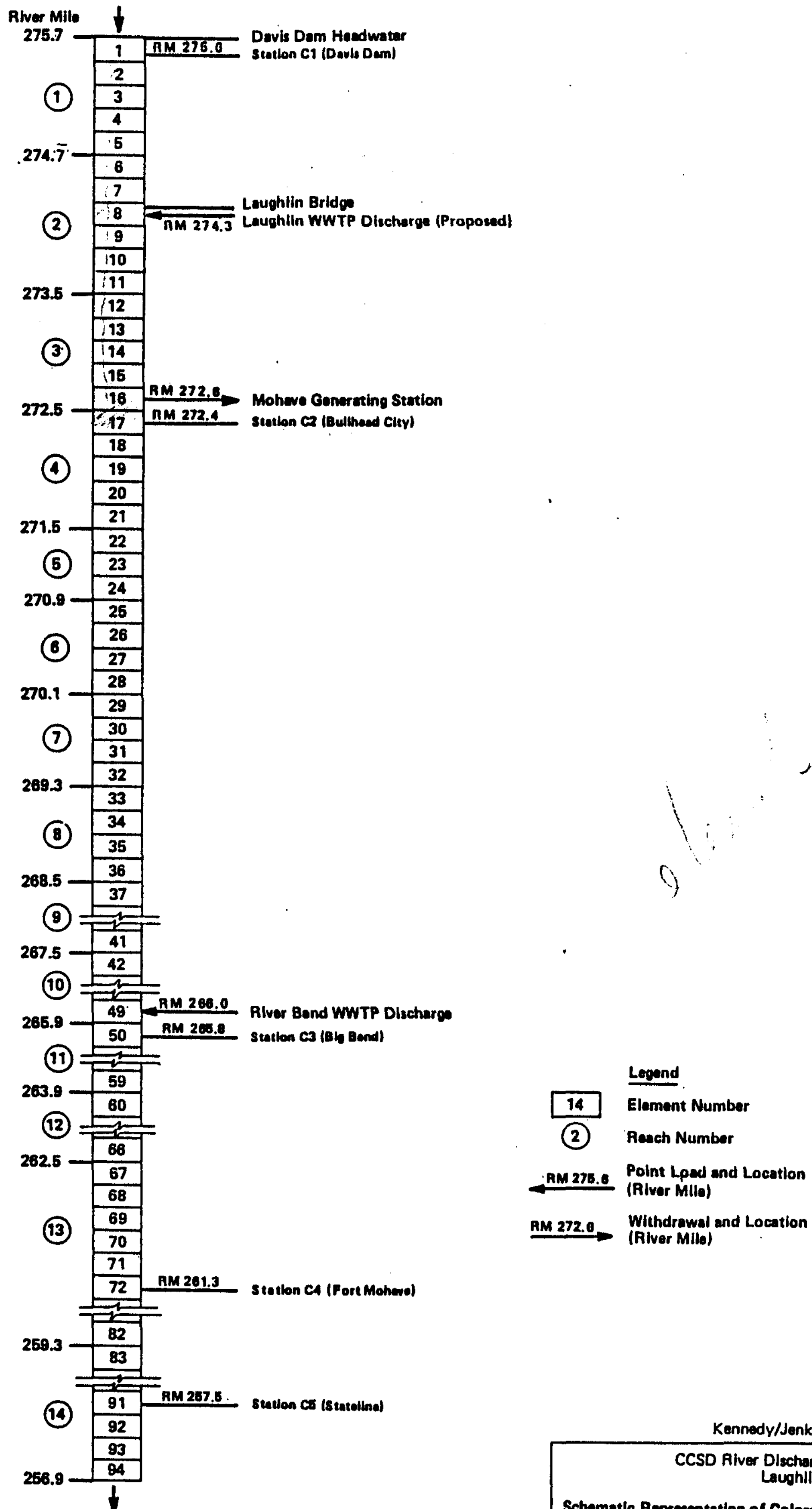
Figure 3



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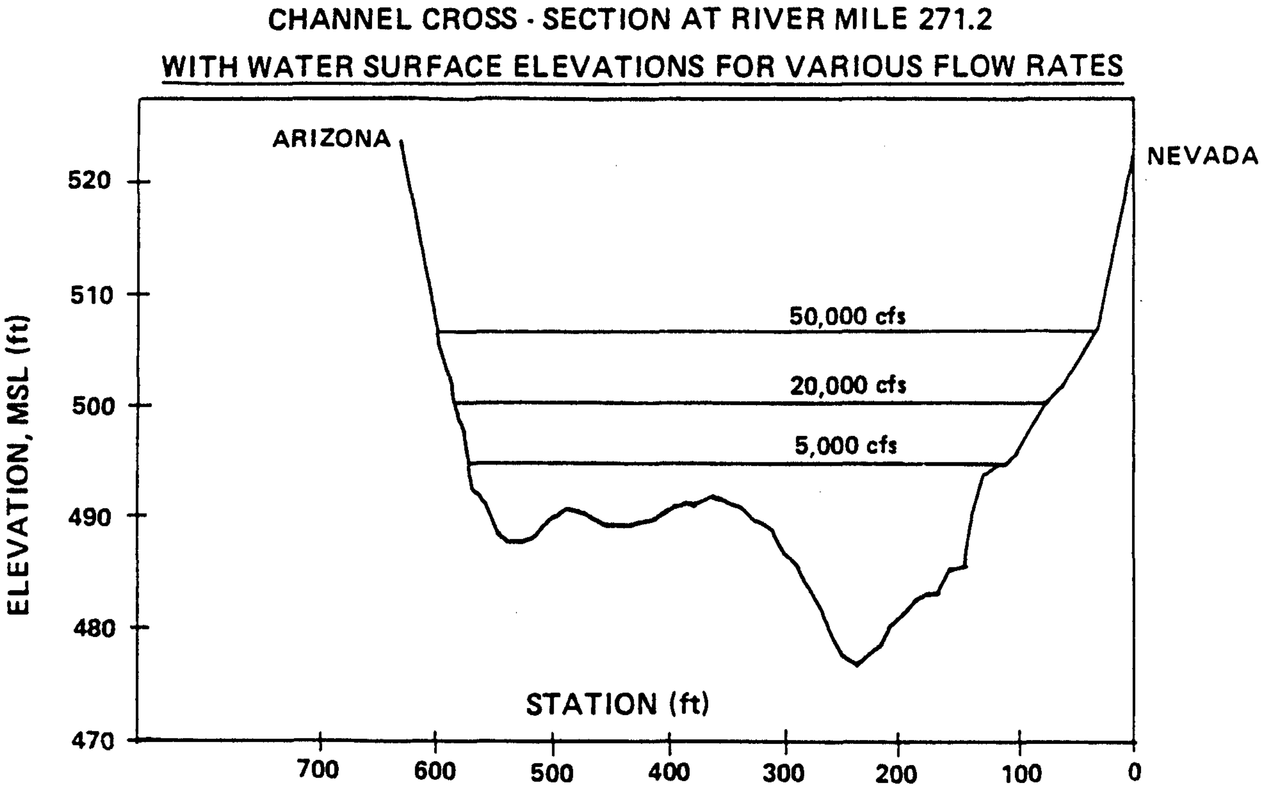
CCSD River Discharge Study
Laughlin,Nevada

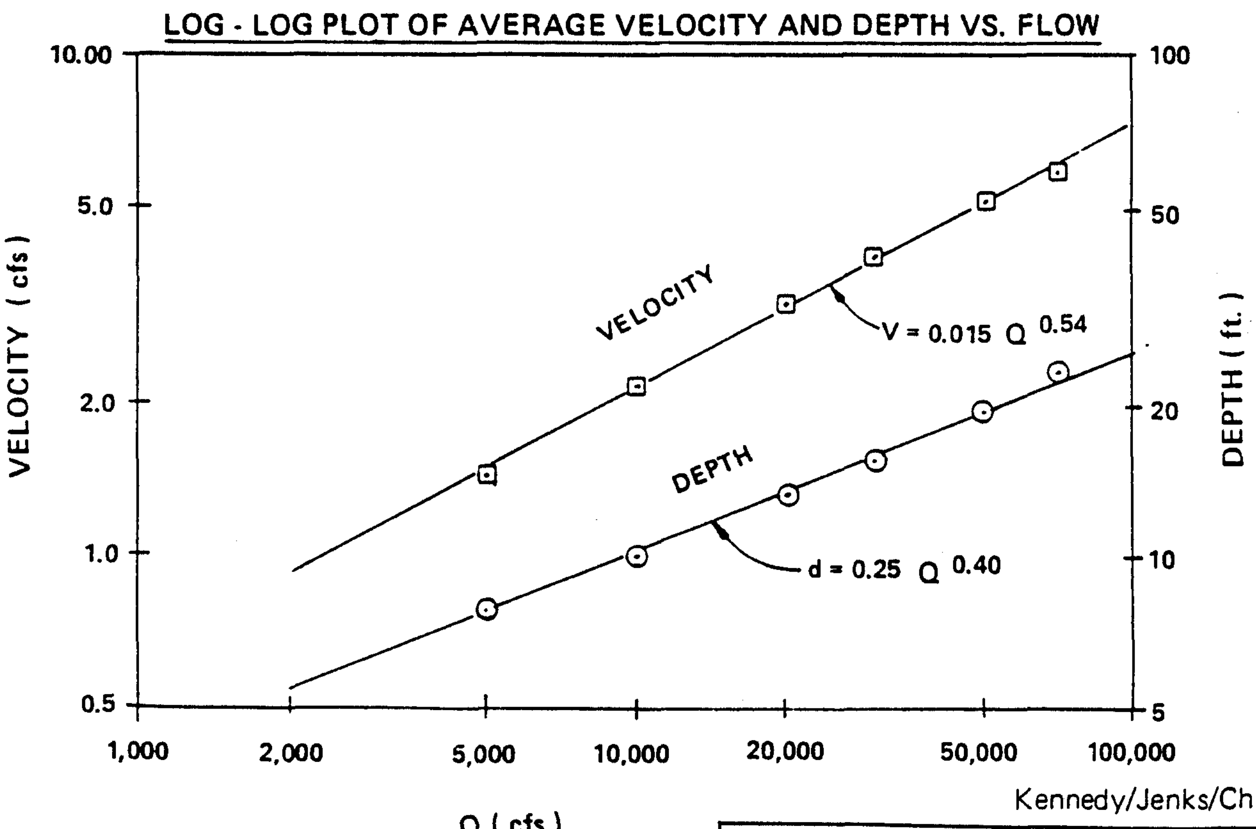
Schematic Representation of Colorado River in QUAL-2E Model

K/J/C 868834
December 1987

Figure 4

Figure 4





Source of data:

USBR, Lower Colorado Region, Boulder City, Nevada. Results of 1987 HEC - 2 Model Runs

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CCSD River Discharge Study
Laughlin, Nevada

Velocity and Depth Variations with Flow - Colorado River Mile 271.2

K/J/C 868834
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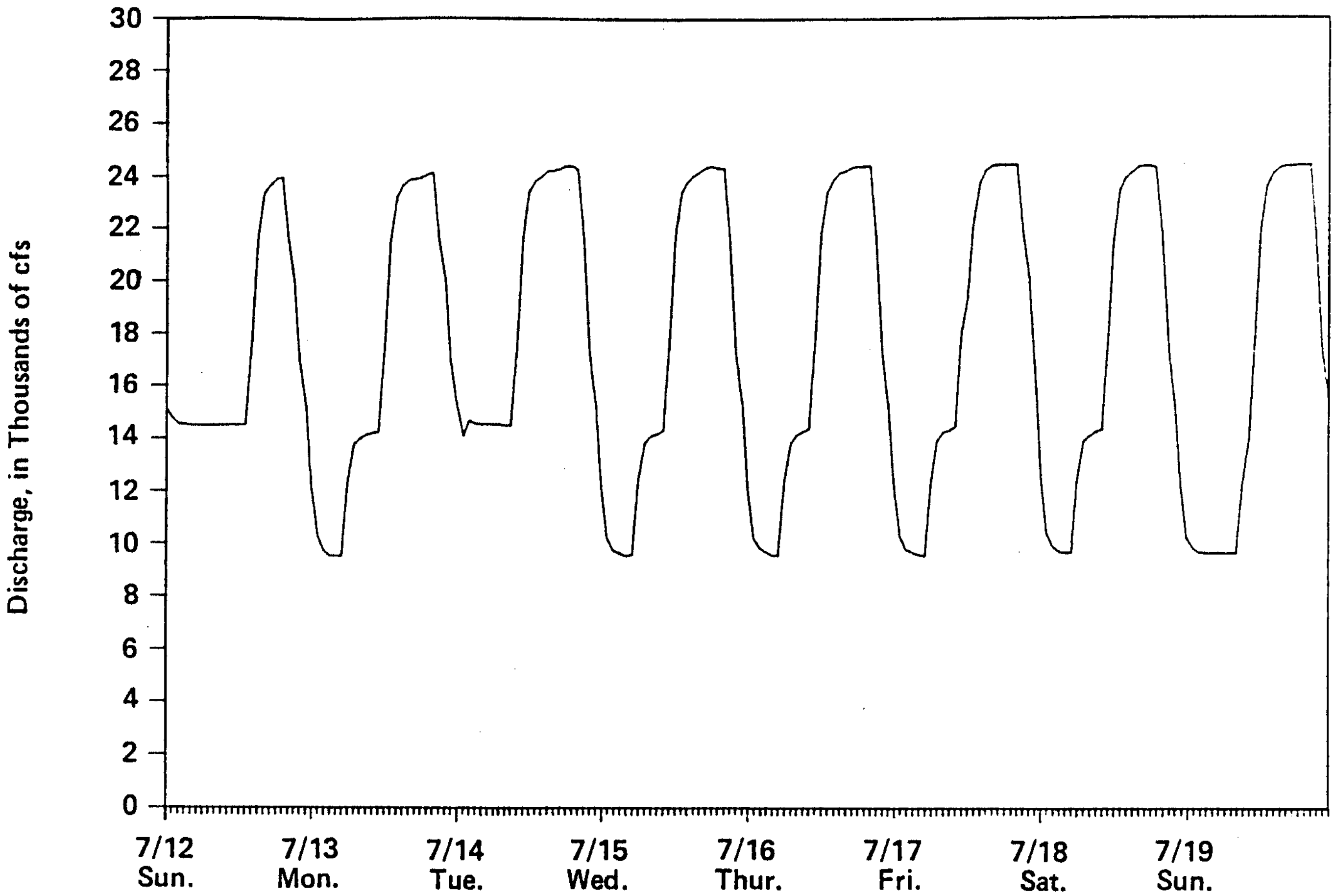
Figure 5

Hourly Flows on the Colorado River
Below Davis Dam (July 12-19, 1987)



Note:

Flow data obtained from U.S. Bureau of Reclamation Operations Records.

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CCSD River Discharge Study
Laughlin, Nevada

Weekly Hydrograph for Davis Dam Discharge, July 12-19, 1987

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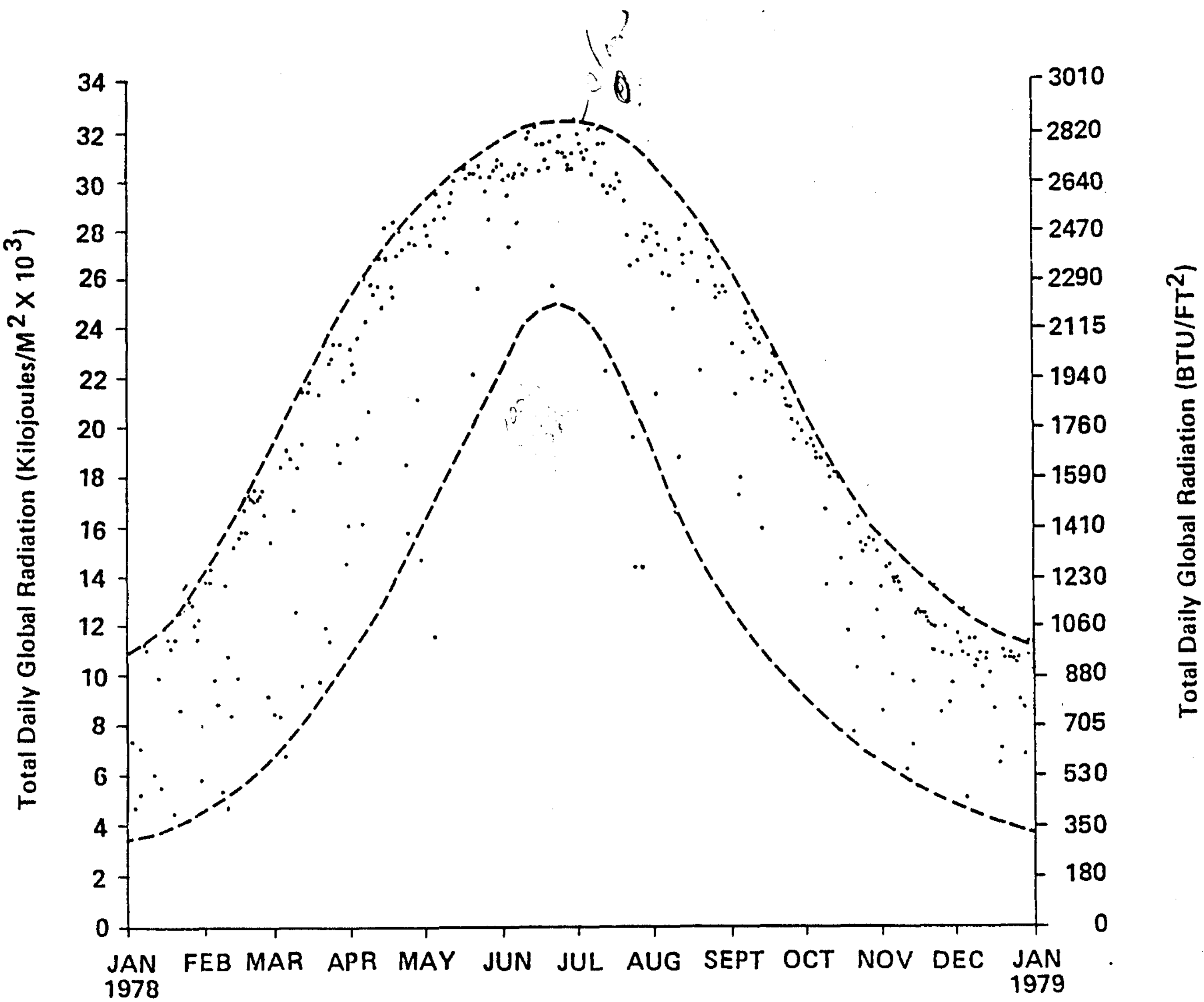
December 1987

Figure 6

Clark County (NV) Global Radiation Envelope



Note:

Data obtained from the National Climatic Data Center, NOAA, for the Las Vegas Solar Radiation Measurement Station.

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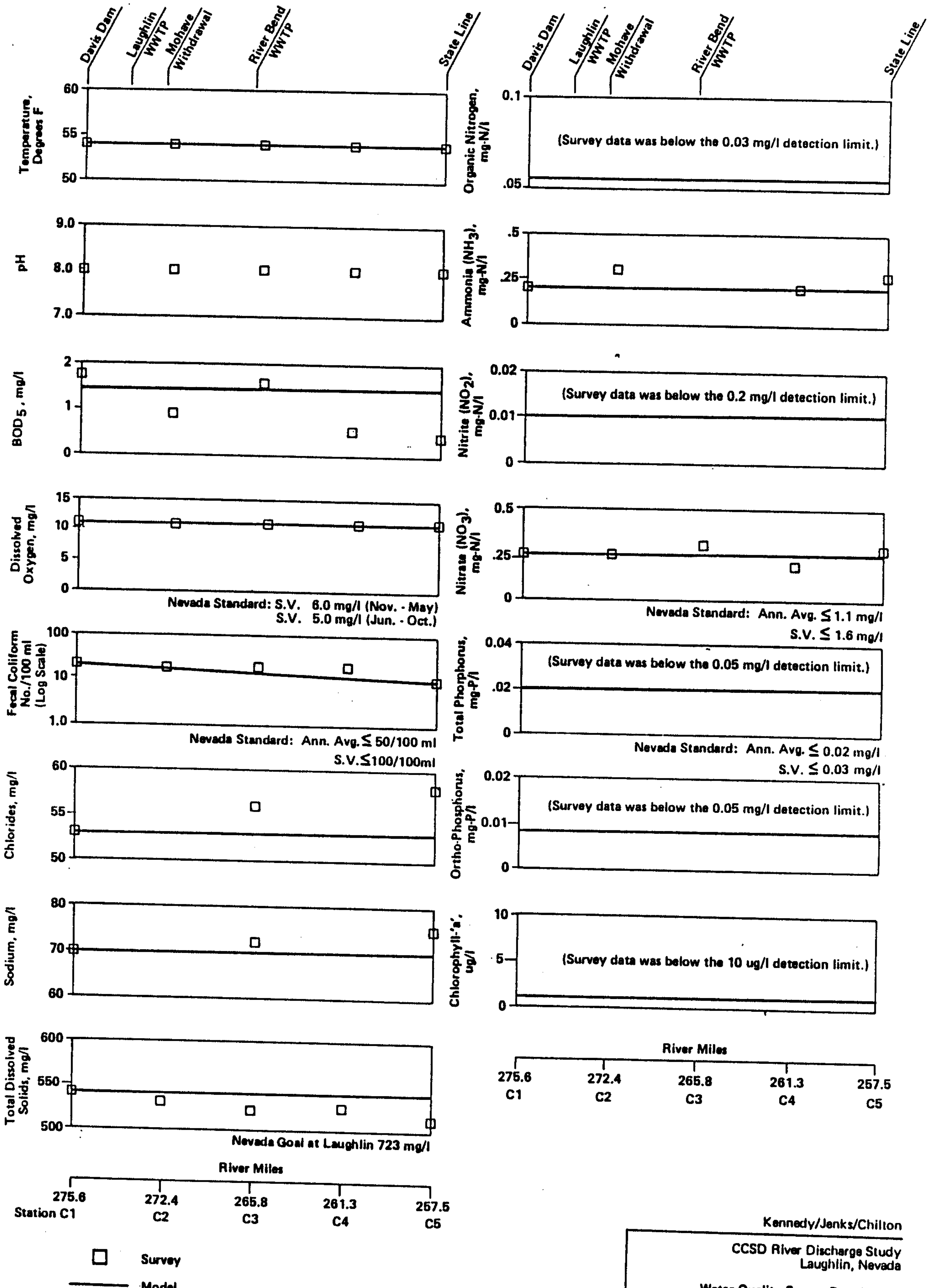
CCSD River Discharge Study
Laughlin, Nevada

Global Radiation Envelope for Clark County, Nevada

K/J/C 868834
December 1987

Figure 7



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CCSD River Discharge Study
Laughlin, Nevada

Water Quality Survey Data Versus Model Verification Results February 1987

K/J/C 868834
December 1987

Figure 8

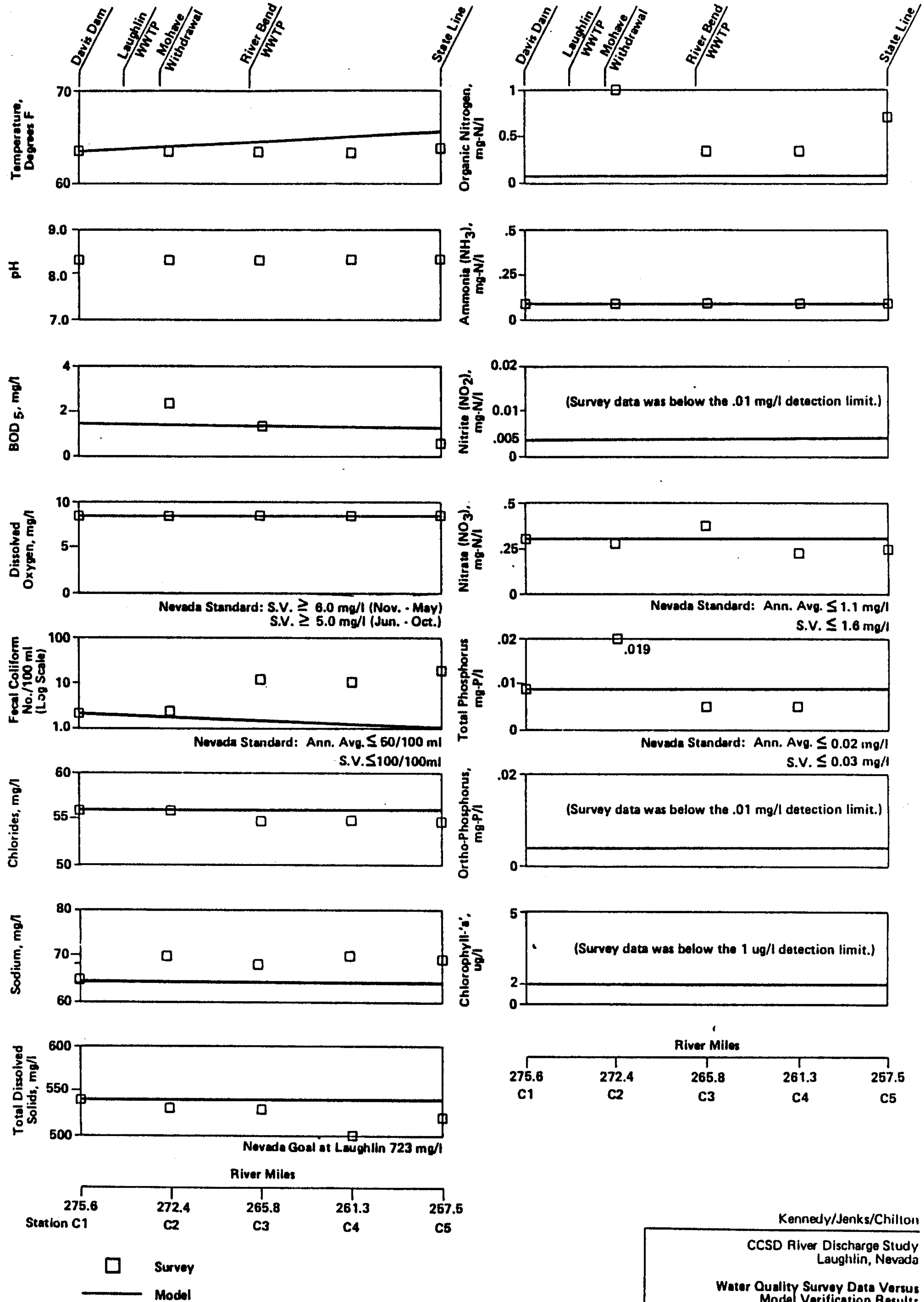


Figure 9

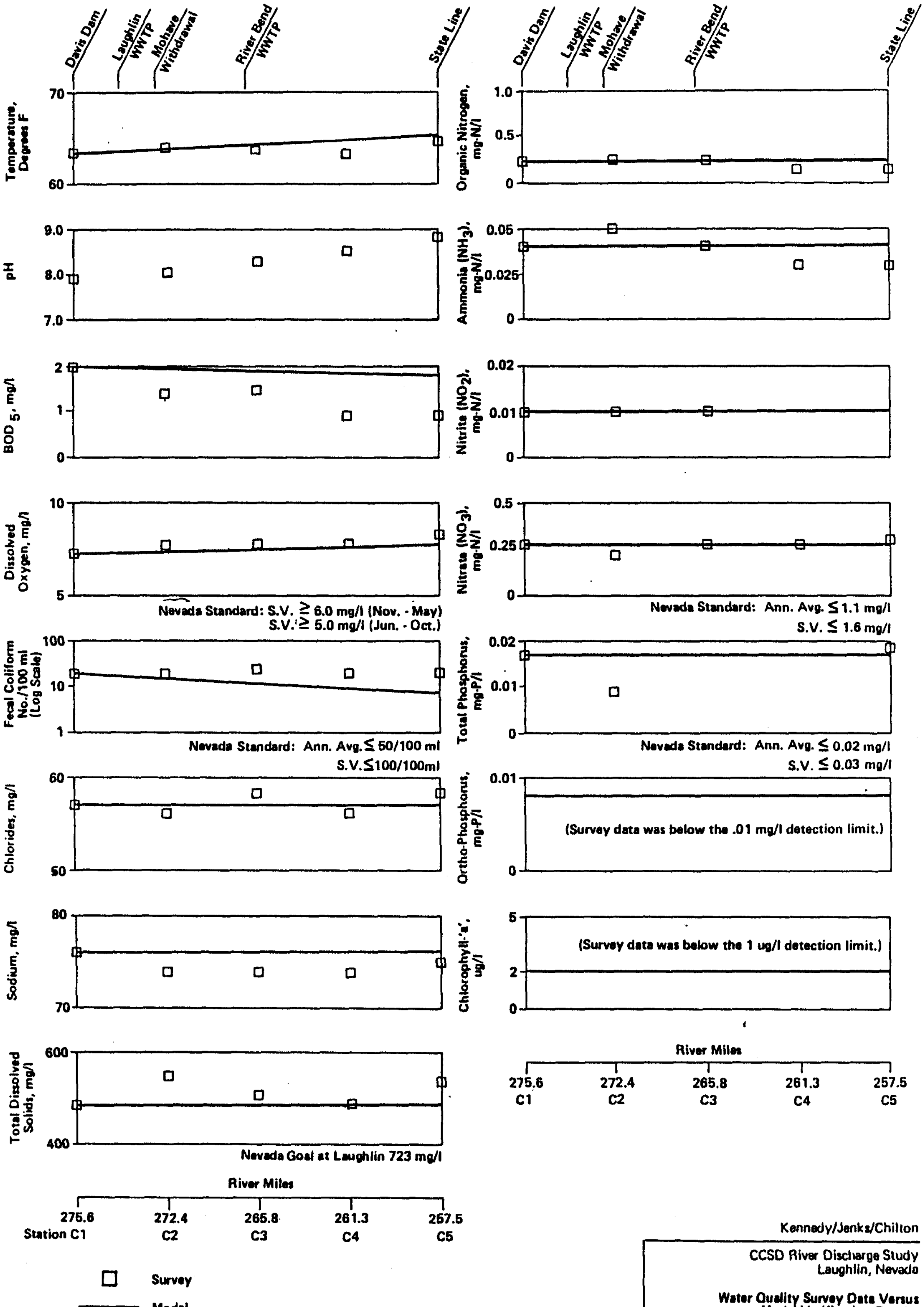
Kennedy/Jenks/Chilton

CCSD River Discharge Study
Laughlin, Nevada

Water Quality Survey Data Versus Model Verification Results June 1987

K/J/C 868034
December 1987

Figure 9



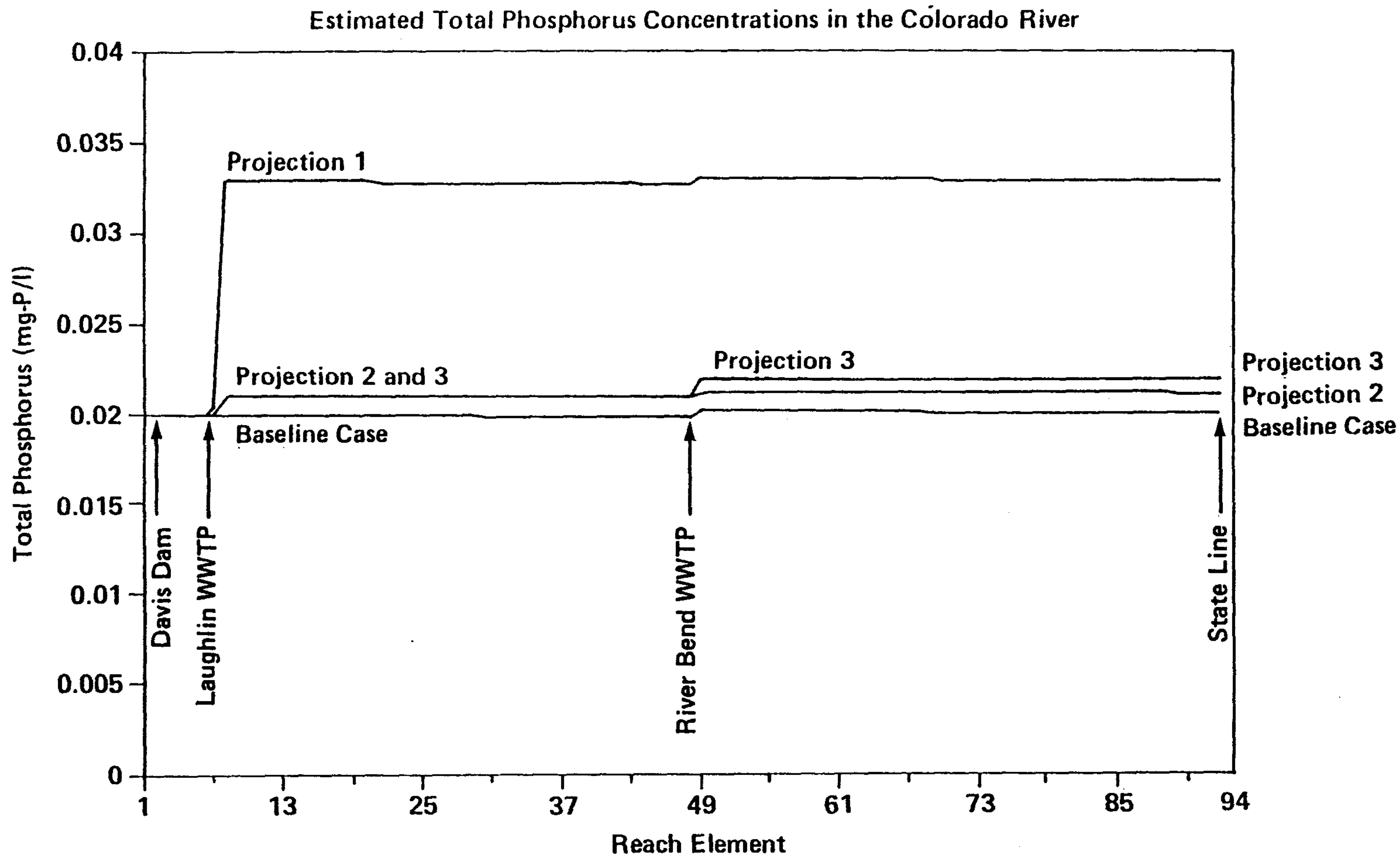
Kennedy/Jenks/Chilton

CCSD River Discharge Study
Laughlin, Nevada

Water Quality Survey Data Versus Model Verification Results October 1987

K/J/C 868834
December 1987

Figure 1



Kennedy/Jenks/Chilton

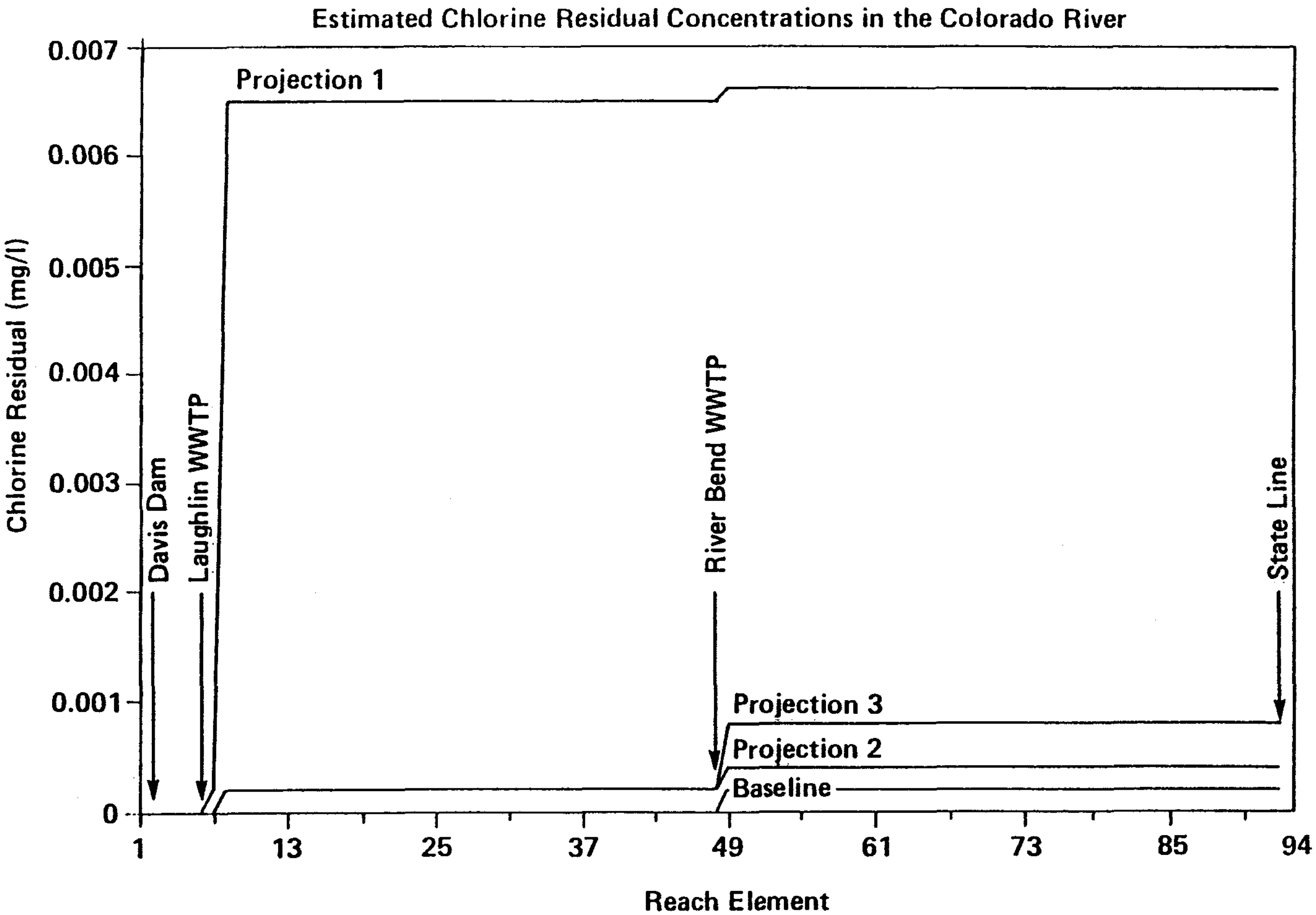
CCSD River Discharge Study
Laughlin, Nevada

Model Projection Run Results
Total Phosphorus Concentrations

K/J/C 868834
December 1987

Figure 11

Figure 11



Kennedy/Jenks/Chilton

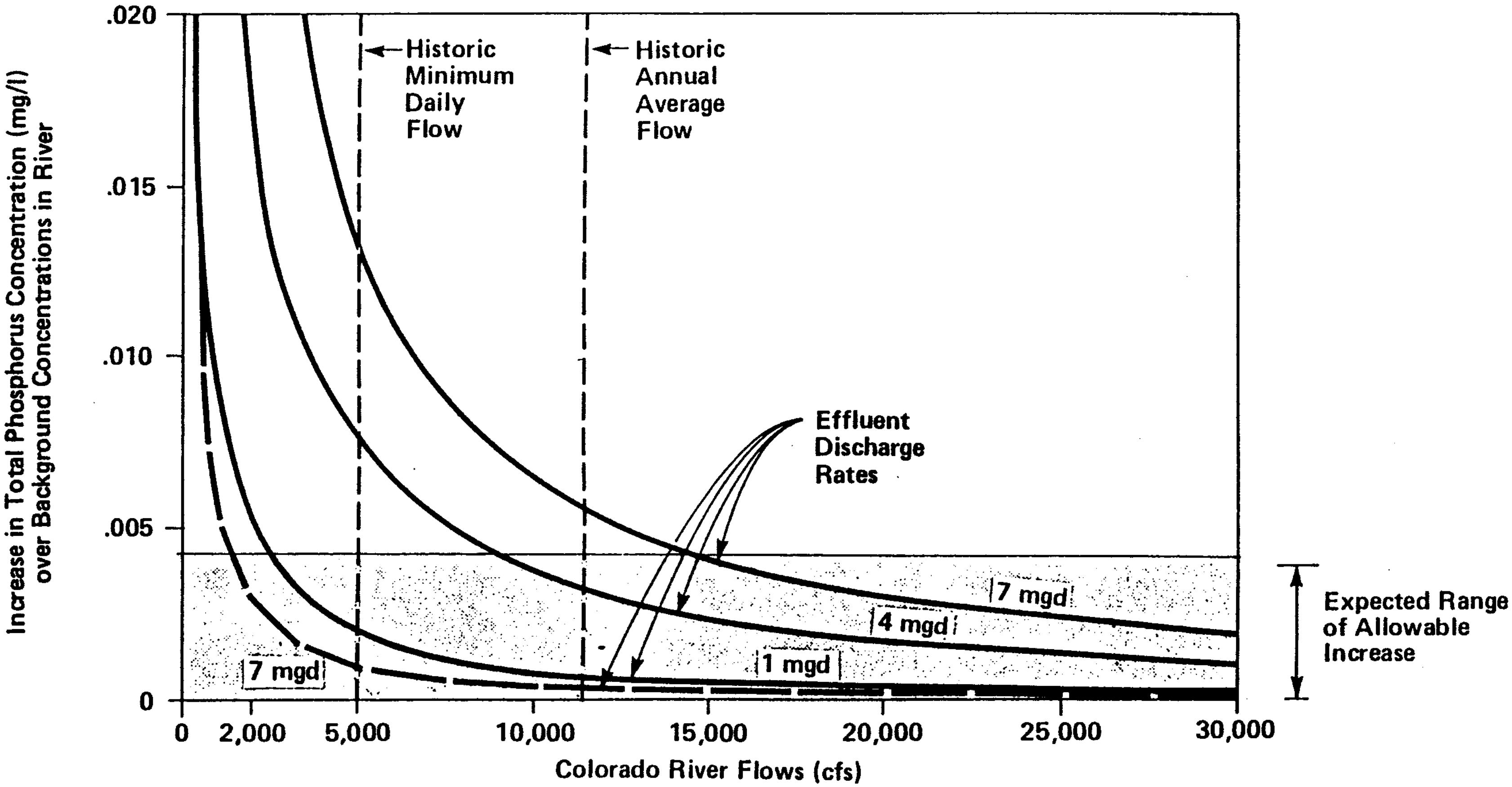
CCSD River Discharge Study
Laughlin, Nevada

Model Projection Run Results
Chlorine Residual Concentrations

K/J/C 868834
December 1987

Figure 12

Figure 12



Legend

Effluent Discharge without Phosphorus Removal (total phosphorus concentration = 6.0 mg-P/l)

Effluent Discharge with Phosphorus Removal (total phosphorus concentration = 0.5 mg-P/l)

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CCSD River Discharge Study
Laughlin, Nevada

Impacts of Proposed Laughlin Effluent Discharge on Phosphorus Levels in the Colorado River

K/J/C 868834
December 1987

Figure 13

ATTACHMENT A

REFERENCES

REFERENCES

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ATTACHMENT B

REPORT TO KENNEDY/JENKS/CHILTON INC.
"DYE DIFFUSION STUDY AND OUTFALL DIFFUSER DESIGN FOR LAUGHLIN, NEVADA"
FLOW SCIENCE, INC., NOVEMBER 23, 1987.

SEE SECTION III, DYE DIFFUSION STUDY FOR THIS REPORT

ATTACHMENT C

U.S. BUREAU OF RECLAMATION
PLOTS OF CROSS SECTIONS
RIVER MILE 275.6 TO 257.1, LOWER COLORADO RIVER

SEE APPENDIX

ATTACHMENT D

PLOTS OF VELOCITY AND DEPTH VERSUS RIVER DISCHARGE FOR COLORADO RIVER REACHES

SEE APPENDIX

ATTACHMENT E

COMPUTER OUTPUT WITH RESULTS OF MODEL VERIFICATION RUNS

SEE APPENDIX

ATTACHMENT F

COMPUTER OUTPUT WITH RESULTS OF MODEL PROJECTION RUNS

SEE APPENDIX

ATTACHMENT G

PROBABILITY PLOTS OF HISTORICAL WATER QUALITY DATA FOR THE COLORADO RIVER BELOW DAVIS DAM

SEE APPENDIX

Section III
Task 4.0 Dye Diffusion Study

DYE DIFFUSION STUDY

ATTACHMENT B

TO

SECTION I

COLORADO RIVER MODEL

ATTACHMENT B

REPORT TO KENNEDY/JENKS/CHILTON INC.
"DYE DIFFUSION STUDY AND OUTFALL DIFFUSER DESIGN FOR LAUGHLIN, NEVADA"
FLOW SCIENCE, INC., NOVEMBER 23, 1987.

Flow Science Incorporated
690 East Green Street
Pasadena, California 91101
(818) 304-1134

FLOW/SCIENCE

REPORT
to
KENNEDY/JENKS/CHILTON

DYE DIFFUSION STUDY

and

OUTFALL DIFFUSER DESIGN

for

LAUGHLIN, NEVADA

Flow Science Incorporated

690 East Green Street

Pasadena, CA 91101

FSI Reference 8704033
November 23, 1987

PART I: DYE DIFFUSION STUDY

INTRODUCTION

A system for returning treated wastewater to the Colorado River is being considered by Clark County Sanitation District for the City of Laughlin, Nevada. Proper design of such a system depends crucially on understanding the ability of the river flow turbulence to disperse and mix such return flows. Although theory does exist to describe the mixing ability of rivers (see Reference 1), it is important that the actual dispersing property be measured in the field to corroborate the analysis for the actual river. To this end, a field measurement program to establish the river dispersion coefficient was planned jointly by Kennedy/Jenks/Chilton and Flow Science Incorporated. The field work was completed on October 18, 1987, and this report describes the studies and presents the results obtained therefrom.

BACKGROUND

The dispersion of an effluent added to a river is described by the theory of turbulent mixing. As is described in standard texts (see, for example, Ref. 1), the mixing process occurs in three stages. First, there is jet-induced mixing that results from the manner in which the effluent is discharged. This mixing is controlled primarily by the geometry of the discharge structure. Second, there is an interaction between the discharge and the river flow that results in relatively rapid mixing of the discharge through the water depth. This stage of mixing can also be enhanced both by the design of the discharge structure and any possible density difference between the discharged effluent and the river water. In general, this mixing process is complete within a distance of several river depths from the point of discharge. The third, and final, stage is mixing across the river. This is in general a slow process that results in the effluent becoming completely mixed with the river flow to attain the ultimate possible dilution. Full mixing may not occur until many tens of river widths downstream from the point of discharge. This last mixing process has two basic elements, one is the turbulence associated with the river water motion, and the other is the transverse secondary flows that transport materials across the river. These flows are induced by river bends, sand bars, and shoals. In a straight section of river with reasonably constant depth the transverse mixing is slow because these secondary currents are minimal. However, for a river with many curves, pools, and shoals, complete mixing will occur much more rapidly.

The location studied for the proposed Laughlin wastewater discharge is the Nevada side of the Colorado River at the Laughlin Bridge. Downstream of this site, the river has a relatively straight alignment for a distance of about 10,000 ft (3000 meters), extending from the bridge to a cooling water intake for Southern California Edison's Mohave Generating Station. structure. The river cross-section in this straight reach is also relatively uniform, with an almost constant depth across the middle two-thirds of the river and gentle bottom slopes up to the river banks with a grade of approximately 2 in 100 (see Figure I-1). It is to be expected that in this reach of river the transverse mixing will be controlled almost solely by the river turbulence. Downstream of this straight section there is a sharp bend in the river, and the river bottom drops rapidly into a deep pool with a strong recirculating eddy. It is to be expected that this eddy will generate rapid mixing across the river.

PURPOSE OF FIELD STUDY

The purpose of the field studies described in this report was to establish the rate of lateral mixing across the river in the straight reach downstream of the bridge. This mixing rate is described by the lateral dispersion coefficient, a numerical quantity that determines the rate at which the peak concentration of a released effluent is reduced with distance from the point of release. By releasing a dye solution of known concentration at a constant flow rate, it becomes possible to determine the lateral dispersion coefficient by measuring the peak dye concentration at known distances downstream from the point of release. Knowledge of this lateral dispersion coefficient enables prediction of the concentration, at any location, of the constituents of treated wastewater released into the river. Optimal design of a discharge structure is therefore possible.

It is shown in Fischer et al. (Ref. 1, Eq. 5.7) that the concentration C(x,y) of a tracer at any point (x,y) downstream from a release point in a river is given by

$$C(x,y) = \left[\frac{M}{Ud}\right]\left[\frac{1}{4\pi\varepsilon_t x/U}\right]^{1/2} \exp\left(-y^2 \frac{U}{4\varepsilon_t x}\right)$$

where

x is the downstream distance from the release point (m)
y is the crosstream distance from the release point (m)
U is the river mean velocity (m/sec)
d is the mean river depth (m)
ε_t is the lateral dispersion coefficient (m^2/sec)
M is rate of tracer mass release (kgm/sec)
C(x,y) is the tracer concentration at (x,y) (kgm/m^3)

Therefore, on the axis of the effluent plume the concentration of effluent tracer is a maximum with the value C(x,0) and the lateral dispersion coefficient ε_t is given by

$$\varepsilon_t = \left(\frac{1}{4\pi x U}\right)\left(\frac{M}{dC(x,0)}\right)^2$$

In a field study all the quantities on the right-hand side are measured, or known, so that calculation of the lateral dispersion coefficient ε_t is possible. These formulas are appropriate for a discharge plume as long as it occupies only a fraction of the stream width. When the plume width becomes an appreciable fraction of the river width the calculations must be modified to account for the river banks, as described in Fischer et al., pg. 113, Eq. 5.9.

In addition to direct calculation of the lateral dispersion coefficient from measurement of concentrations of a released effluent, it is also possible to estimate it from physical details of the river flow. Laboratory and field experience has shown that a good estimate of ε_t can be obtained simply from a knowledge of the mean bottom shear stress and the water depth. In turn, the bottom shear stress is specified by the water surface slope, since the rate at which potential energy is released by the falling water must match the rate at which frictional work is done by the bottom shear stress. In hydraulics texts (Ref. 2) it is shown that

$$u_* = (gdS)^{1/2}$$

where

u_* is the shear velocity (m/sec)
g is the gravitational acceleration (9.82 m/sec^2)
d is the water depth (m)
S is the water surface slope (m/m)

With u_* known, it is shown in Fischer et al. (Ref. 1) that

$$\varepsilon_t \approx 0.15du_*$$

with the numerical coefficient actually ranging from 0.1 to 0.2.

From the above, it is seen that two separate estimates of the turbulent mixing property of the river are possible: one from actual measurements of released dye concentration, and the other inferred from the water surface slope, coupled with prior laboratory and field experience. In the Laughlin studies both methods were used, as will be described subsequently.

FIELD METHODS

As previously described, the direct field measurement of a lateral dispersion coefficient is based upon knowing the concentration of the effluent at specific sites downstream of the point of release. There are three major features of the field effort required to determine this concentration distribution. These are:

(i) the constant rate of release into the river of a known concentration of tracer material,
(ii) the ability to measure the tracer at low concentration within the river flow,
(iii) the ability to fix the location of the point of measurement with respect to the point of release.

Each of these will be discussed in turn.

Release of Tracer

Previous experience with field studies of this type has indicated that an ideal tracer material for release is Rhodamine WT, which is a 20% solution of rhodamine dye in an acid base. Rhodamine can be detected by a fluorometer at concentrations as low as 0.05 parts per billion (ppb). The key element in the tracer discharge is to maintain a constant flow rate of a known concentration. It was decided to maintain a discharge rate that would lead to an approximately 3 ppb concentration in the river if the discharge were well mixed with the total river discharge, which was expected to be 10,000 cubic feet per second (cfs), or 283.2 cubic meters per second (m^3/sec). The initial design of the test discharge system therefore called for a discharge of 0.85 gms/sec of solid rhodamine to give a completely mixed rhodamine concentration of 3 ppb.

In actual test, the mass discharge rate of solid rhodamine was 0.88 gms/sec into a river flow of about 9500 cfs (269 m^3/sec), implying a well-mixed concentration of 3.3 ppb.

The discharge fluid was obtained by mixing 3 liters (3.6 kgm) of 20 per cent Rhodamine WT with 77 liters of river water, to provide a discharge fluid with 8.9 gms of solid rhodamine per liter of discharge solution. This solution was released at the rate of 6 liters/min through a constantly monitored Fischer-Porter flow meter. The actual release of tracer dye solution was via a diffuser constructed from an 8-foot long section of 1/2 inch diameter galvanized iron pipe, which had been drilled with 20 holes, each 1 mm (0.040 inch) in diameter. The tracer solution was pumped from a mixing tank to a storage tank and thence via another pump through the flow meter and out the diffuser. The entire discharge assembly was located on board a pontoon boat moored to the second bridge pier from the Nevada shoreline of the river. The tracer discharge configuration is shown schematically in Figure I-2, and in use in Figure I-3.

Measurement of Tracer Concentration

The concentration of rhodamine in the river water was measured with a Turner flow-through fluorometer located on board a small boat, which could be maneuvered in the river within the tracer discharge plume. The fluorometer was calibrated with 100 ppb (parts per billion) and 200 ppb standard solutions made from the Rhodamine WT 20 percent solution and riverwater at the river temperature. (Rhodamine fluorescence is particularly sensitive to temperature variations so that uniform temperature of both calibration solutions and the field concentrations is important.) Calibration of the fluorometer the night before the field study and on the morning of the study showed no instrument drift at the 100 ppb level. The instrument showed a linear response in the range 0-200 ppb, but became non-linear at 500 ppb. All field measurements were in the range 0-100 ppb.

The fluorometer was mounted in line with a 2 gallon per minute pump using 5/8-inch diameter plastic garden hose. A T-valve enabled rapid switching from one inlet hose about 3 feet long, whose end was located at a depth of 1 ft below the surface, to another about 10 feet long. The latter hose end was held near the river bottom by two pounds of lead. It was apparent that at stations in the river more than 200 ft (61 m) from the point of discharge the released dye was well mixed with depth, so that only surface measurements were continued for the duration of the study.

Location of Fluorometer

The fluorometer was mounted on a small maneuverable boat equipped with a survey rod that could be observed from a total station onshore. The boat crew and surveyor were in constant radio communication. This system enabled the precise determination of the boat location and water depth. In addition, relative water surface elevations were established by locating the survey rod at the water surface at the bridge pier and at a location 9100 ft downstream. The water surface slope so established was 4.95×10^{-4} at a river flow rate of 9500 cfs.

RESULTS OF THE STUDY

The results of the field work established the tracer dye concentration at specified locations downstream of the release point. The maximum width of the dye plume and the river bottom profile were also established. The following Table I-1 gives the peak measured dye concentration at the distance specified from the point of release. Column 1 is the distance from the point of release, column 2 gives the peak concentration, as measured on a profile through the plume at that distance location. Column 3 is a check measurement established by locating the fluorometer inlet at what appeared to be the visual center of the plume. Column 3 measurements were recorded on a second pass of the survey boat at the conclusion of the test after all of the profiles had been established.

Distance vs Tracer Concentration			
Column 1		Column 2	Column 3
Distance from Source		Peak concentration on profile	Check measurement visual peak
(ft)	(m)	(ppb)	(ppb)
200	61	100	
500	152	52	48
1000	305	41	32
2000	610	33	25
5000	1524	21.5	19
8000	2438	15.0	17.0
10000	3048	5.0	5.0

Table I-1. Tracer dye concentration at locations indicated.

Calculation of the lateral diffusion coefficient at any distance from the point of discharge requires that the mean flow velocity be known. This was not measured directly but was inferred both from the known river flow rate and river cross-sectional area, and from the Manning's equation with an estimated roughness coefficient.

From the river depth profile and width it is estimated that the flow cross-sectional area is approximately 3000 sq ft, giving a mean velocity of 3.17 ft/sec at a river discharge of 9500 cfs.

Alternatively, Manning's equation, which is

$$U = \frac{d^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

where

U is the mean velocity (m^2/sec)
d is the water depth (m)
S is the water surface slope
n is the Manning's roughness coefficient

(Note that if the depth is taken in feet the coeffficient is 1.486 not 1.00, and the velocity is in ft/sec. The "n" value remains the same.)

This formula gives

$U = 0.91$ m/sec (3.00 ft/sec)

when

$d = 2.13$ m (7.00 ft)
$S = 0.000495$
$n = 0.040$ (stony cobbled river)

This is consistent with the estimate based on cross-sectional area and flow rate.

Note that an independent assessment of the Manning's "n" can be made using the methods in Daugherty and Ingersoll (Ref. 2). According to this text, the Darcy-Weisbach friction factor is related to "n" by the equation

$$n = d^{\frac{1}{6}} \left(\frac{f}{8g}\right)^{\frac{1}{2}}$$

and f is in turn related to the relative roughness of the channel through the formula

$$f^{-1/2} = 2\log_{10}(14.8\frac{d}{\varepsilon})$$

where ε is the size of the river roughness, and d is the water depth. Roughness elements about one foot in size give an f value of 0.062 when the water depth is 7 feet. This translates to a value of n of about 0.035,which in turn represents a river velocity of 3.43 ft/sec. In other words, there is about a 10 percent uncertainty in the estimate of the river velocity and hence the estimates for dispersion coefficient.

In addition the shear velocity u_* computed from

$$u_* = (gdS)^{1/2}$$
$$= 0.10 m/sec (0.334 ft/sec)$$

This is about 10 percent of the mean velocity, which is again consistent.

In the calculations of the lateral diffusion coefficient we therefore use the estimate of 0.91 m/sec (3.00 ft/sec) for the river mean velocity.

With the above information the lateral dispersion coefficient can be calculated from the data in Table I-1, according to the formula previously presented. The results are presented in Table I-2.

Lateral Dispersion Coefficient			
Column 1		Column 2	Column 3
Distance from Source		From peak conc. measurement	From check measurement
(ft)	(m)	(m^2/sec)	(m^2/sec)
200	61	0.0243	
500	152	0.0362	0.0425
1000	305	0.0290	0.0476
2000	610	0.0224	0.0390
5000	1524	0.0211	0.0270
8000	2438	0.0271	0.0211

Table I-2. Lateral dispersion coefficient deduced from concentration measurements.

The average of all the field test results in Table I-2 (both peak concentration measurements and check measurements) shows a lateral dispersion coefficient of 0.0307 ± 0.0028 m^2/sec, or 307 ± 28 cm^2/sec.

A computation of this dispersion coefficient using the physical properties of the flow as described previously in the formula

$$\varepsilon_t = 0.15 d u_*$$

gives an estimate of 0.032 m^2/sec, or 320 cm^2/sec, based on the shear velocity of 0.10 m/sec and depth of 2.13 m. To within the error in measurement this is in almost exact agreement with the direct measurement.

One further calculation is possible from the field data and model. This is the approximate width of the tracer plume. Using the formula for C(x,y) presented on page 2, the boundary of the plume can be defined by the points where the concentration falls to about 5 to 10 percent of the peak concentration. Given the river flow velocity and the previously obtained estimate of the dispersion coefficient, the plume width to % concentration is

$$y = 2\left[-4x\frac{\varepsilon_t}{U}\log_e\frac{\%}{100}\right]^{1/2}$$

Table I-3 presents the approximate measured plume width and that calculated from the relationship above. The agreement is very good, given that the boundaries of the plume to a given concentration could only be approximately estabilished in the fast moving river.

Plume Width							
Column 1		Column 2		Column 3		Column 4	
Distance From Source		Calculated Width @ 10%		Calculated Width @ 5%		Measured Estimate	
(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)
61	200	9	29	10	33	<13	<42
152	500	14	46	16	52	15	49
305	1000	20	65	23	75	19	62
610	2000	28	92	32	105	26	85
1524	5000	44	145	51	167	51	167
2438	8000	56	183	64	210	>51	>167

Table I-3. Calculated vs actual plume width based on $U = 0.91$ m/sec., $\varepsilon_t = 0.032 m^2/sec$

Finally, one key observation made during the test was that the river bend, located approximately 10,000 feet downstream from the Laughlin bridge, generates very significant secondary currents. These secondary currents include both a reverse flow eddy near the surface on the Nevada shore and a transverse current that carries water from near the Nevada shore to the Arizona shore. The fluorometer measurements showed that the deep pool downstream of the river bend had a peak dye concentration of 5.0 ppb. This should be compared to the estimated completely mixed concentration of 3.3 ppb. This result indicates that mixing across the river was almost complete at this location and field observation of the dye plume in the river confirmed this. The visible dye plume approaching the river bend was approximately 160 feet wide (about one third of the river width), whereas around the river bend no separate plume could be distinguished in the essentially uniform color river.

CONCLUSIONS FROM THE FIELD STUDY

The estimates of the lateral dispersion coefficient for the Colorado River at Laughlin, Nevada, agree extremely well with those predicted by the methods of Fischer et al. (Ref.1).

Since the lateral dispersion coefficient is a key factor in the design of a diffuser system for return of treated wastewater to the river, a strong basis for design has been estabilished.

Field studies show that in the straight reach of the river downstream of the Laughlin bridge the lateral dispersion coefficient can be defined by

$$\varepsilon_t = 0.15du_*$$

where

d is the water depth
u_* is the shear velocity

and

$$u_* = (gdS)^{1/2}$$

where

g is the gravitational acceleration
S is the water surface slope

Around the river bend downstream of the Laughlin bridge the river is well mixed.

The design of a diffuser system can therefore be based on the water depth and the water surface slope, and with the river roughness and rating curve known, the dispersion coefficient can be closely estimated as a function of the flow rate in the river. This will be used as the basis for the design of a discharge system in Part II of this report.

PART II: WASTEWATER OUTFALL DIFFUSER

INTRODUCTION

Clark County (Nevada) Sanitation District is considering construction of an outfall diffuser to return treated wastewater from the City of Laughlin to the Colorado River. Part II of this report presents the results of an analysis of candidate designs for this outfall diffuser. The basis for the report will be the methods of diffuser design and analysis as described in the text "Mixing in Inland and Coastal Waters" by Fischer *et al* (Ref. 1). Part I of this report presented the results of a field study at the Laughlin site that showed clearly that the prediction of the mixing properties of the river at the site can be estimated to within ±15 percent, if the river flow is known.

The field study was performed during a period of low river flow, which will be the most critical time for the diffuser operation. This means that the dispersion coefficients used in the diffuser analysis and design have been verified for the very flows of greatest importance to the diffuser performance.

PROPOSED FLOWS

The proposed effluent discharge rates will vary from 1-7 mgd (million gallons per day) representing flows in the range 1.55-10.8 cfs, (0.044 - 0.31 m^3/sec). The minimum river flow at which it is proposed that effluent will be released is 5000 cfs (142 m^3/sec). This base flow is established when a single turbine unit is being operated at Davis Dam, and it most often occurs very early in the morning when electricity demand is low and effluent flow rates are low. The maximum anticipated ratio of effluent to river flow is therefore approximately 1:462. The results of the field study indicate that it should be possible, through appropriate diffuser design, to attain dilutions close to 460 downstream of the river bend located south of the Laughlin bridge.

The physical properties of the effluent that may be important to the design and operation of the diffuser are its difference in temperature and dissolved solids concentration from the river water. Table II-1 presents the maximum and minimum effluent temperatures expected. In addition, the effluent is reported to have a maximum total dissolved solids of 1420 mg/liter. By comparison, the K/J/C Engineers' June, February and October sample reports, dated 28 July 1987, 5 May 1987 and 14 December 1987 respectively, show the river temperatures to range between 16.0 - 18.0 degrees Celsius in June, 11.6 - 12.5 degrees Celsius in February, and 16.3 - 20.0 degrees in October. The river temperature during the field study on October 18, 1987, was 17 degrees Celsius. River samples show a total dissolved solids of 540 mg/liter.

River and Effluent Temperatures				
Month	River Temperature Min.	Max.	Effluent Temperature Min.	Max.
Nov.			18	23
Dec.			17	22
Jan.			18	21
Feb.	11.6	12.5	18	22
Mar.			21	23
Apr.			22	24.3
May			22.2	25.6
Jun.	16.0	18.0	25.0	27.0
Jul.			25.5	28.0
Aug.			28.0	29.0
Sep.			23.0	27.0
Oct.	16.3	20.0	22.0	25.0

Table II-1. River and effluent water temperatures.

Using the above data it is possible to derive the maximum difference in density between the proposed effluent and the river water. This occurs with the river at 16 degrees and the effluent at 29 degrees. Accounting also for the difference in total dissolved solids concentration, the difference in density is calculated to be 1.852 kgm/m^3.

The minimum river flow of 5000 cfs (142 m^3/sec) is believed to be equivalent to a water depth of 4.5 ft (1.37 m) at the Laughlin Bridge with a mean river current velocity of 2.24 ft/sec (0.68 m/sec). These values are computed using a water surface slope of 4.95×10^{-4} (as measured at the site), and a Manning's "n" value of 0.040 with an equivalent river width of 500 ft based on the estimated cross-sectional areas of 2230 ft^2. At this water depth and surface slope the estimated lateral dispersion coefficient is 0.0175 m^2/sec (175cm^2/sec), according to the formulae developed in Part I of this report.

The relevant data at a river flow of 5000 cfs (142 m^3/sec) are summarized in Table II.2.

River flow	Q	5000	cfs	142	m^3/sec
River velocity	U	2.24	ft/sec	0.68	m/sec
River depth	d	4.46	ft	1.36	m
Shear velocity	u_*	.27	ft/sec	0.081	m/sec
Dispersion coeff.	ε_t	0.188	ft^2/sec	0.0175	m^2/sec
Density diff.	$\Delta\rho$	0.116	lb/ft^3	1.852	kgm/m^3

Table II-2. Relevant data for the river flow at 5000 cfs (142 m^3/sec).

PROPOSED EFFLUENT DILUTION

The calculation of the effluent dilution at the minimum flow can proceed based on two different design philosophies. One philosophy would indicate that the effluent should be immediately mixed with as much river flow as possible to attain the maximum possible dilution in the minimum length of river flow. According to this line of reasoning, a minimum reach of river will be affected by the effluent discharge. However, in order to implement this design approach it is necessary to construct a discharge structure that spans the river, in effect creating a bar across the river. If the structure extends across the complete crossection of the river there will be a region of low dilution that any migrating fish will have to pass through.

An alternative philosophy is to simply release the effluent at a single point in the river and allow the mixing to proceed downstream, thus creating an impact zone of low dilution effluent that extends down the river in a narrow band rather than across the river. In this discharge configuration it is presumed that no bar is created across the river and migrating fish can find an effectively non-impacted section of the river in which to negotiate the point of effluent discharge.

At the Laughlin site it appears appropriate to adopt a hybrid of these two design philosophies. If the discharge of effluent is restricted to one-half of the river, and the rate of mixing scheduled in such a way that the effluent is almost fully mixed with that half of the river flow as the flow enters the river bend, then complete mixing will rapidly ensue in the recirculating zone at the river bend. In this way only half of the river will be impacted at dilutions less than that of the fully diluted effluent. Given that the actual discharge structure will be restricted to the Nevada side of the river this design philosophy seems logical.

The final point for consideration is whether there is any specific advantage to building a discharge structure that extends the full width of the Nevada side of the river. In order to consider this it is necessary to understand the three different mixing processes that are involved when an effluent is introduced into a moving body of water. As explained in Part I of this report, the three processes are:

(a) diffuser induced mixing, where the diffuser discharge jets entrain ambient water into the jets and jet turbulence is the primary mixing mechanism.
(b) mixing over the water depth as a result of turbulence in the ambient fluid.
(c) mixing across the river by the river turbulence.

In a highly turbulent flow such as the Colorado River at Laughlin, diffuser jet mixing is very quickly overwhelmed by the ambient turbulent mixing. (This was very apparent in the dye studies performed on the river, where the dye released was injected from a small diffuser.) The diffuser jets rapidly mix over the water depth so that unless the effluent is spread uniformly over the river section at the point of discharge, it is the river turbulence generating the lateral mixing that controls the dilution rate. The effect of the discharge structure itself is therefore represented by a change in the effective location of the effluent discharge point. To put this another way, if the discharge diffuser itself provides a 50:1 dilution within 50 feet of the point of discharge, this same dilution may have been attained within 150 ft of the point of discharge if the diffuser did not exist at all, and there had been a single point discharge into the river. In other words, the diffuser would in this case change the effective origin of the discharge point by 100 feet. In so far as the river is concerned, at a point 8000 ft downstream there may be no effective change in the dilution whether the diffuser is present or not. Clearly, this will not be the case if a diffuser discharges effluent uniformly over the Nevada half of the river.

Given the above discussion the question to resolve is the following: Should a diffuser be constructed that distributes effluent uniformly over the Nevada half of the river, or is it appropriate to discharge the effluent at, say, four locations, making sure that at these four locations the effluent is very rapidly mixed over the water depth.

The reason for considering these two alternate approaches is that very significant construction savings may be possible by utilizing the Laughlin Bridge and the bridge piers as a support structure for the proposed discharge. This report therefore addresses two possible discharge configurations, corresponding to diffuser structures located on the bridge piers, and therefore orientated parallel to the flow, and an alternate of a diffusion structure spanning the Nevada half of the river.

BRIDGE PIER DIFFUSERS

The Laughlin Bridge has a total of five piers located in the stream. It is not known if the central pier is wholly or partially within the Nevada state line. Assuming that this pier is excluded from possible use, then there are two piers accessible for use as diffuser supports. It can be envisaged that a diffuser could be attached on each side of pier, giving a total of four diffusers and a total diffuser length of between 80 ft and 100 ft, depending upon the length of pier available. The minimum water depth at a flow of 5000 cfs is estimated to be approximately 4.5 ft, so that locating each diffuser about two feet from the river bottom would avoid interference with the river cobbles moving down the river, and yet not expose the diffuser at low water. The scheme is depicted in Figure II-1.

If the proposed discharge is split evenly between the four diffusers, then each pier would introduce one-half of the flow into the river stream. On this basis the peak concentration of effluent, and the plume width downstream of each pier, can be calculated using the methods described in Part I. The appropriate dispersion coefficient for these calculations is 0.0175 m^2/sec, with a water depth of 1.36 meters and a stream velocity of 0.68 m/sec, as presented in Table II-2. The concentration calculation assumes no effective use of the diffuser to provide additional initial dilution. Table II-3 summarizes the results of such a calculation, assuming that the effluent is split equally between two piers, and that there is no initial dilution from the action of the diffuser on each pier. The calculated width of the plume generated as a function of distance downstream from the pier is given in Table II-4. Since the piers are 120 ft (37 m) apart it can be seen that the plumes will begin to interact about when they enter the river bend, where each plume is about 120 ft (35 m) wide, as defined by a concentration of 10 per cent of the maximum centerline concentration. Tables II-3 and II-4 therefore establish a "worst case" situation if two piers were used with no initial dilution from the diffuser, other than mixing over the depth.

Dilution of Effluent					
Distance from Source		Effluent Flow Rate 0.5 mgd (22 kgm/sec)		Effluent Flow Rate 3.5 mgd (154 kgm/sec)	
(ft)	(m)	Max. Conc. (gm/l)	Min. Dilution	Max. Conc. (gm/l)	Min. Dilution
200	61	5.4	185	37.8	26.4
500	152	3.4	294	23.8	42
1000	305	2.4	417	16.8	60
2000	610	1.7	588	11.9	84
5000	1524	1.1	909	7.7	130
8000	2438	.85	1177	6.0	168
Fully diluted		0.31	3237	2.16	462

Table II-3 Concentration of effluent and dilution for 1 mgd and 7 mgd flows with flow split between two piers. Assumes no additional dilution from diffusers.

Width of Plume from Each Pier			
Distance from Pier		Plume Width	
(ft)	(m)	@ 10% (m)	@ 5% (m)
200	61	5	6
500	152	8	9
1000	305	11	13
2000	610	16	18
5000	1524	25	29
8000	2348	31	35
10000	3048	35	40

Table II-4. Width of plume downstream assuming point source with no diffuser action.

The effectiveness of using a diffuser to establish initial dilution can now be established. For example, for the 1 mgd discharge any diffuser design must attain a dilution of better than 185:1 at a point 200 ft downstream of the pier to be any more effective than the rate at which the river is mixing the flow. Thus, for such low flows it may be cost effective not to use any diffuser at all. However, for the discharge of 7 mgd the predicted dilution at 200 ft (61 m) downsteam is only 26:1, so that there is potential to hasten the dilution process by constructing an effective diffuser. Clearly the most effective diffuser, insofar as mixing is concerned, is one that spreads the discharge uniformly over the Nevada half of the river, and this will be considered subsequently.

If the flow is uniformly distributed to four bridge pier diffusers, each 20 ft long and located parallel to the river flow and two feet from the river bottom, then the initial dilution can be predicted from a consideration of the rate of flow of river water past the diffuser. To perform this calculation it is necessary to assess the cross-section of the river stream tube that intersects the diffuser. This will be controlled by the velocity at which the effluent is jetted into the river stream from the diffuser orifices.

With four diffusers 20 ft (6 m) long, the maximum discharge per unit length is 0.0125 m^3/sec/m (0.135 cfs/ft). This flow could be sustained through 1.0-inch diameter orifices spaced one foot apart and discharging at a velocity of 25 ft/sec, which represents a jet to river velocity ratio of about 11 to 1. For this type of diffuser the dilution obtained is governed by the size of the stream tube intercepted by the diffuser jets, which in turn is governed by the trajectory of the diffuser jets as they discharge into the flow. This subject is addressed in Fischer *et al.* (Ref. 1, p. 352). It is shown that a jet discharging in a crossflow will penetrate an approximate distance z given by the relationship

$$z = Cz_M(x/z_M)^{\frac{1}{3}}$$

where

- z is the crosstream coordinate of jet centerline
- x is the downstream coordinate of the jet centerline
- z_M is a scale length defined by the jet parameters
- C is a constant, (approx. 2.0)

The scale length z_M is defined by jet momentum flux, M, and the river velocity, U. The jet momentum flux is given by $M=Qu_j$, where Q is the jet flow rate and u_j the jet velocity, and $z_M = M^{1/2}/U$.

For a 1-inch diameter jet discharging at 25 ft/sec (7.6 m/sec), the jet will travel approximately 5 ft (1.5 m) into the stream in the time the flow travels the length of the diffuser 20 ft (6 m). Thus, we can estimate that a diffuser oriented parallel to the flow, and located on one side of a pier, will intersect a flow tube defined by the water depth and the farthest distance a jet will reach into the flow, about 5 ft (1.5 m). Each diffuser will therefore produce an initial dilution that is defined by the ratio of river flow in this tube to the diffuser flow, or about 19:1 if the river depth is 4.5 ft (1.36 m) and the velocity 2.24 ft/sec (0.68 m/sec). (Each diffuser will have, at maximum, a flow of 2.7 cfs, which is one quarter of the total flow of 10.8 cfs).

It can be seen that this dilution is not that different from what would be expected at 200 ft (61 m) downstream if the discharge were released from a single source point.

Furthermore, the width of the plume from each pier (two diffusers) will be roughly of the same width as that calculated for the single source plume at about 200 ft (61 m) downstream. In other words, the effect of the diffusers is to move all of the dilutions about 200 ft (61 m) upstream from where they would have occurred if the discharge had been released from two source points located one on each pier. Of course, the region of the river bed influenced by effluent with a dilution of less than 20 is, with the diffuser, confined to a small region in the immediate neighborhood of the pier.

ALTERNATIVE DIFFUSER DESIGN

If the dilution patterns generated by the low cost discharge design previously discussed are unacceptable, then an alternate design giving high immediate dilutions can be considered. In such a design a diffuser would be constructed across the river within the Nevada state line.

Consider the same 80 feet of diffuser as before with a maximum anticipated flow per unit length of 0.135 cfs/ft (0.0125 m^3/sec/m). The immediate dilution that could be obtained from such a diffuser is the river flow per unit width over the diffuser divided by the diffuser flow per unit length, which is 75:1. If in addition an allowance is made for a horizontal spread a distance equal to twice the water depth, then this initial dilution will be increased to about 83 :1. Clearly, the longer the diffuser the higher the immediately available dilution because the discharge per unit length of diffuser can be reduced. For a diffuser spanning the river between two piers (120 ft, 37 meters), the dilution could be increased to 120. For a diffuser spanning almost the entire Nevada side of the river, about 240 ft (73 m), the dilution would be about 230, which is half the ultimate dilution of 460.

The design of a diffuser to accomplish these initial dilutions is relatively straightforward, and simply requires determination of an appropriate jet orifice size and spacing along the diffuser. The following Table II-5 gives the expected dilutions for diffusers of different lengths, based on restricting the orifice discharge velocity to 15 ft/sec. (For diffuser jets directed toward the water surface it is probably desirable to reduce the velocity to avoid water surface displacement.)

The calculation of the dilution of the jet mixing is straightforward since the jets will not interact immediately. The transition from the initial jet mixing to the condition where the discharge is completely mixed with the river flow intercepted by the diffuser, is more complex and must consider the merging of the jets. This part of the analysis is best done using one of the available computer codes , such as UDKHDEN (Ref. 3). Although this code in particular does not model the mixing generated by the river flow turbulence, it does simulate the jet merging and uses an "aspiration" coefficient to give an approximate estimate of the mixing in the jet-merging phase of flow. In this way it can provide an estimate of the distance downstream from the diffuser at which the discharge will be fully mixed with the intercepted river flow. However, this code will not properly model the subsequent spread of the mixed effluent across the river, since it does not include any information about the river turbulence. Table II-5 includes the results of UDKHDEN calculations to determine the estimated distance downstream where the diffuser jet discharge is fully mixed with the intercepted river flow across the diffuser.

Dilutions From Cross-stream Diffusers			
Diffuser length (ft)	80	120	240
Flow/unit length (cfs/ft)	0.135	.090	.045
Orifice velocity (ft/sec)	15	15	15
Orifice spacing (ft)	1.0	1.5	3.0
Orifice diameter (ins)	1.25	1.25	1.25
Estimated fully mixed dilution	83	120	230
UDKHDEN Dilution @ 50 ft	77	97	175
UDKHDEN Dilution @ 100 ft	102	126	225
UDKHDEN Dilution @ 200 ft	>120	160	>280

Table II-5. Dilution estimates based on river flow interception compared with UDKHDEN calculated dilutions.

RANGE OF FLOWS

It is apparent that the diffuser will not always be operating at the highest or lowest flow rates. The 1 mgd flow rate is presumed to be representative of the initial flow rates, whereas the 7 mgd represents the immediate maximum flow anticipated from growth. The diffuser designs discussed here could be staged to match the anticipated growth. For the bridge pier proposal, diffusers could be added one or two at a time. For the cross-stream diffusers it would seem appropriate to select and install a structure once, and if necessary close off diffuser ports until the flows develop to sustain the jet flows associated with each port. This technique has often been used to avoid more than one construction effort. For example, the City of Sacramento waste water diffuser has only recently had additional discharge ports opened, even though the diffuser was initially placed in operation more than 10 years ago. The detailed design calculations for this system should address the specific range of flows that the system will face in operation.

EFFECT OF BUOYANCY

The maximum density difference between the effluent and the river is expected to be 1.85 kgm/m^3 (0.116 lb/ft^3). (See Table II-2.) The maximum relative density deficiency is 0.0019. This means that there are buoyant forces acting on the discharge in both the diffuser jets and the turbulent mixing in the river. For jets the relative effect of momentum and buoyancy is represented by a length scale l_M, which is defined as

$$l_M = \frac{M^{\frac{3}{4}}}{B^{1/2}}$$

where

M is the jet momentum flux (previously defined)
B is the jet buoyancy flux

which is given by

$$B = g\frac{\Delta\rho}{\rho}Q$$

In these relationships Q is the jet flow rate, u_j is the jet velocity, g the gravitational acceleration, and $\Delta\rho/\rho$ the relative density difference between the river and effluent.

When l_M is large then the jet momentum is the dominant factor. For diffuser jets at 25 ft/sec, l_M is 27 ft (8m), and with diffuser jets at 15 ft/sec it is found that l_M is 19 ft (6m). This means that the buoyancy of the effluent will have negligible effect on the jet mixing, since the influence of the jet momentum is overwhelming.

Similarly for the diffuser flow, the effect of buoyancy is governed by the ratio $F = U^3/b$ (Roberts, Ref. 4), where b is the buoyancy flux per unit length of the diffuser, i.e. B divided by the diffuser length. For large values of the parameter F, Roberts has shown that buoyancy effects may be neglected in diffuser design. The smallest value of b will occur with the shortest diffuser considered, which in this case is 80 ft. For this case b is equal to the buoyancy flux from a single jet and has the value 0.0083 ft^3/sec^3, so with $U = 2.24$ ft/sec, F is very large.

From the above discussion it is apparent that the effect of the discharge buoyancy can be ignored in the diffuser design at the highest flow rates. At the lower flow rates it is anticipated that the diffuser length will be adjusted, either physically or through temporary port closures, to match the anticipated discharges to the design configuration. When the detailed design is considered this is something that should be checked, primarily to be sure that the diffuser ports always operate with a value of l_M greater than the square root of the port crossectional area. This will guarantee that discharge ports will always flow full. In addition, to prevent the discharge plumes from floating to the surface it is desirable that l_M be substantially greater that the diameter of the jet orifice.

SUMMARY

Two alternative geometric configurations have been considered for the discharge structure to return treated Laughlin wastewater to the Colorado River. These are:

(1) Diffusers aligned parallel to the river flow and attached to the two bridge piers on the Nevada side of the bridge. This will give a total of four diffusers each 20 ft in length.

(2) Diffusers aligned perpendicular to the river flow (i.e., crosstream). Three possible diffuser lengths were considered, 80 ft, 120 ft and 240 ft.

Parallel Diffusers

In this configuration it is proposed that each diffuser have 20 one-inch diameter discharge ports orientated to discharge across the river stream normal to the bridge pier. The diffusers are located at mid-depth during minimum river flow, i.e., approximately 27 inches from the river bottom. At the maximum anticipated flow these diffusers will produce an initial dilution of 20:1 within about 20 ft from the upstream point of discharge. Two parallel streams of effluent will be created in which the dilutions with distance are as specified in Table II-2. The minimum dilution in the stream just prior to entering the river bend, 10,000 ft downstream of the bridge, will be close to 190, whereas the fully mixed dilution will be about 460.

Perpendicular Diffusers

In this configuration, diffusers would be constructed to intercept directly signficant fractions of the river flow. The fully intercepted dilution for diffusers of 80, 120, and 240 ft length would be about 80, 120, and 230 respectively, within a distance of 200 ft from the diffusers. Again, full dilution would be dependent upon the flow entering the recirculating zone in the river bend, since there is no other mechanism that can introduce mixing into the Arizona half of the river without the initial discharge being placed within the Arizona half of the river.

Comparing the effect of the two diffusers, it can be seen that the perpendicular (or transverse) diffusers do provide more rapid mixing of the discharged effluent with the river water. Whereas the parallel diffusers could attain a dilution of about 190 as the effluent flow enters the river bend, the transverse diffusers, if 240 ft in length, would attain this dilution within a few hundred feet of the discharge point. However, attainment of full dilution would still require the river to enter the bend and be subject to the cross-stream flows generated there.

Selection of the appropriate design will require consideration of factors other than the hydraulics of the diffusers and mixing.

REFERENCES

(1) Fischer, H. B., List, E. J., Koh, R. C. Y.,Imberger, J., Brooks, N. H., *Mixing in Inland and Coastal Waters*, Academic Press, 1979.

(2) Daugherty, R. L., and Ingersoll, A. C. *Fluid Mechanics*, McGraw-Hill, 1954.

(3) Muellenhoff, W. P., *et al.* Initial mixing characteristics of municipal ocean discharges Vol.I- Procedures and Applications EPA/600/3-85/073a, Nov., 1985.

(4) Roberts, P. J. W., Line plume and ocean outfall dispersion. J. Hydraulics Division ASCE, Vol. 105, No. HY4, pp 313-330, April, 1979.

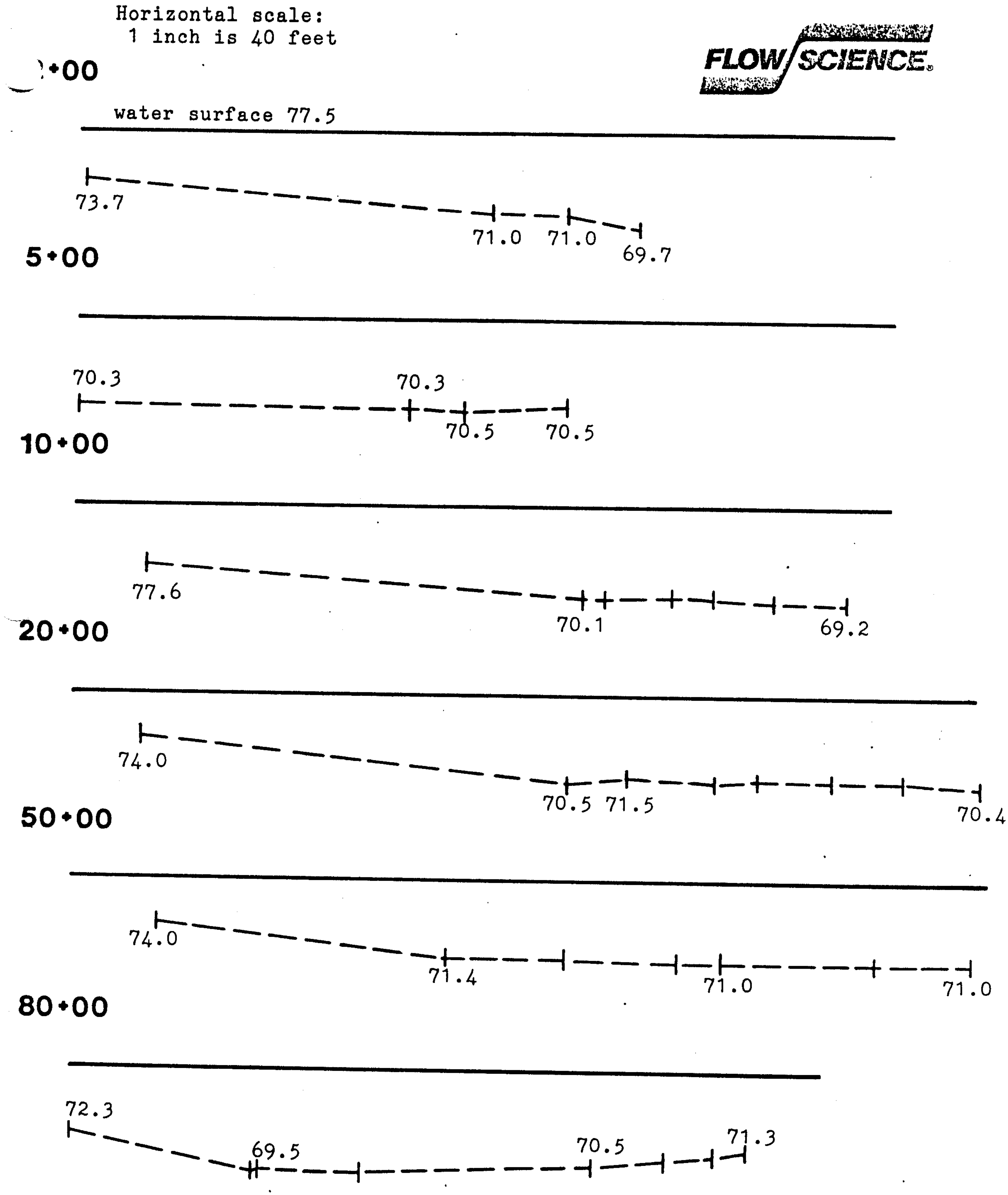

FIGURE I-1. Bottom profiles at stations shown.

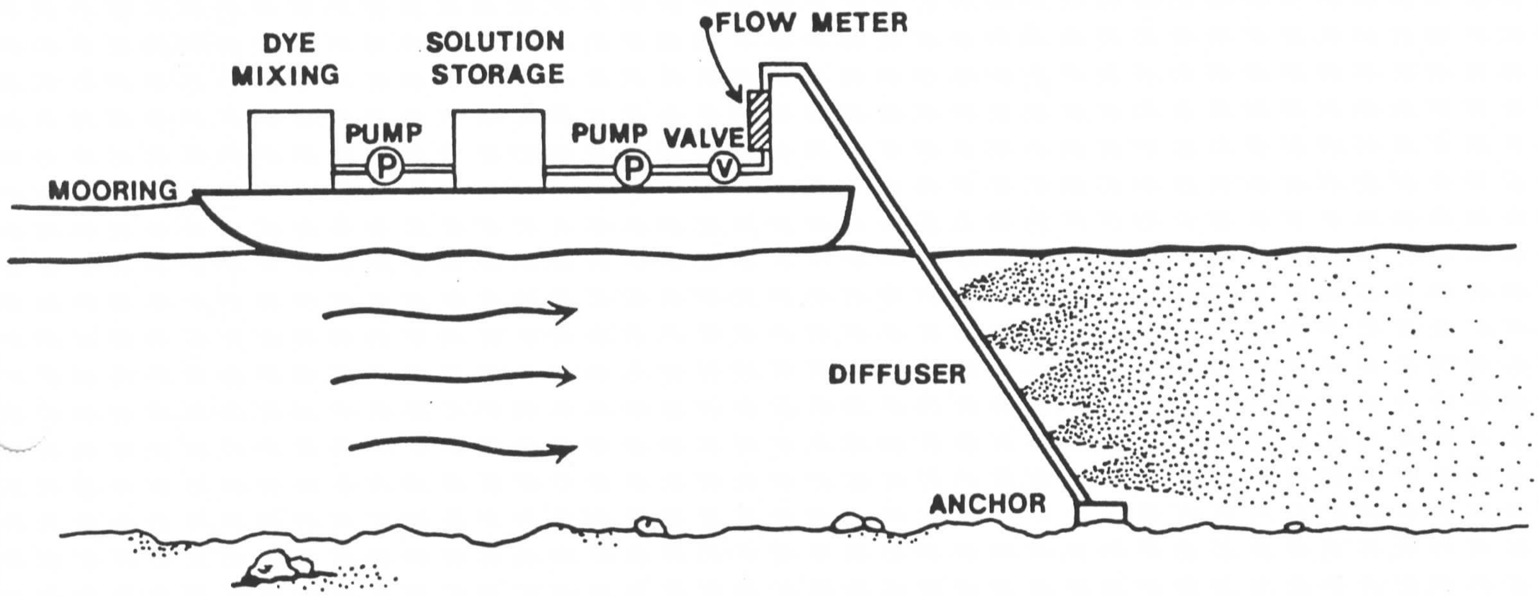

FIGURE I-2. Dye injection system for field study.

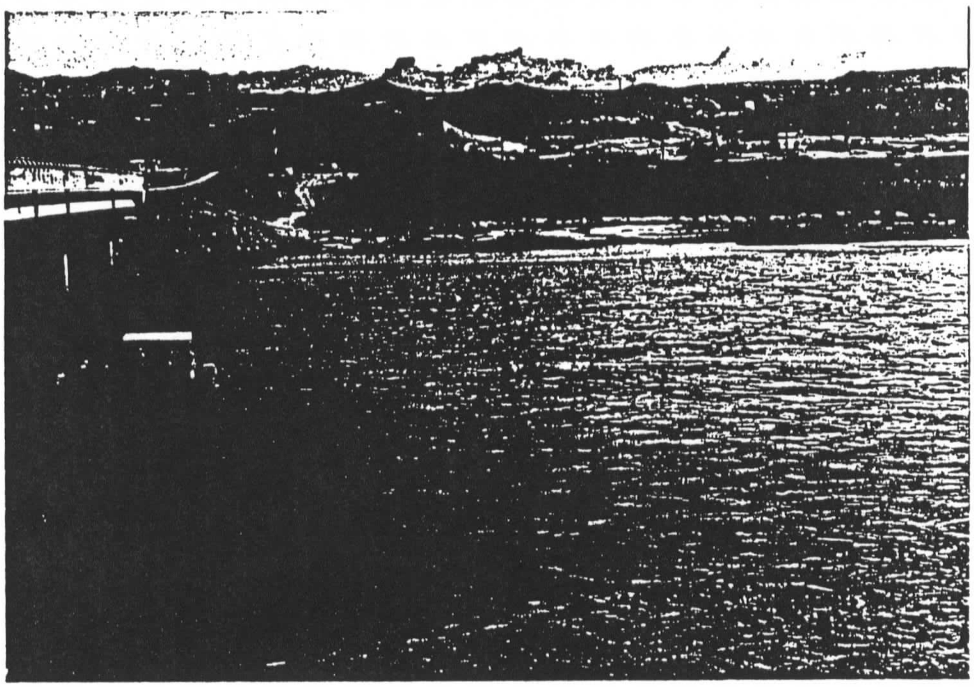

FIGURE I-3. Dye injection system in operation in the field.

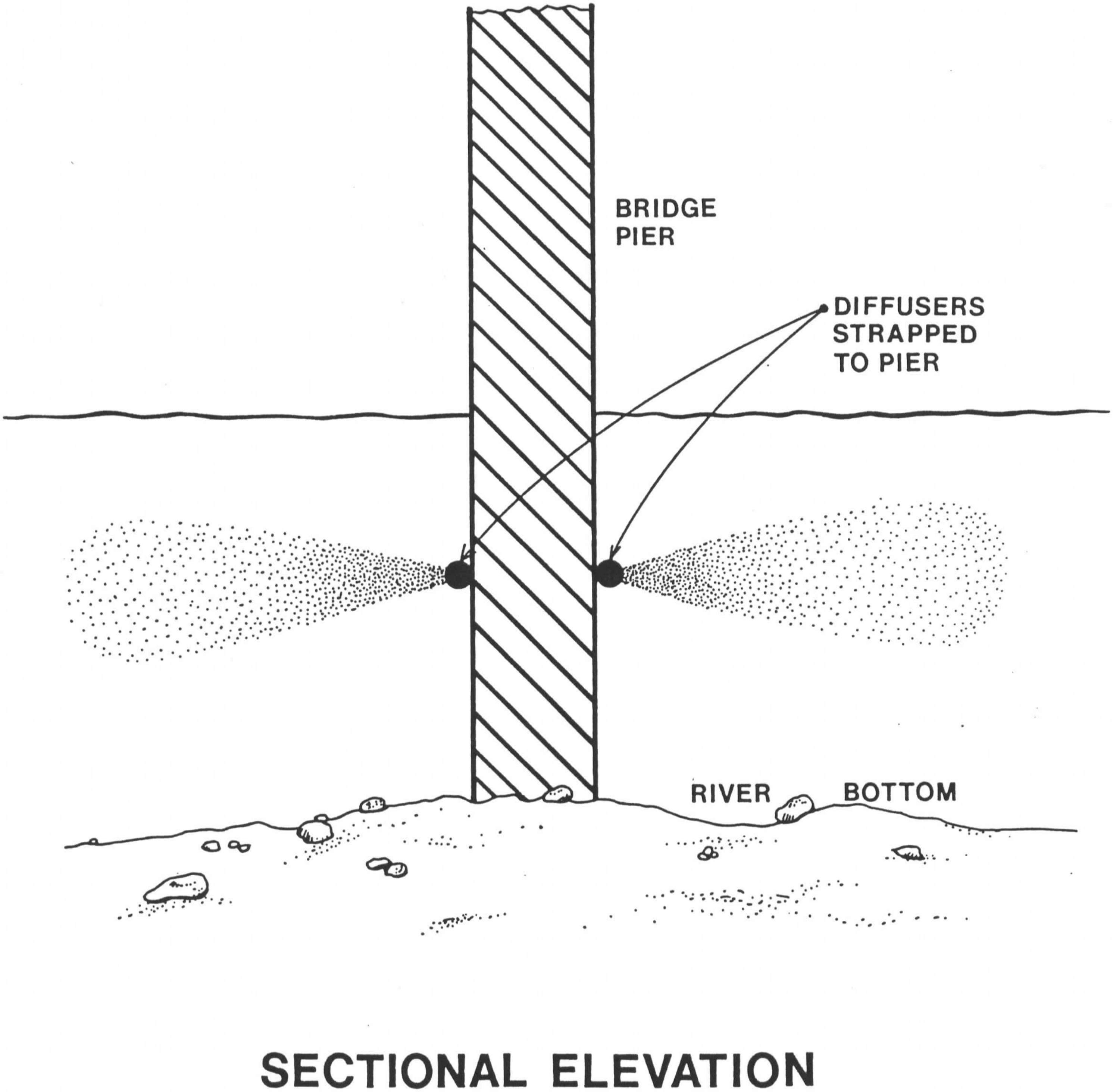

FIGURE II-1(a). Proposed diffuser configuration using bridge pier supports (elevation).

FLOW SCIENCE.

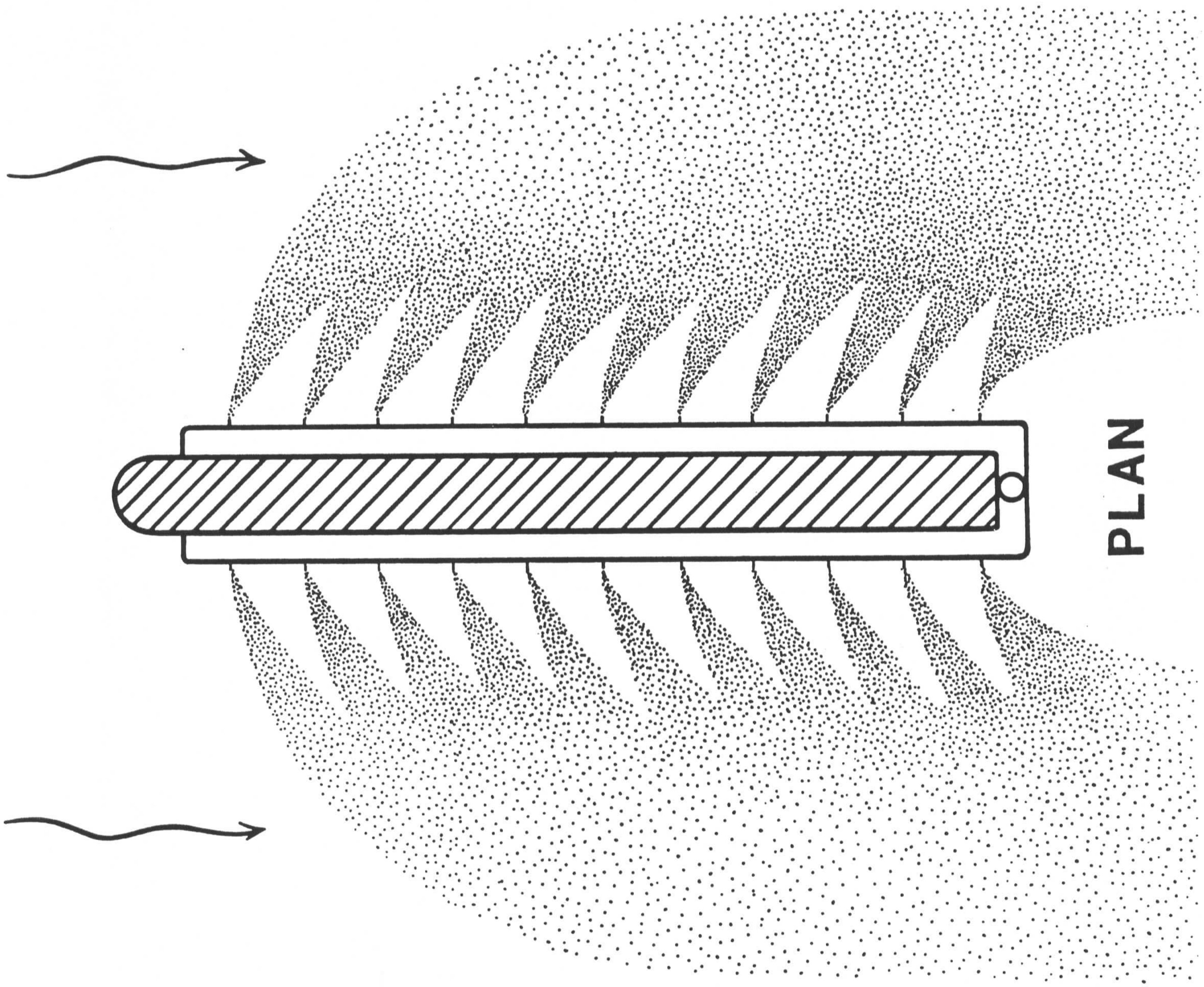

FIGURE II-1(b). Proposed diffuser configuration using bridge pier supports (plan).

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APPENDIX

ATTACHMENT C

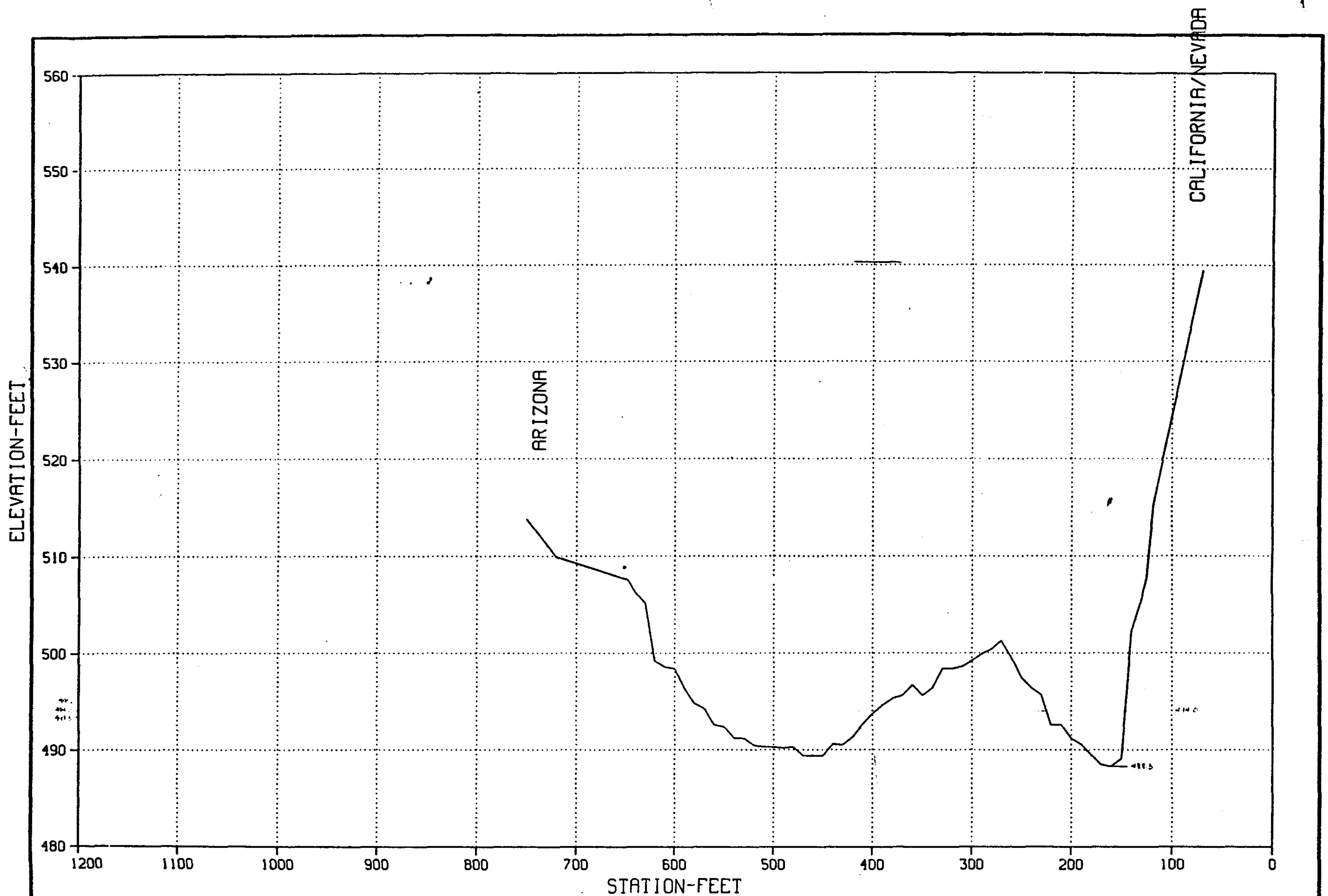
TO

SECTION II

COLORADO RIVER MODEL

ATTACHMENT C

U.S. BUREAU OF RECLAMATION
PLOTS OF CROSS SECTIONS
RIVER MILE 275.6 TO 257.1, LOWER COLORADO RIVER



OLD CROSS SECTION NAMES
RS 27.9

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 275.60

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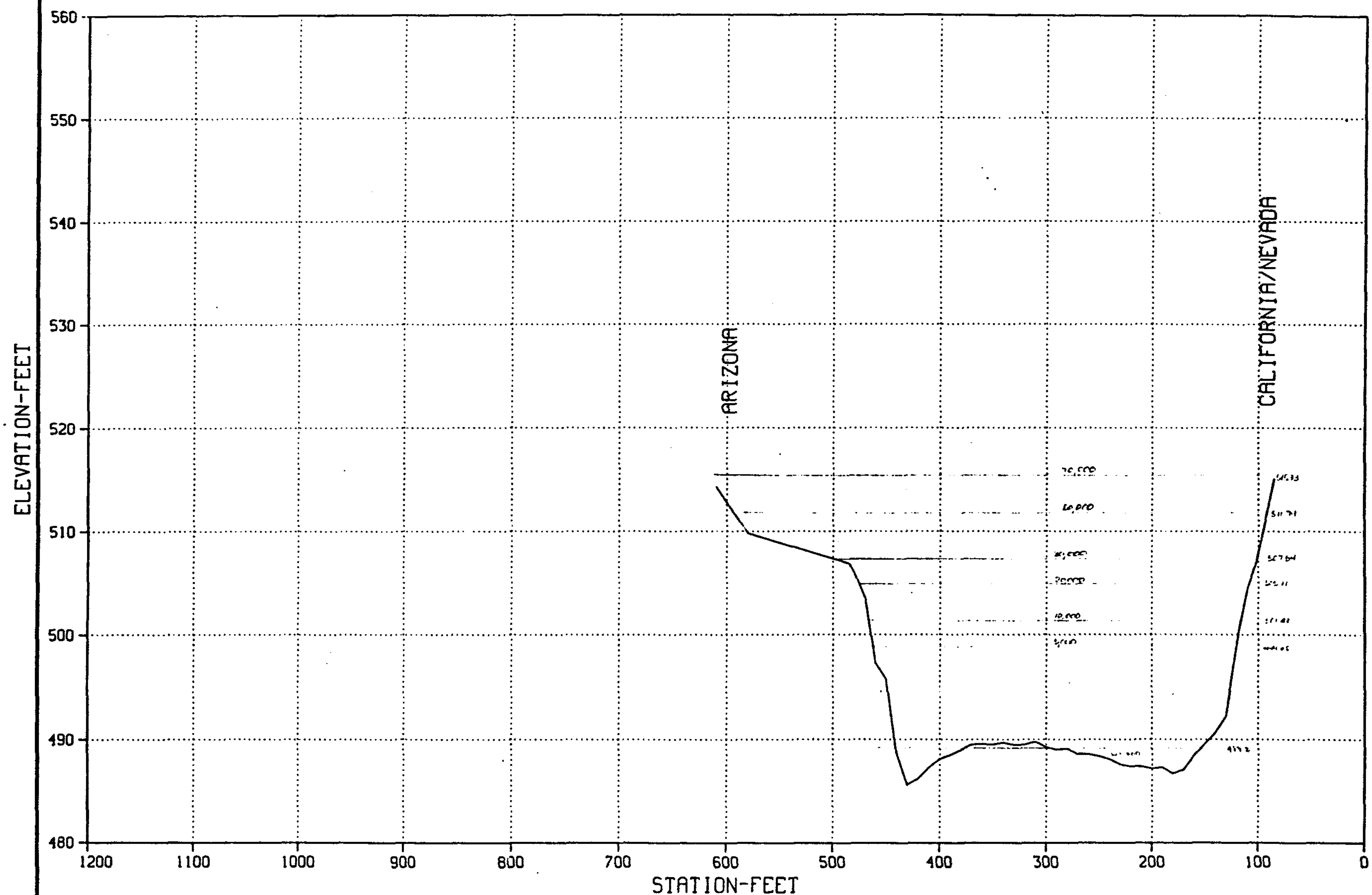

OLD CROSS SECTION NAMES

RS 28

YEAR 1985

LOWER COLORADO RIVER
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RIVER MILE 275.30

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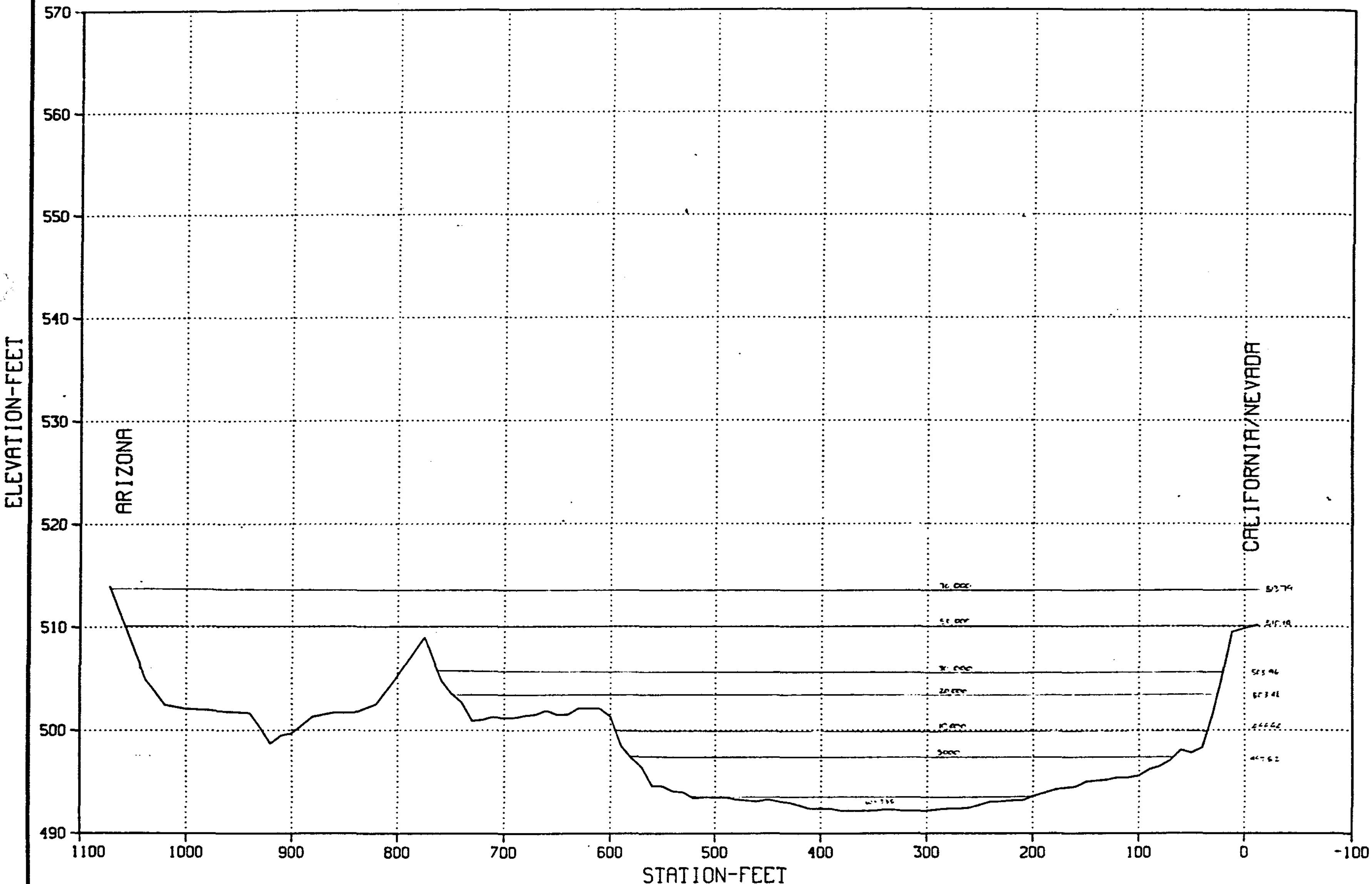

OLD CROSS SECTION NAMES
RS 28A

YEAR 1985

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RIVER MILE 274.10

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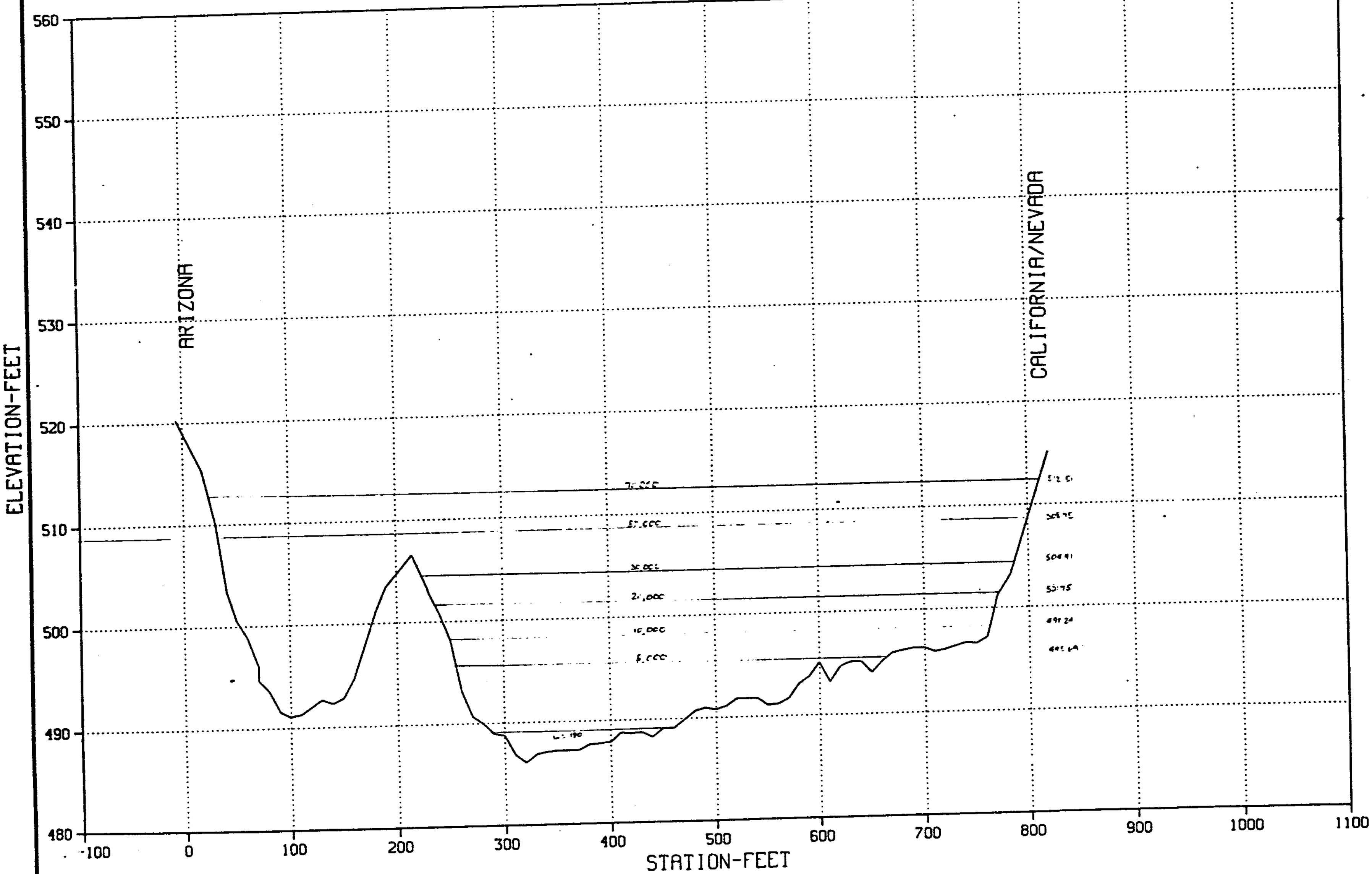

OLD CROSS SECTION NAMES
MI 38.3

YEAR 1985

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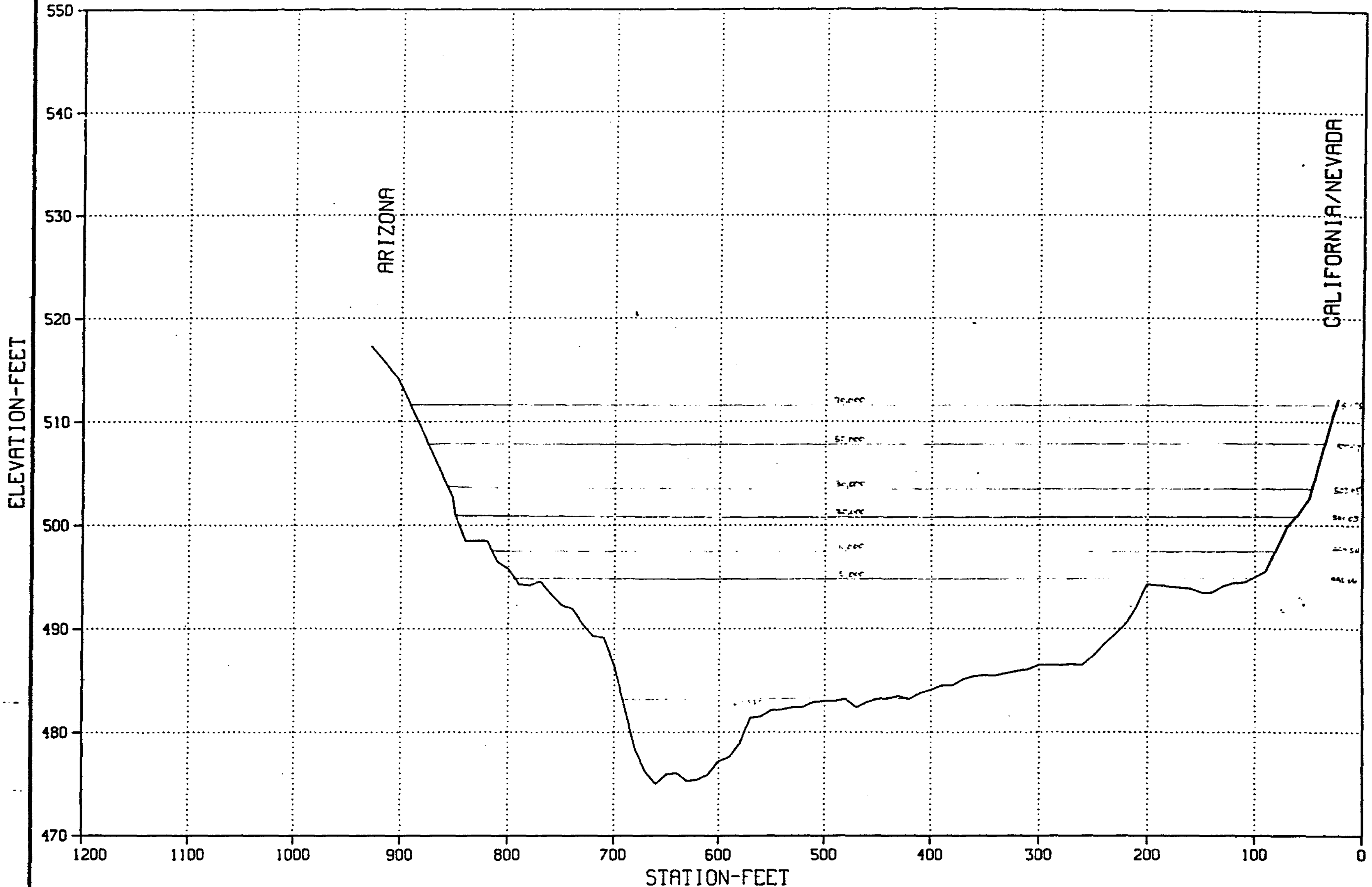
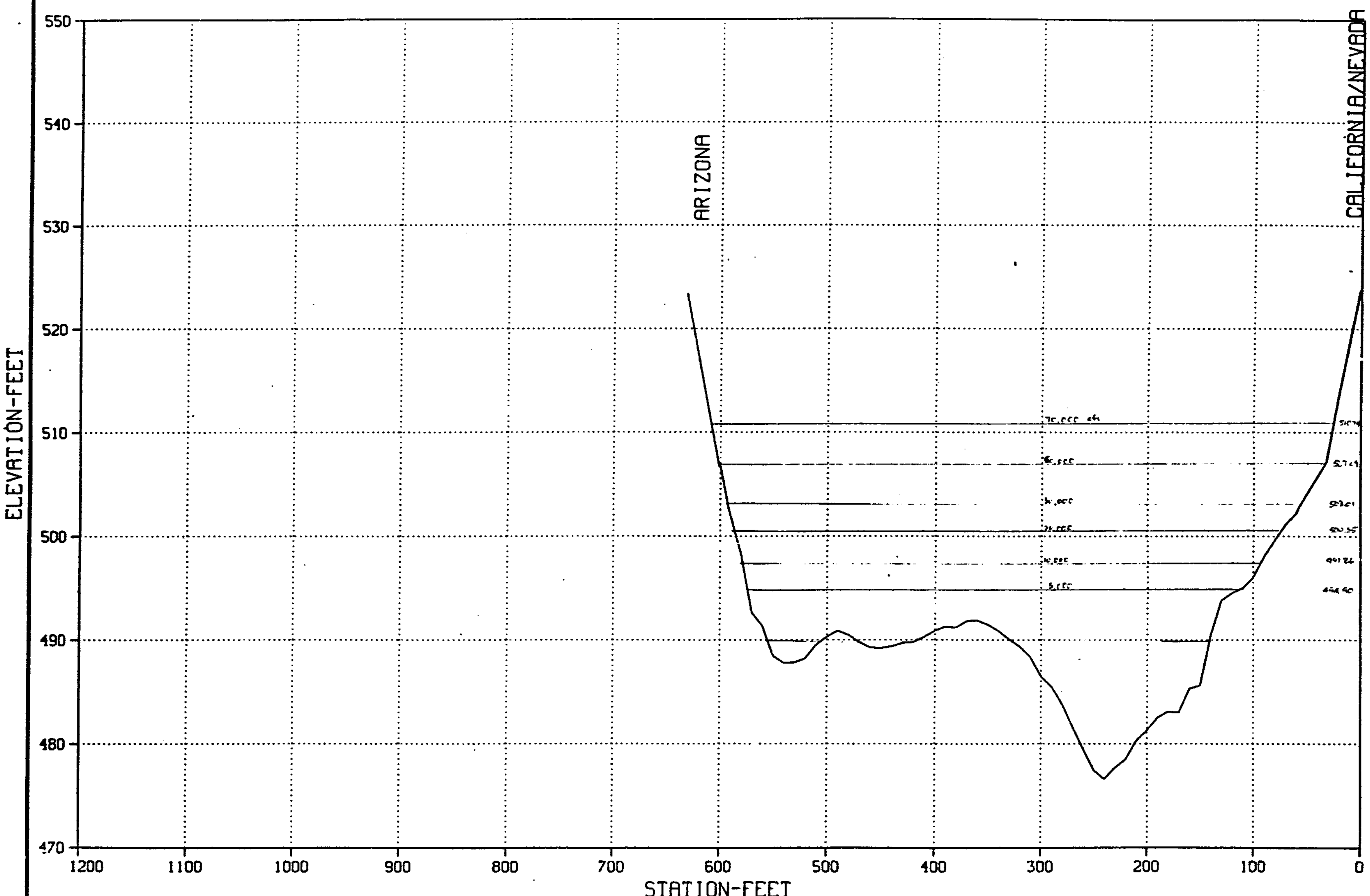
CROSS SECTION AT
RIVER MILE 273.00



OLD CROSS SECTION NAMES
RS 28B

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 271.90

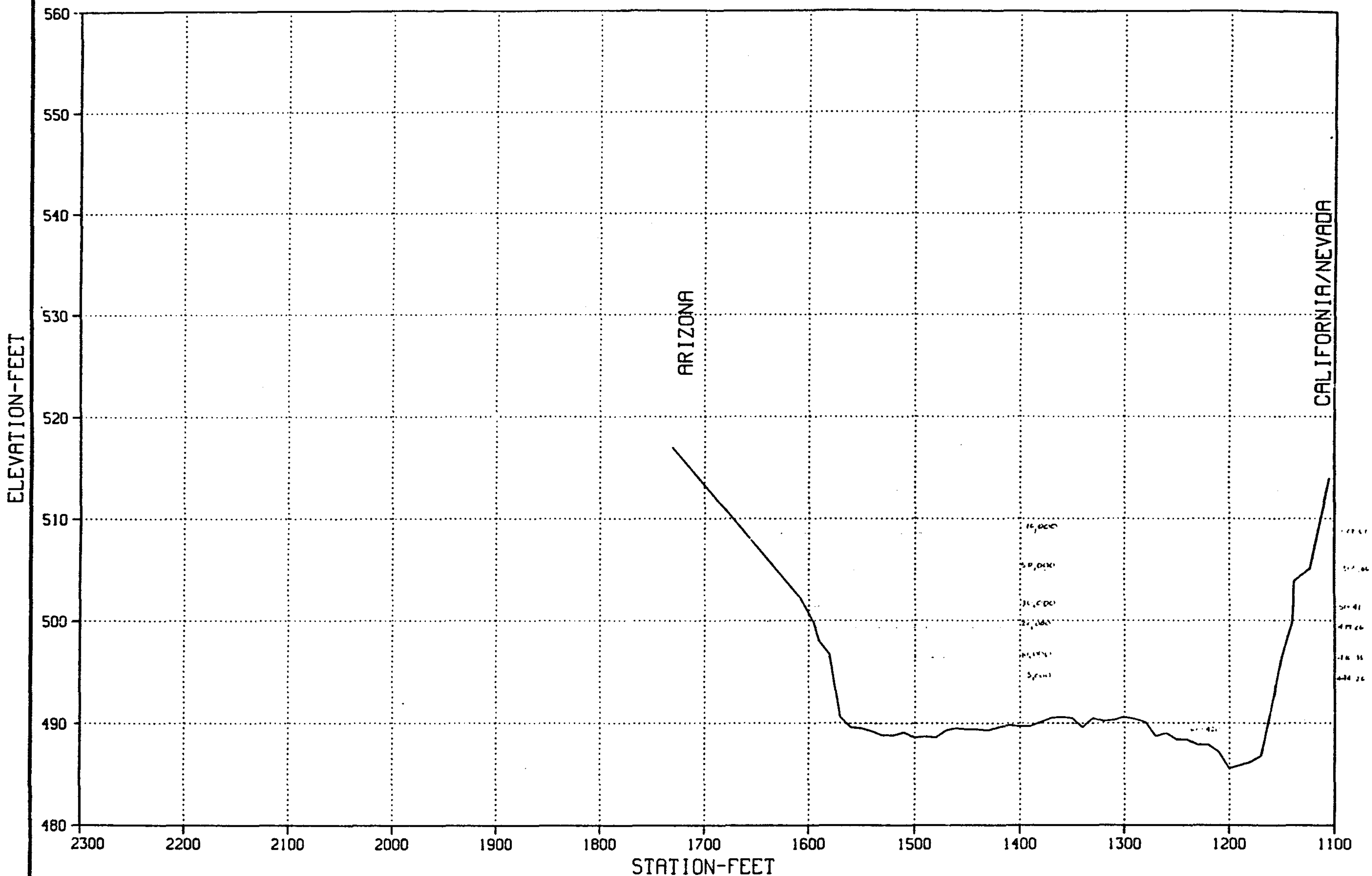


PLOT 48 12.19.00 WED 4 DEC, 1985 JOB-ANOI , BOR REL 9.0/17JUL82 DISSPLA 9.0

OLD CROSS SECTION NAMES
MI 36.5

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 271.20

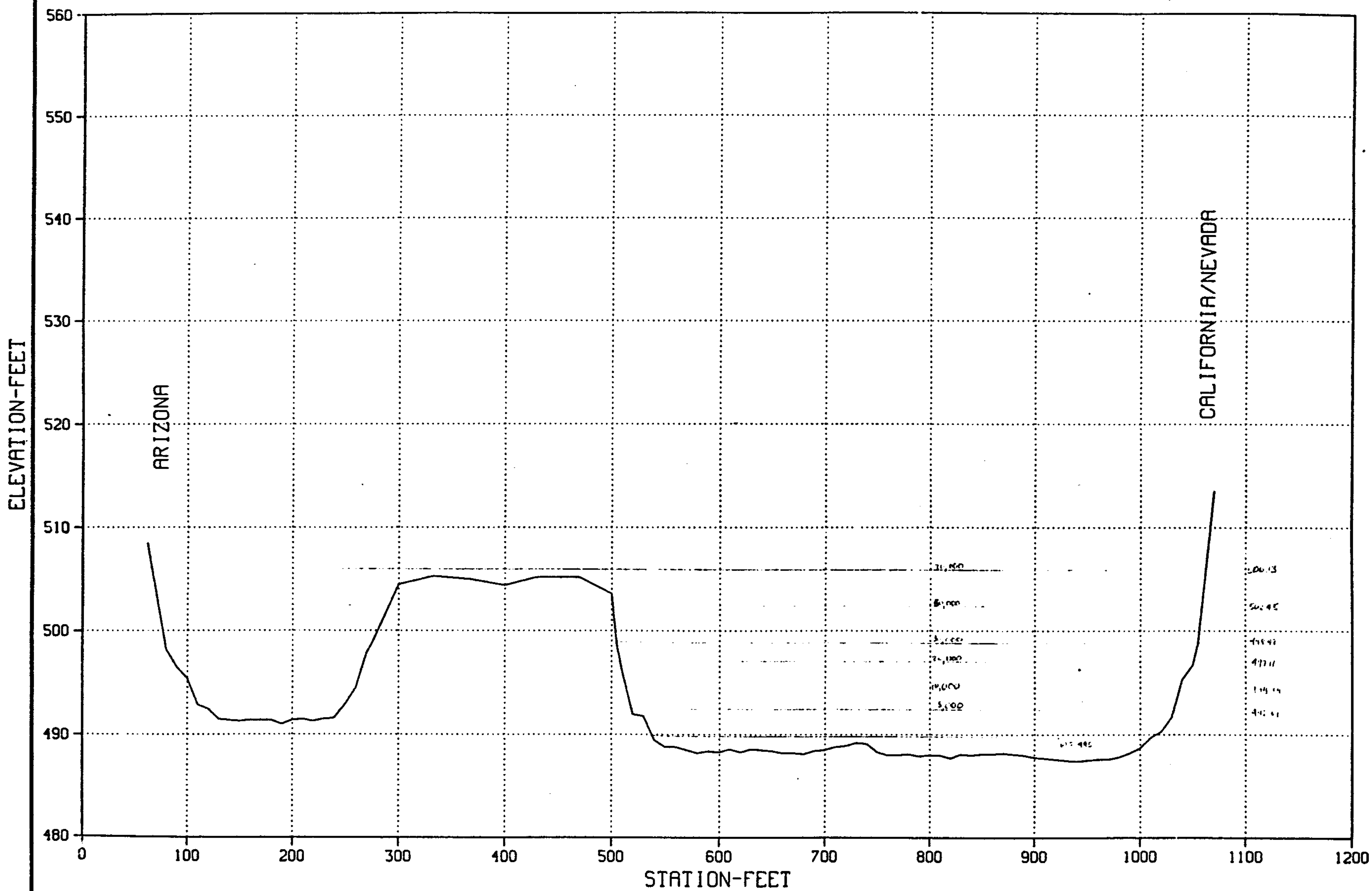


OLD CROSS SECTION NAMES
MI 35.9
RS 29

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 270.50

PLOT 47 12.18.19 WED 4 DEC, 1985 JOB=RAUT , BOR REL 9.0/17JUL82 DISSPLA 9.0



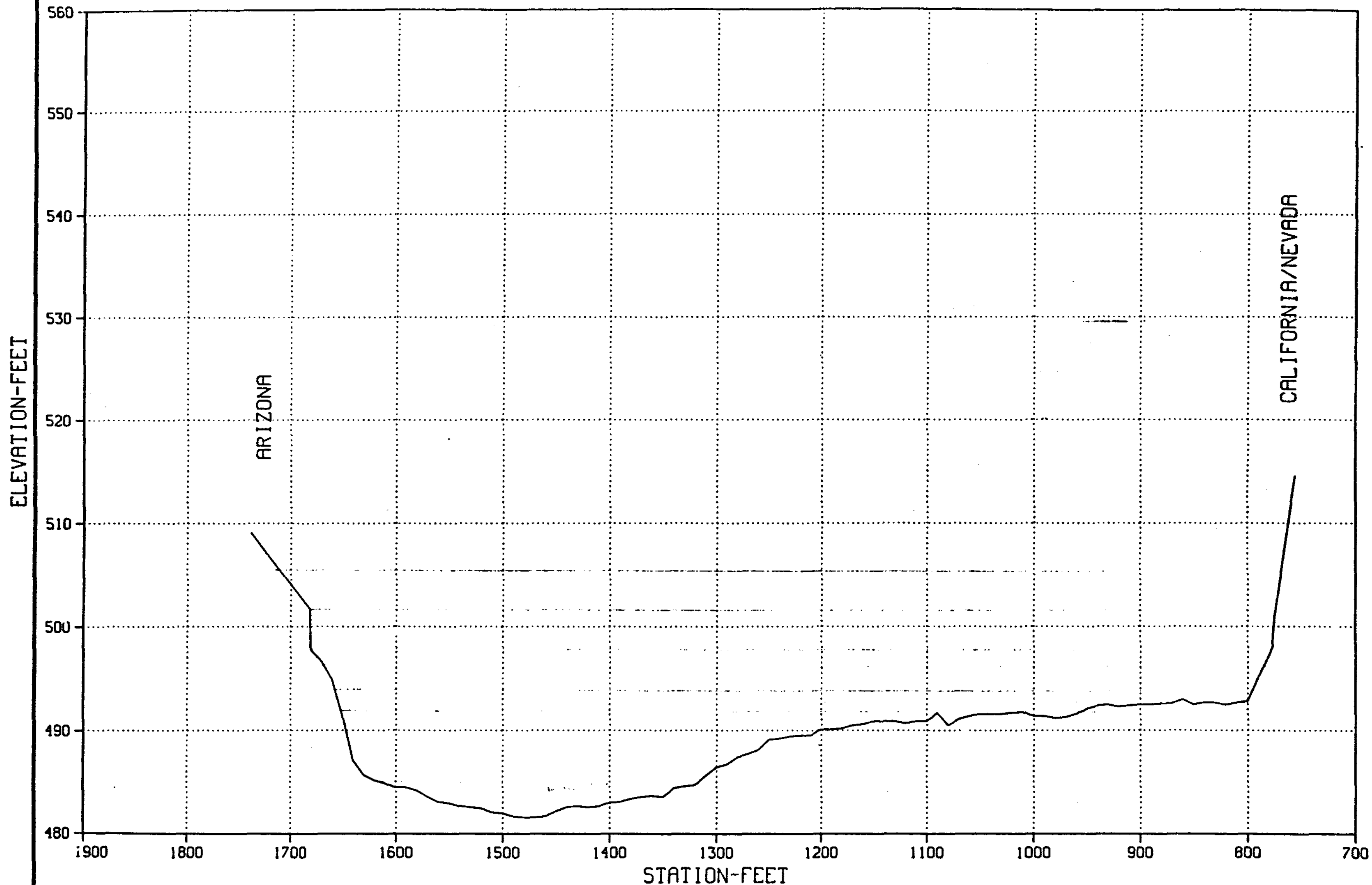
OLD CROSS SECTION NAMES
MI 35.2

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 269.50

PLOT 46 12.16.12 WED 4 DEC, 1985 JOB-ANOI , BCR REL 9.0/17JUL82 DISSPLA 9.0

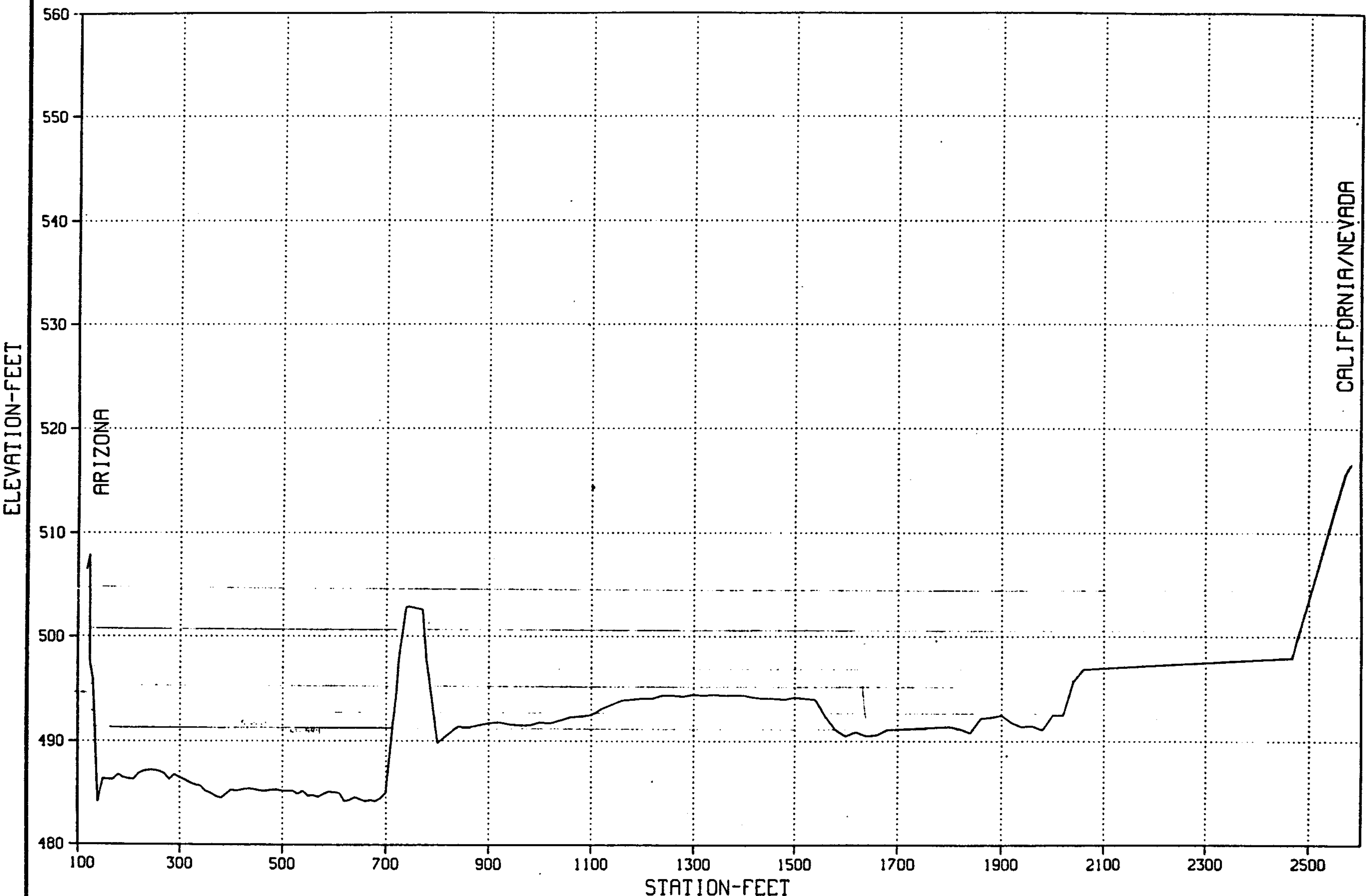
8



· OLD CROSS SECTION NAMES
RS 29A

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 269.00

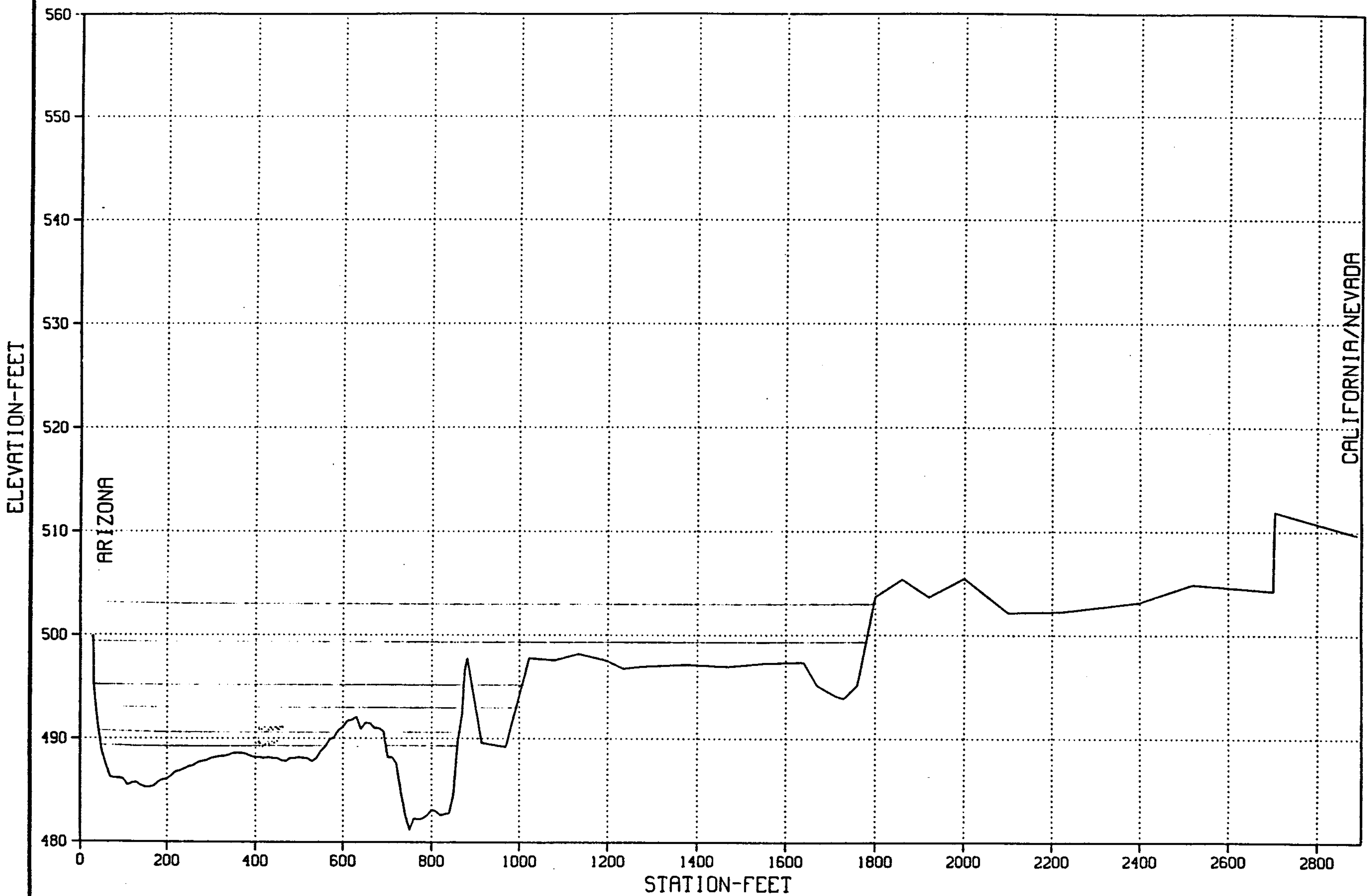


OLD CROSS SECTION NAMES
MI 33.5

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 268.00

PLOT 44 12.12.51 MCD 4 DEC, 1985 JOB-ANOI , BOR REL 9.0/17JUL82 DISSPLA 9.0

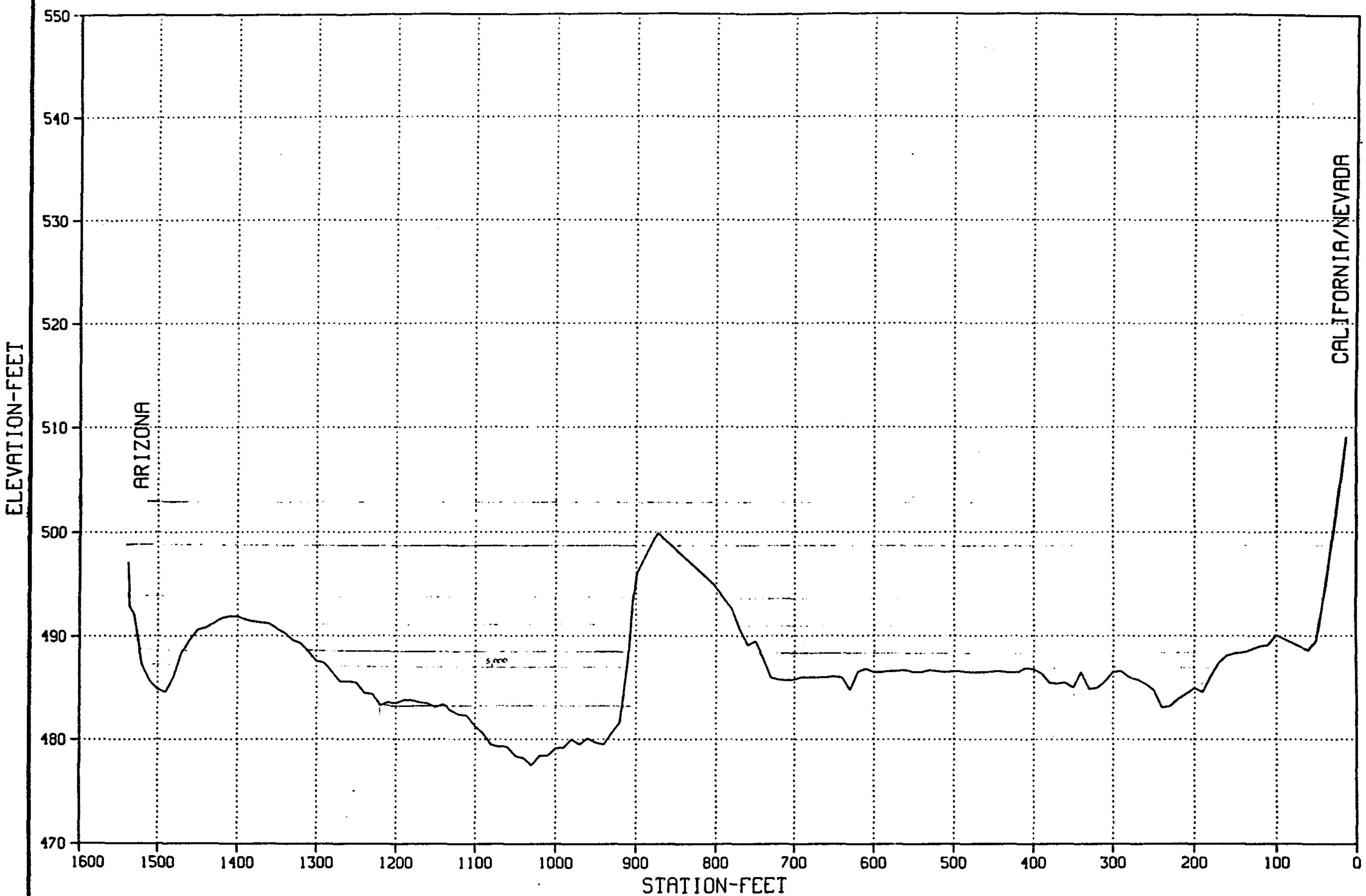


OLD CROSS SECTION NAMES
MI 32.5

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 267.20

PLOT 43 12.12.04 WED 4 DEC, 1985 JOB-ANOI , BOR REL 9.0/17 JUL82 DISSPLA 9.0

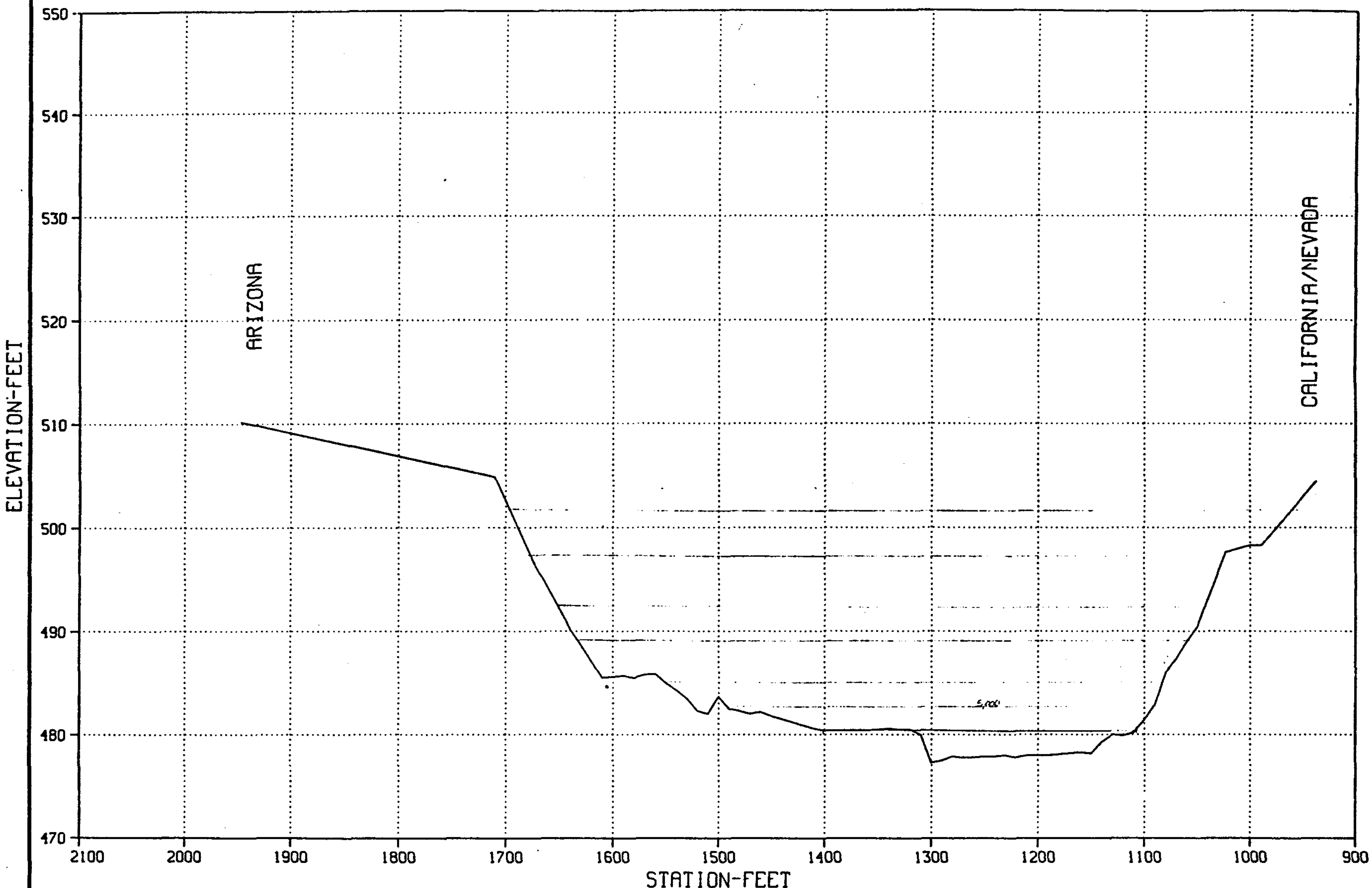


OLD CROSS SECTION NAMES
RS 29B

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 266.50

PLOT 42 12.11.11 WED 4 DEC, 1985 JOB-ANO1 , BOR REL 9.0/17 JUL82 DISSPLA 9.0

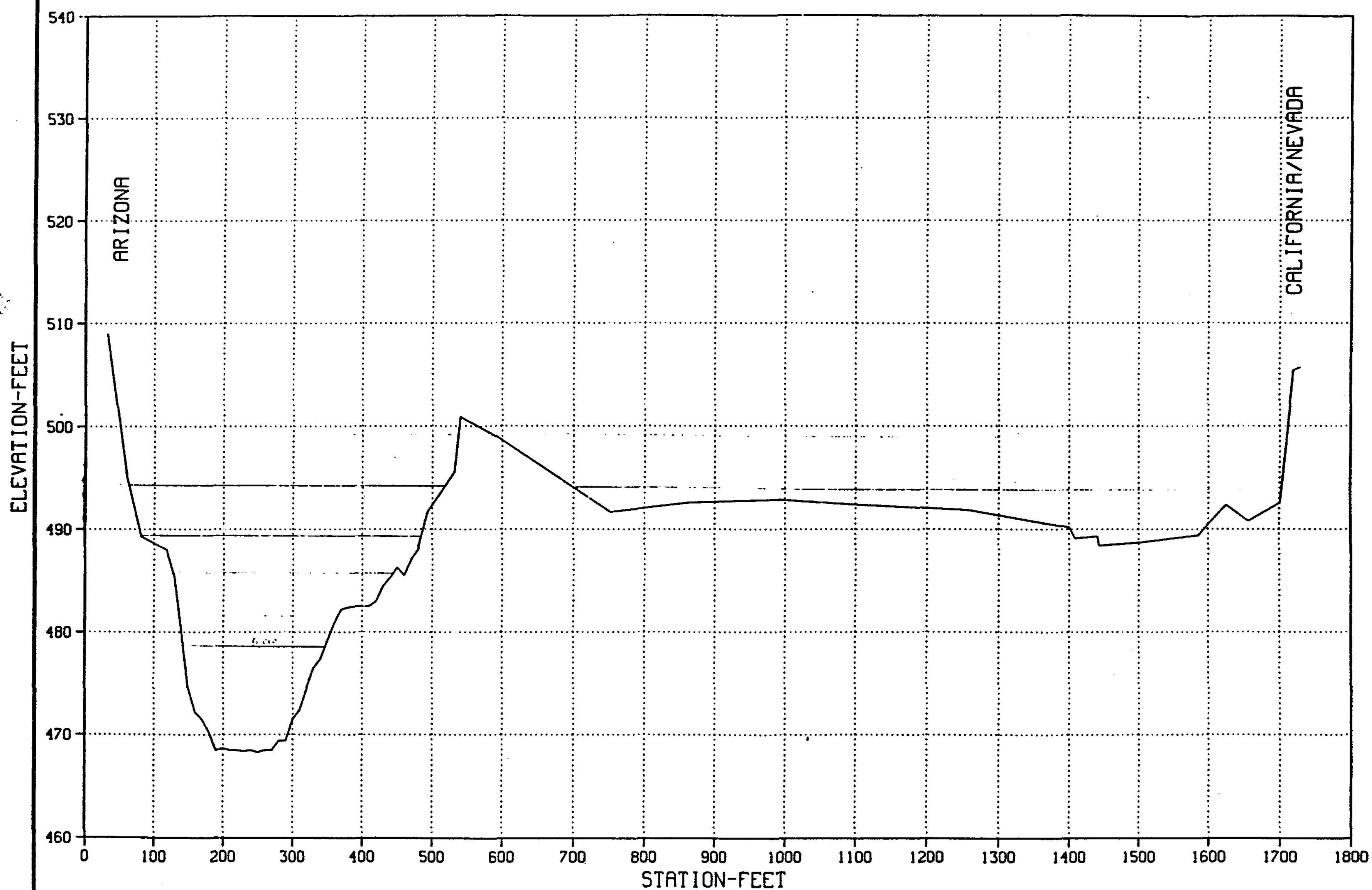


OLD CROSS SECTION NAMES
RS 30

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 265.30

PLOT 41 12.09.42 WED 4 DEC, 1985 JOB=ANOI , BOR REL 9.0/17JUL82 DISSPLA 9.0



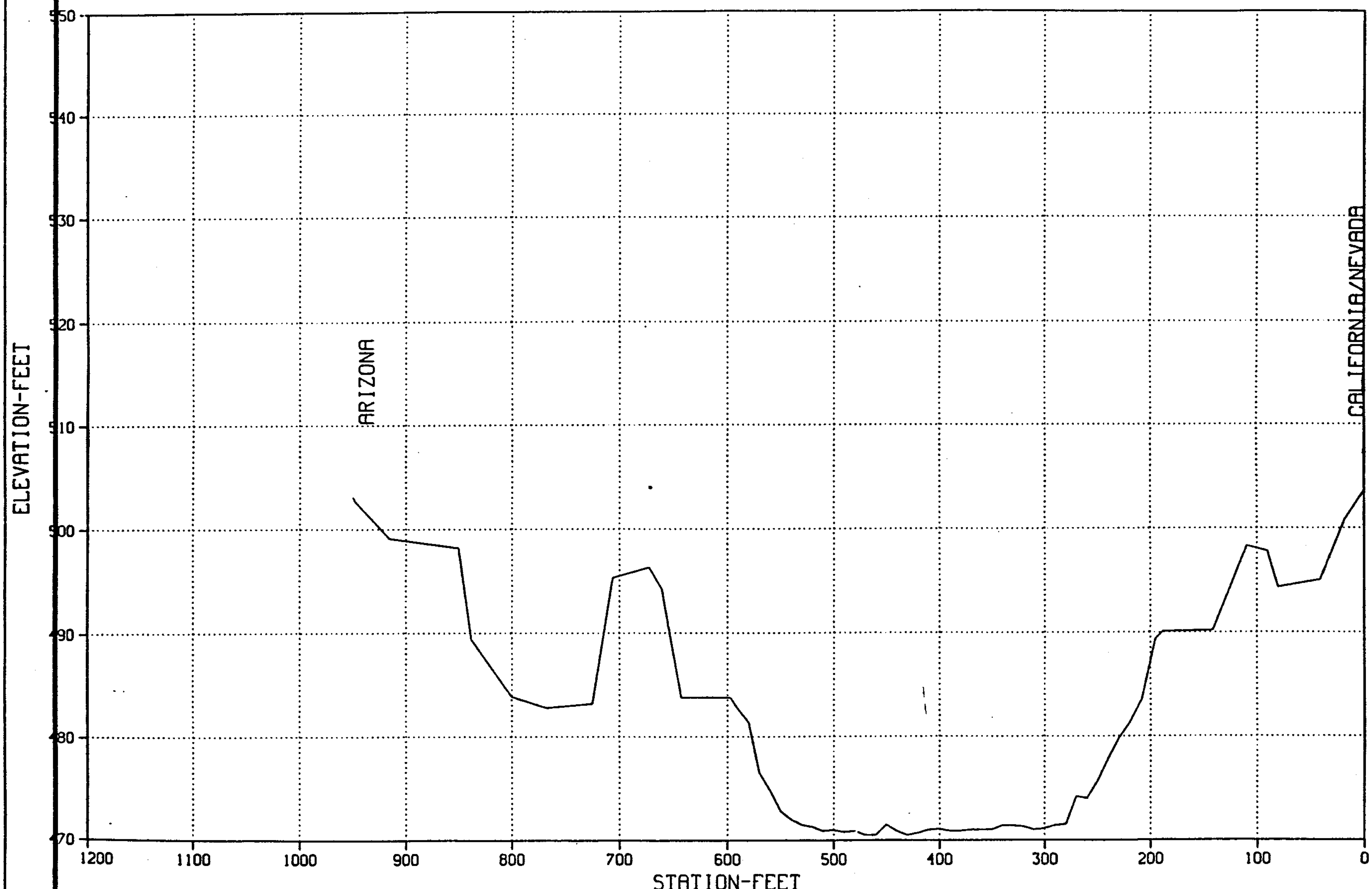
OLD CROSS SECTION NAMES

MI 29.4

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 264.30

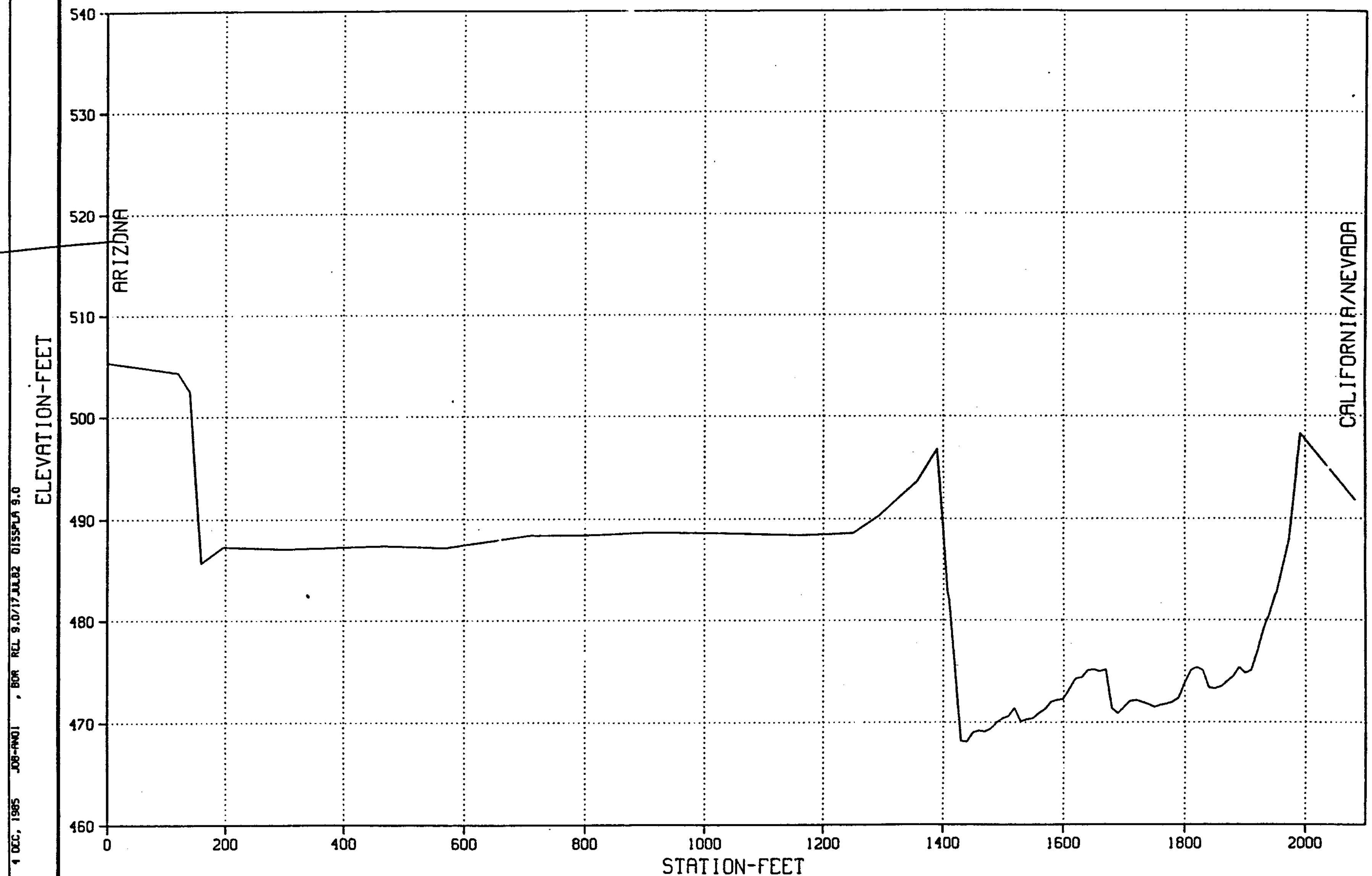
PLOT 10 12.09.11 WED 4 DEC, 1985 JOB-ANOI , BOR REL 9.0/17.JUL82 DISSPLA 9.0



OLD CROSS SECTION NAMES
RS 30A

YEAR 1985

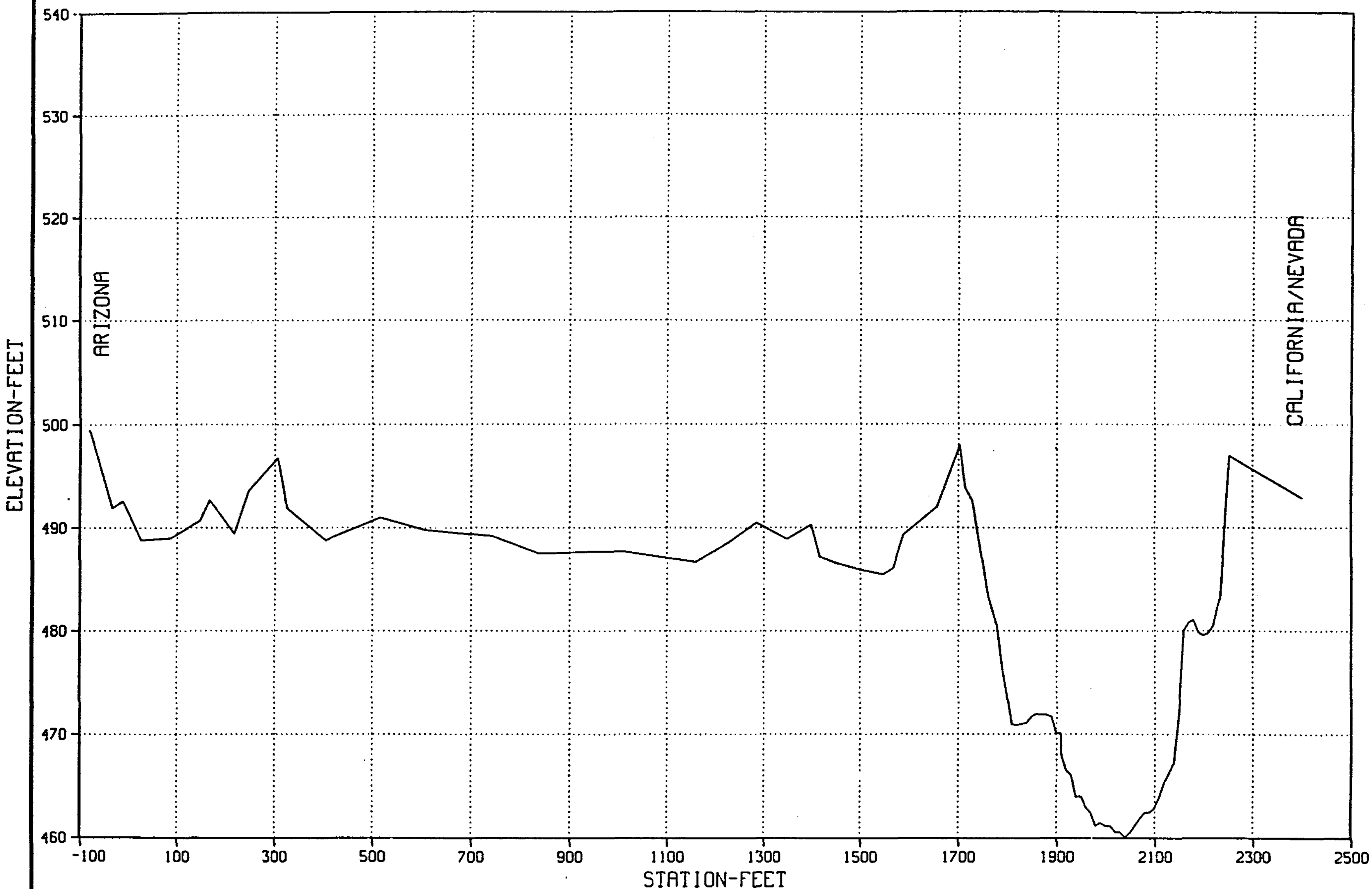
LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 263.30



OLD CROSS SECTION NAMES
MI 28.4

YEAR 1985

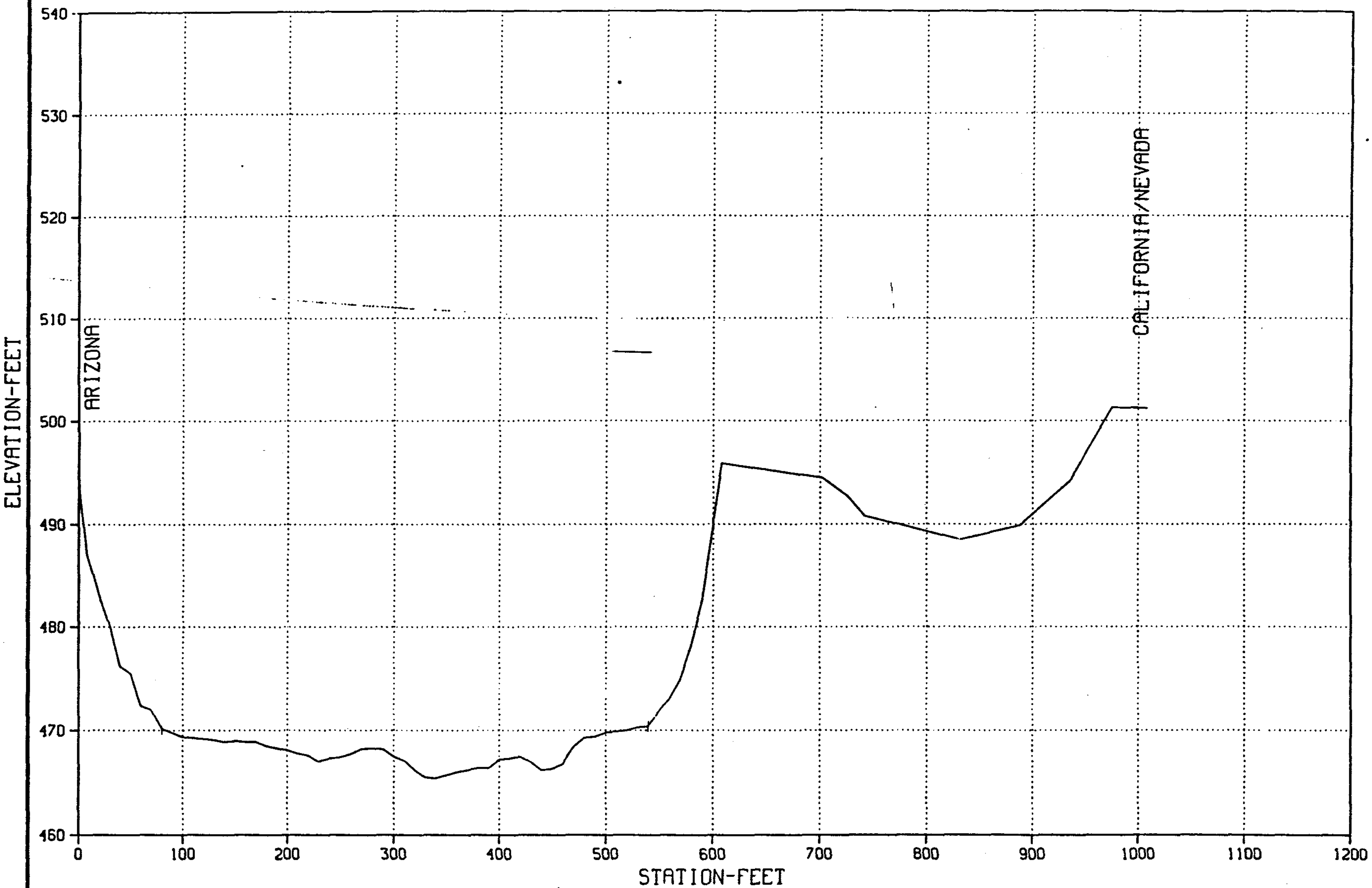
LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 262.90



OLD CROSS SECTION NAMES
MI 28

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 262.20

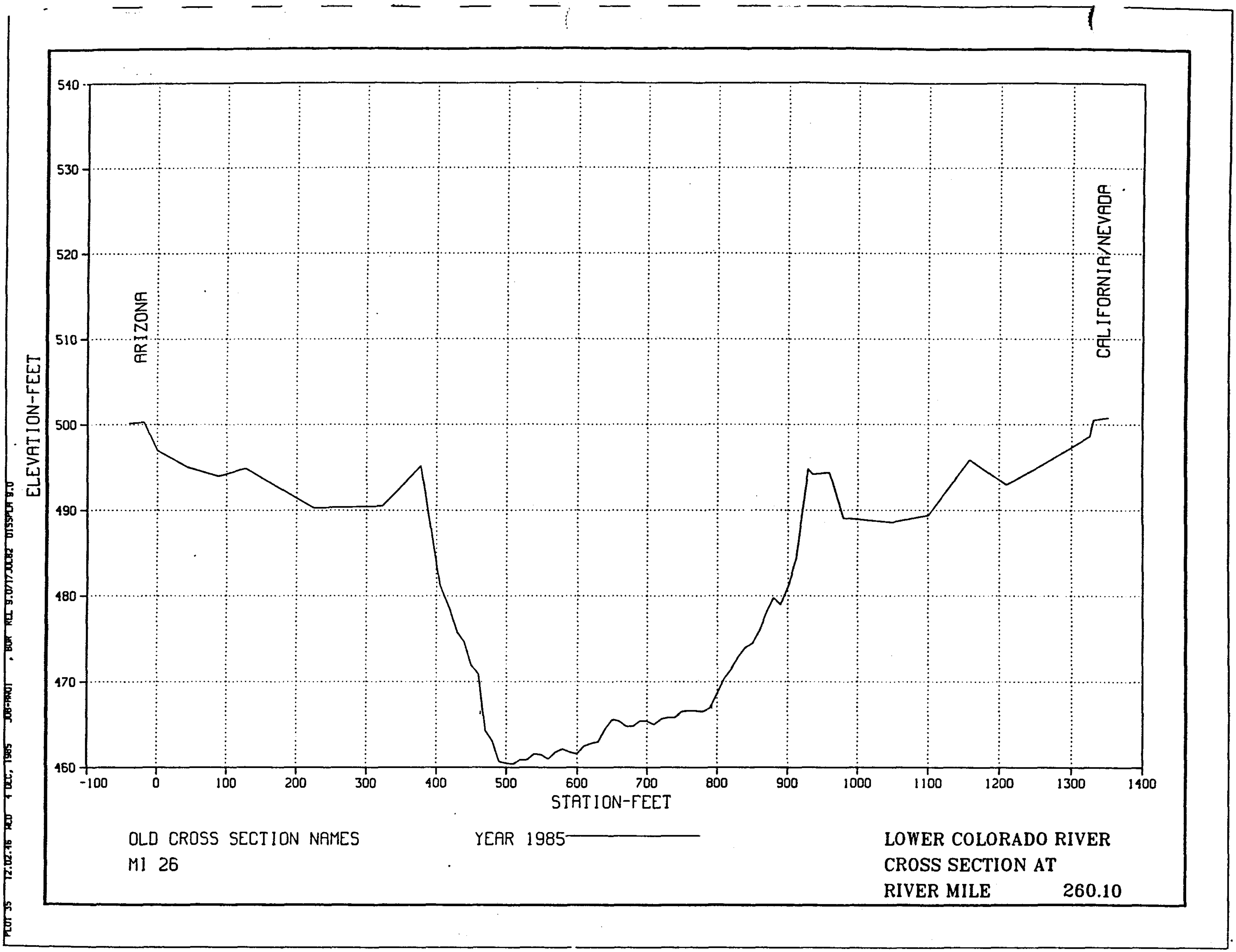


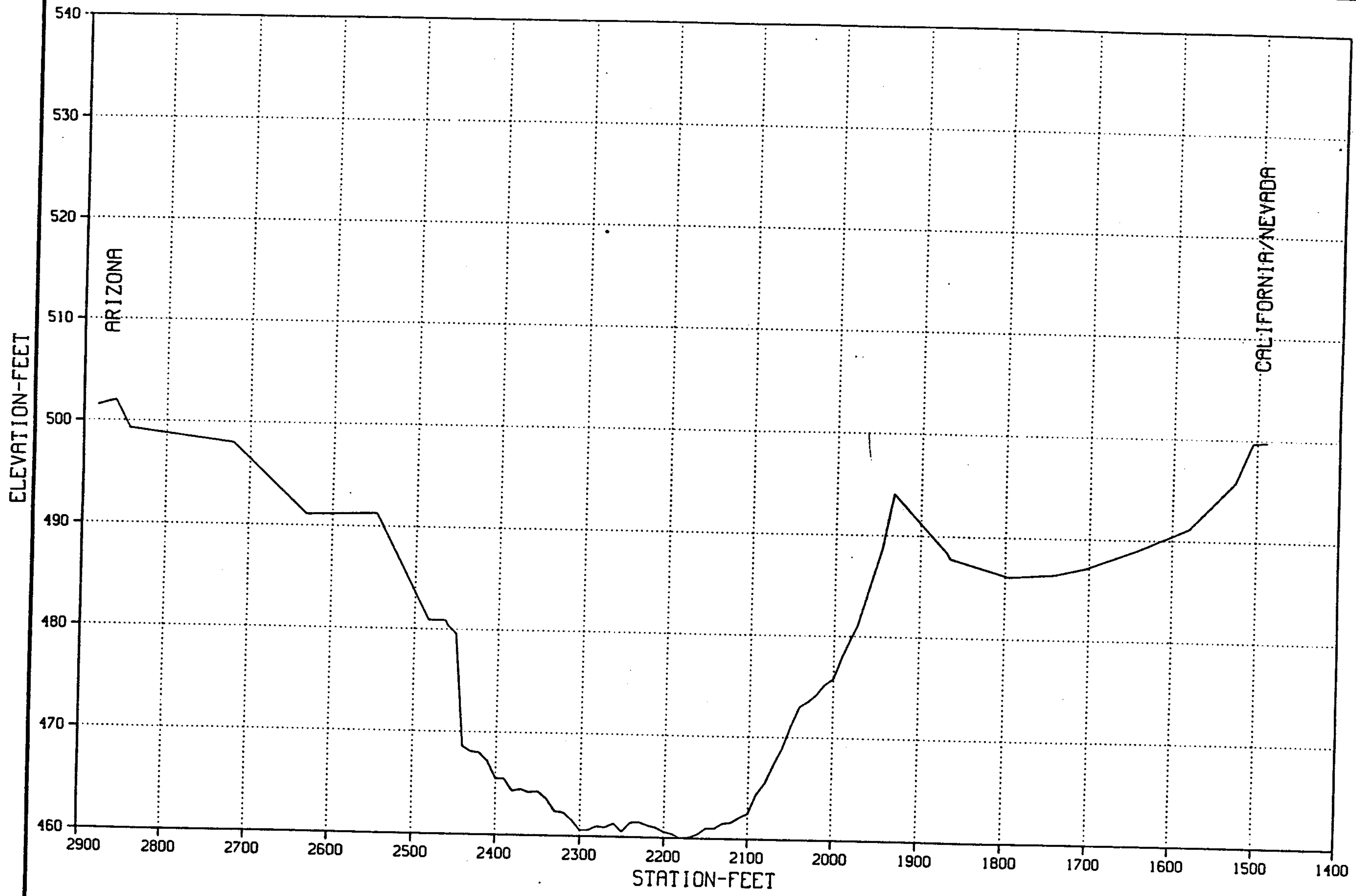
OLD CROSS SECTION NAMES
MI 27

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 261.20

PLOT 36 12.03.32 WED 4 DEC, 1985 JOB=ANOI , BOR RCL 9.0/17 JUL 82 DISSPLA 9.0


540
530
520
510
500
490
480
470
460
ELEVATION-FEET
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
STATION-FEET
ARIZONA
CALIFORNIA/NEVADA
OLD CROSS SECTION NAMES
MI 26
YEAR 1985
LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 260.10

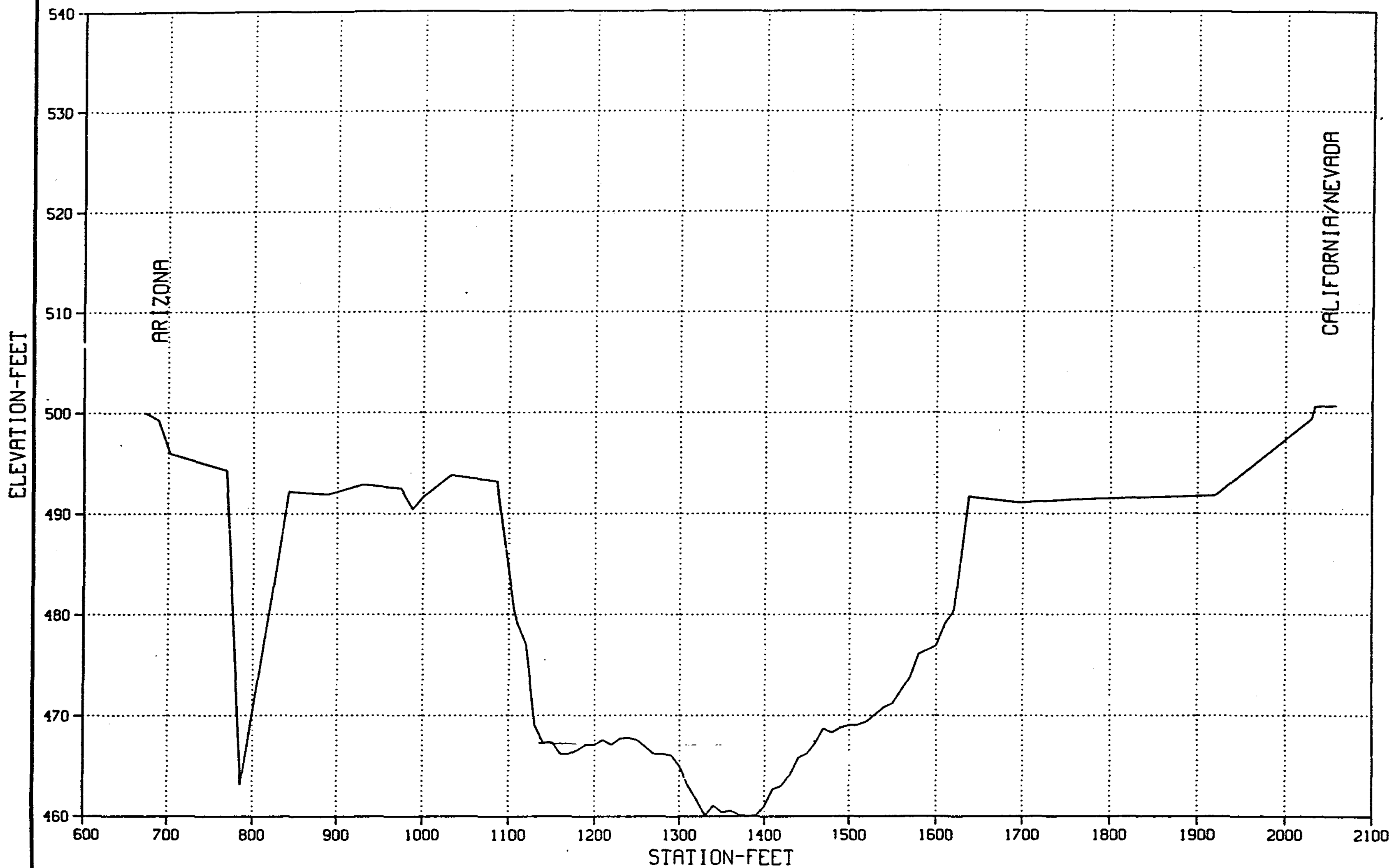


OLD CROSS SECTION NAMES
RS 31

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 259.60

PLOT 34 11.59.55 WED 4 DEC, 1985 JOB-ANOI , BOR RCL 9.0/17JUL82 DISSPLA 9.0

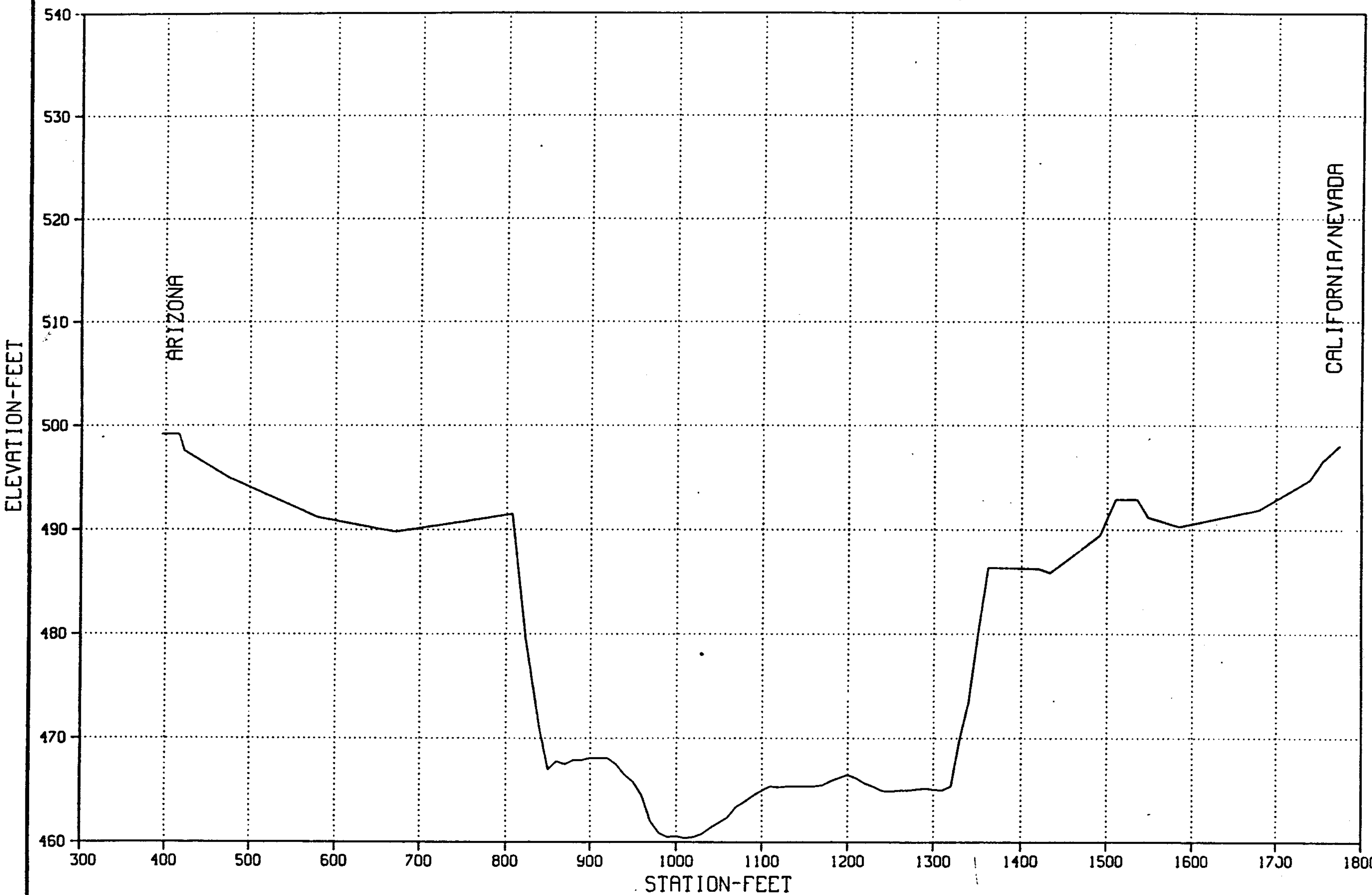


OLD CROSS SECTION NAMES
MI 25

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 259.10

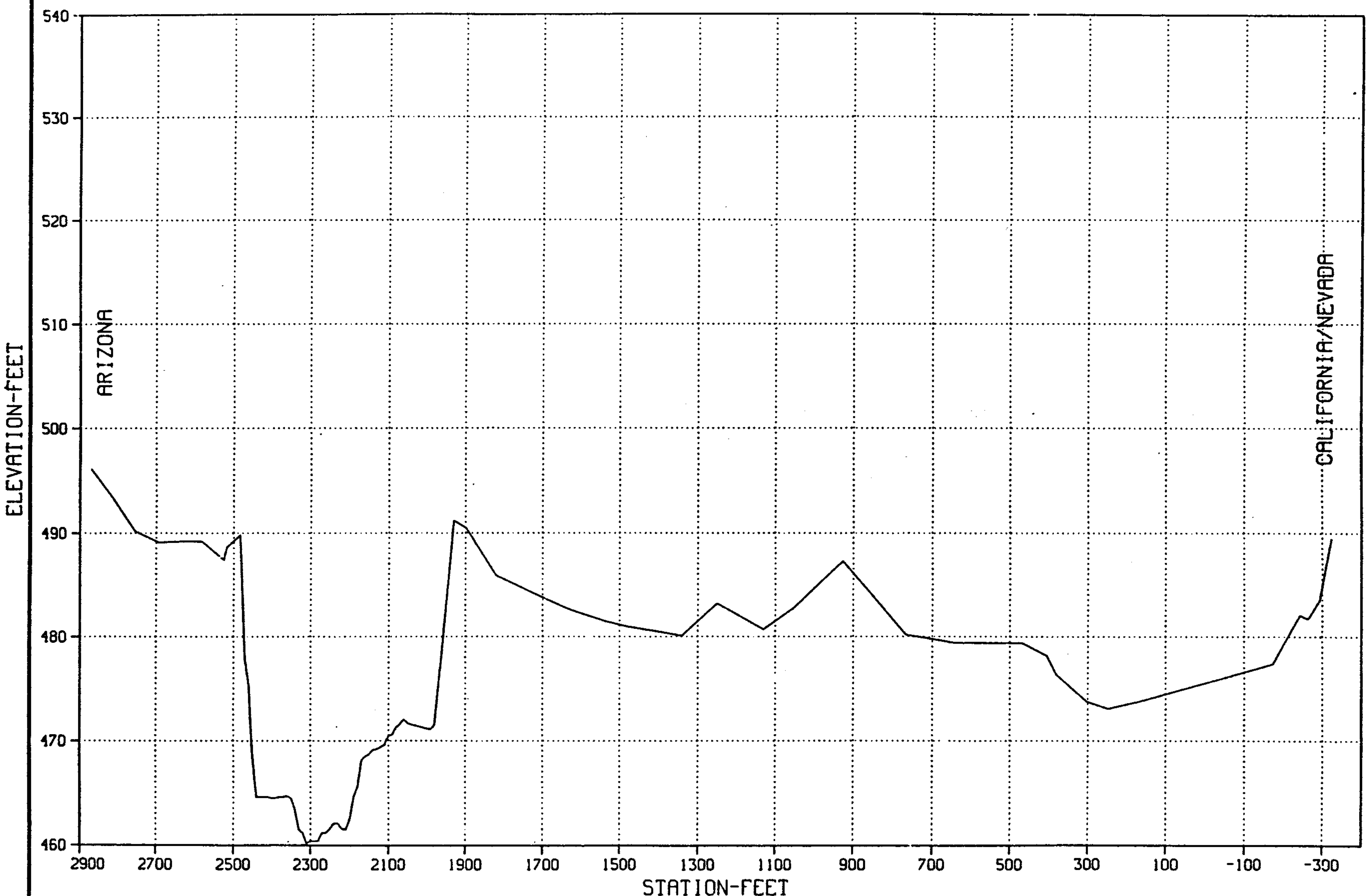
PLOT 33 11.59.09 WED 4 DEC, 1985 JOB-ANVI , BOR REL 9.0/17JUL82 DISSPLA 9.0



OLD CROSS SECTION NAMES
MI 24

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 258.10



OLD CROSS SECTION NAMES
RS 31A

YEAR 1985

LOWER COLORADO RIVER
CROSS SECTION AT
RIVER MILE 257.70

PLOT 31 11.42.38 WED 4 DEC, 1985 JOB=ANOT , BOR REL 9.0/17 JUL82 DISSPLA 9.0

ATTACHMENT D

TO

SECTION II

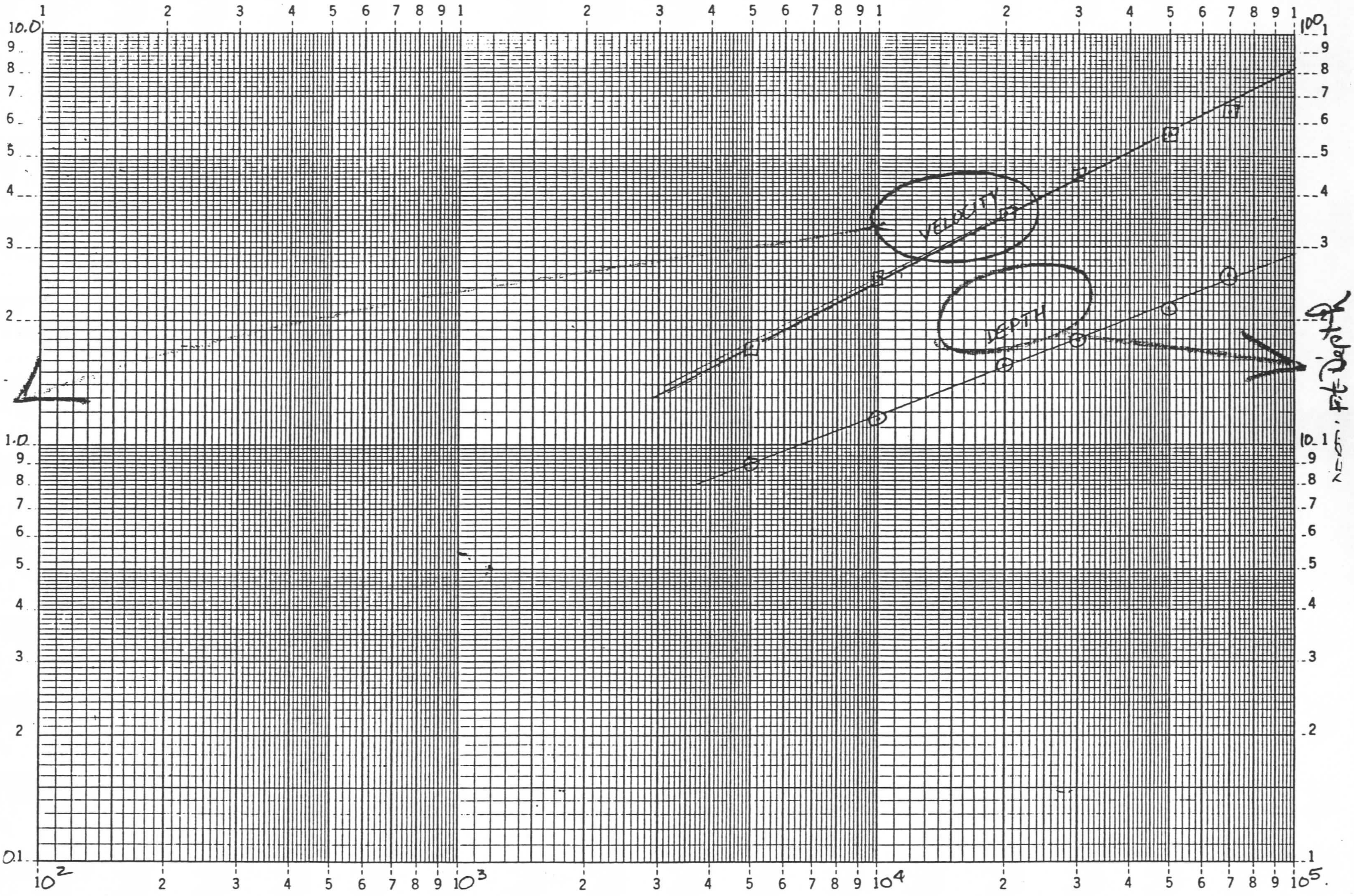
COLORADO RIVER MODEL

ATTACHMENT D

PLOTS OF VELOCITY AND DEPTH VERSUS RIVER DISCHARGE FOR COLORADO RIVER REACHES

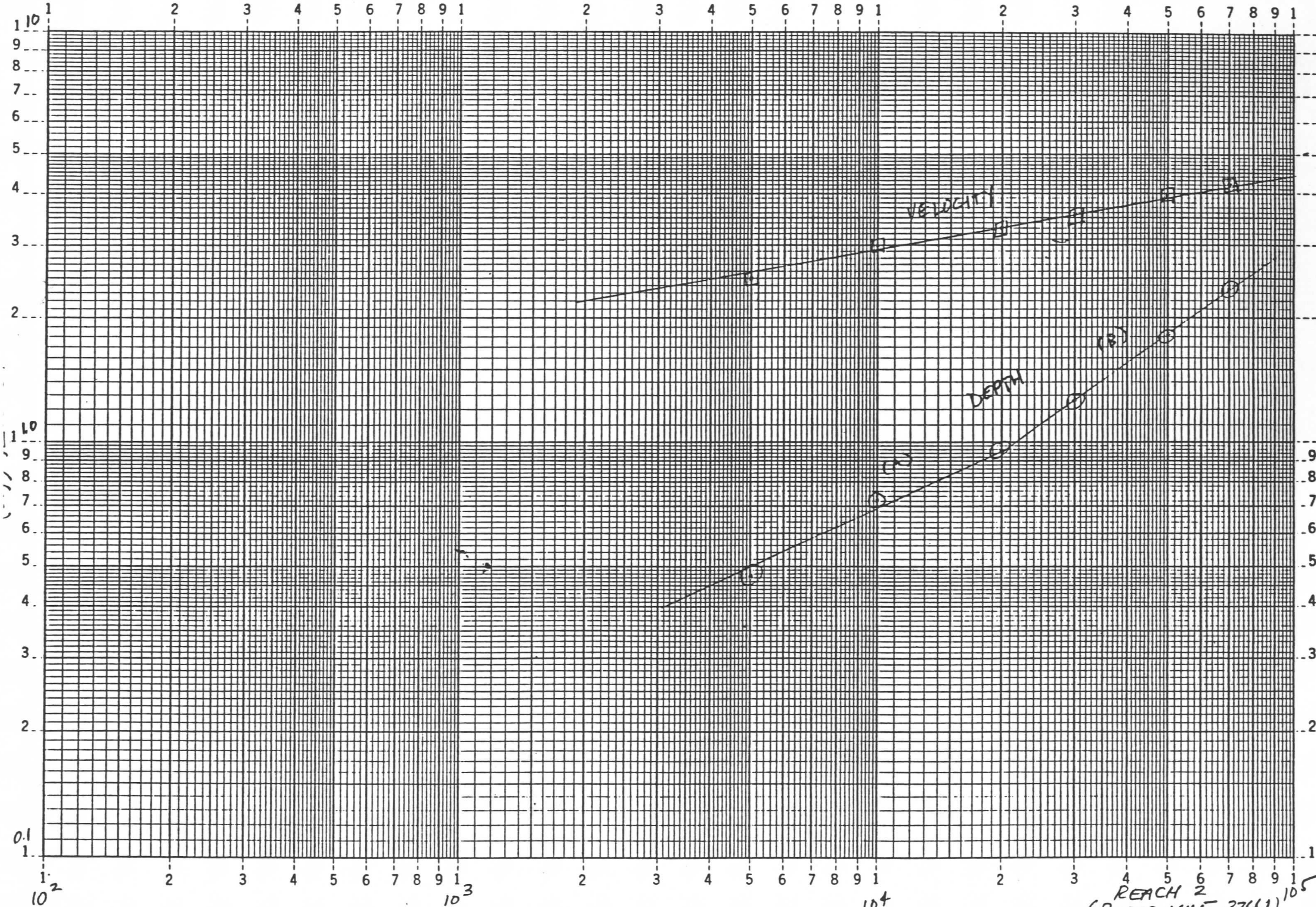
K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7320



Q (cfs)

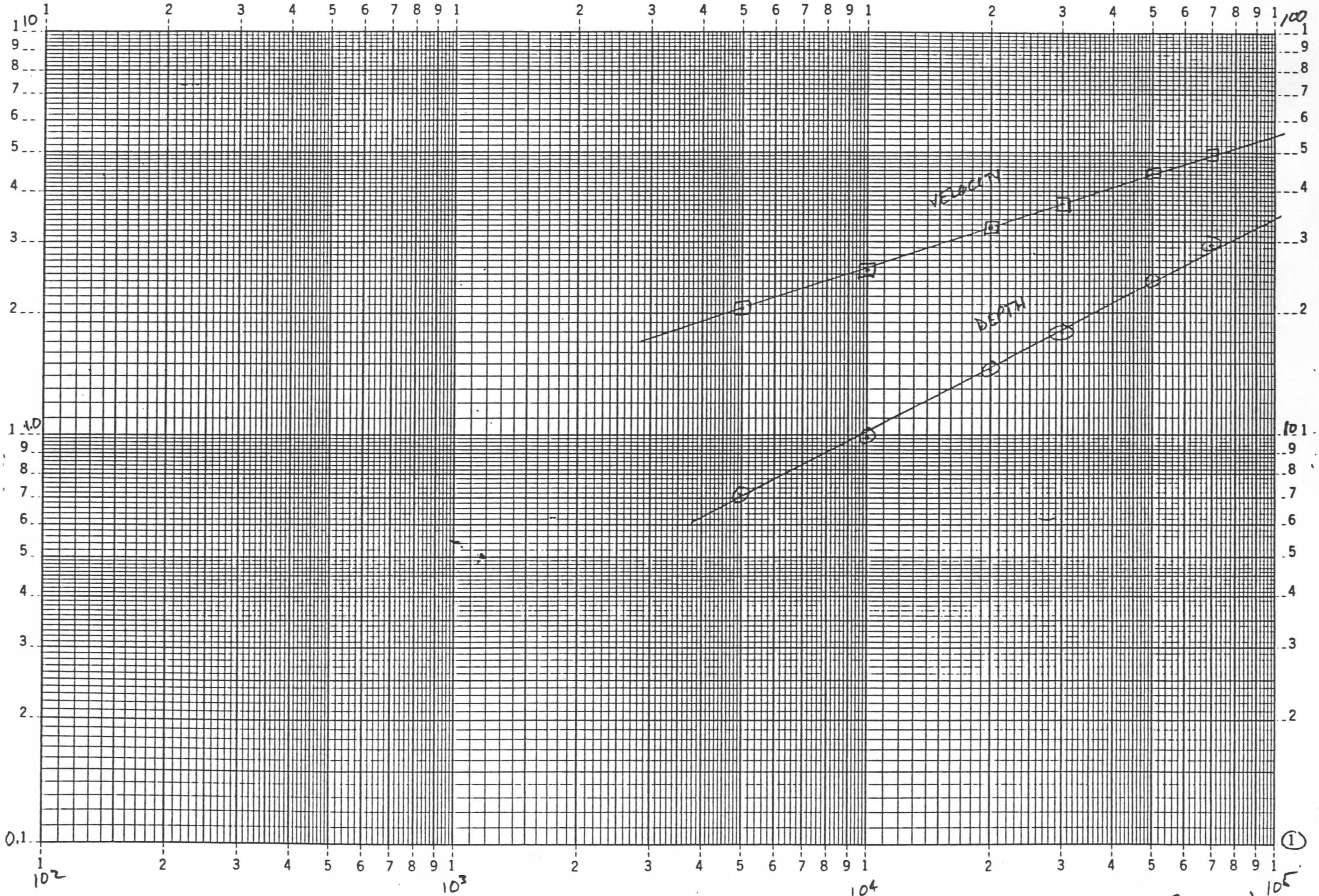
REACH 1 ✓



REACH 2
(RIVER MILE 274.1)
JCB 4-13-87

K•E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

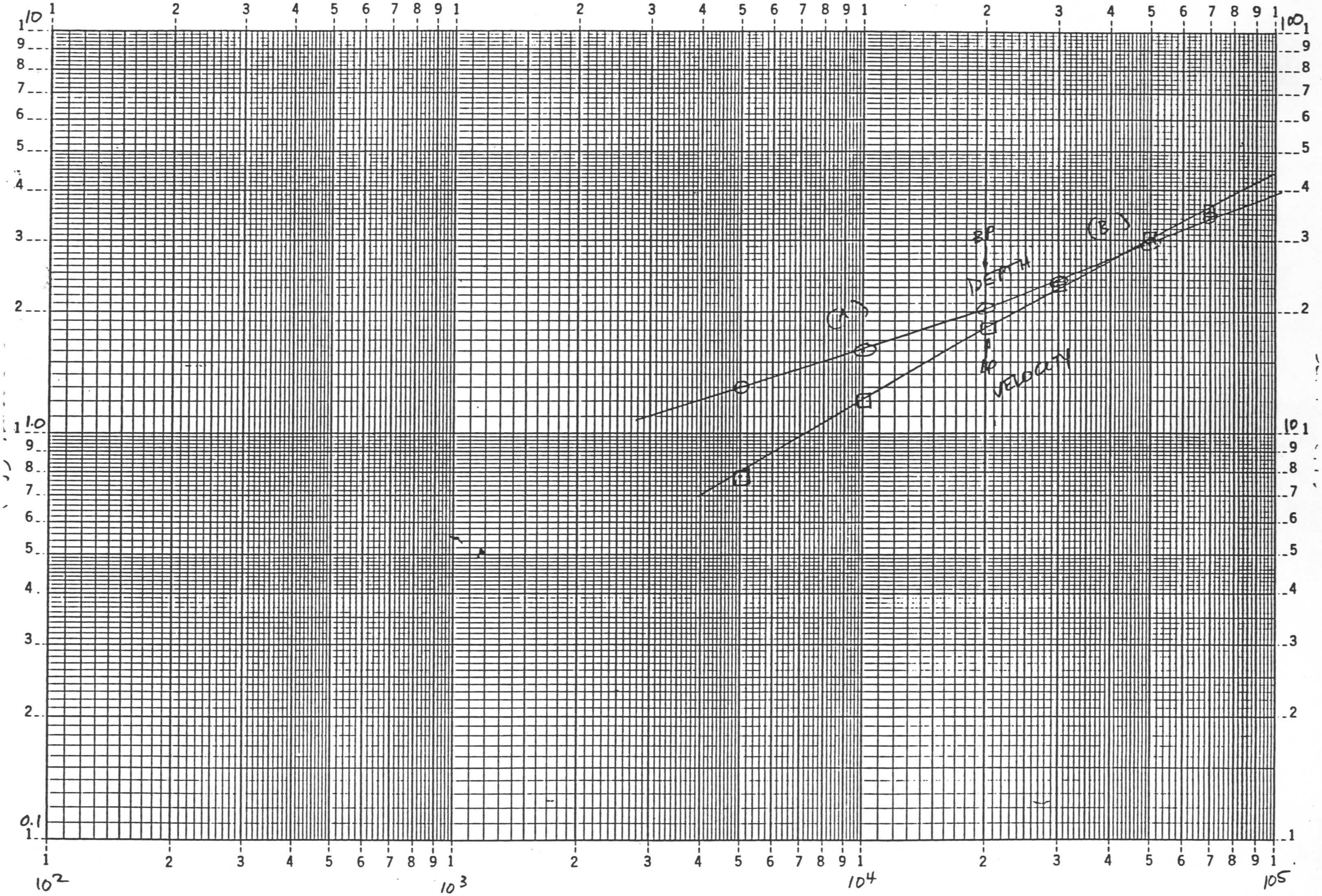
46 7320



REACH 3 (RM 273.0)

K·E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

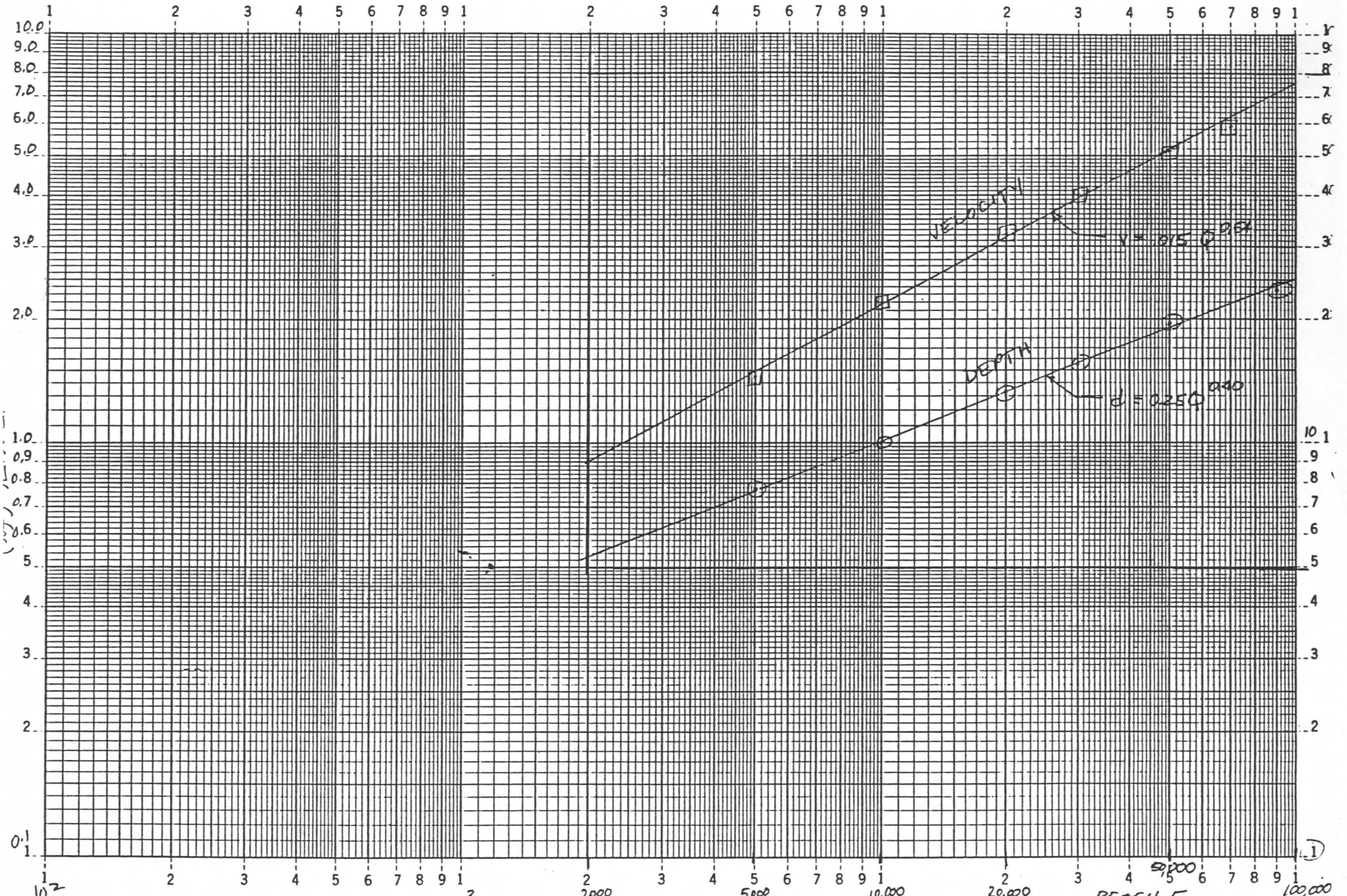
46 7320



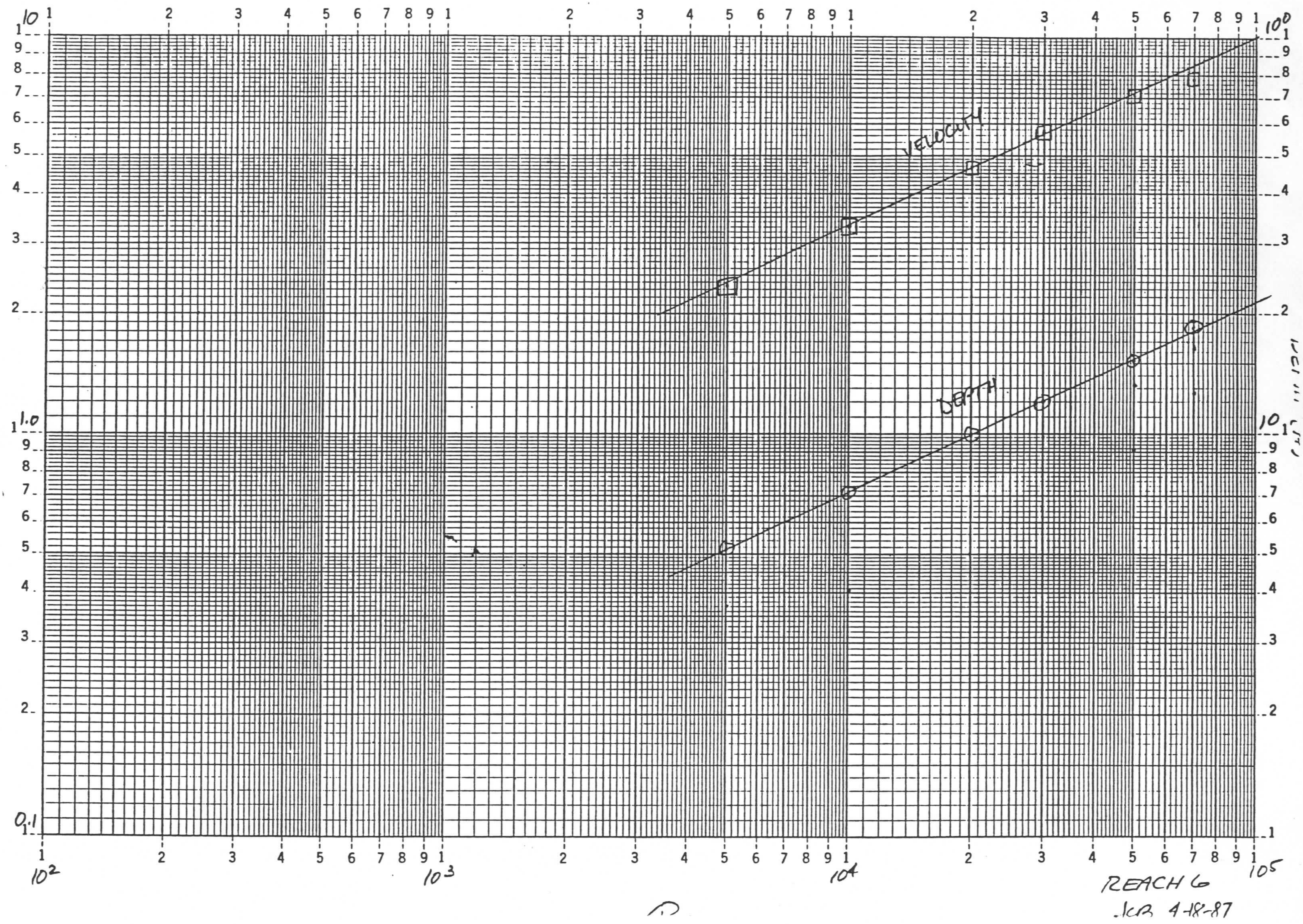
REACH 4

K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7320

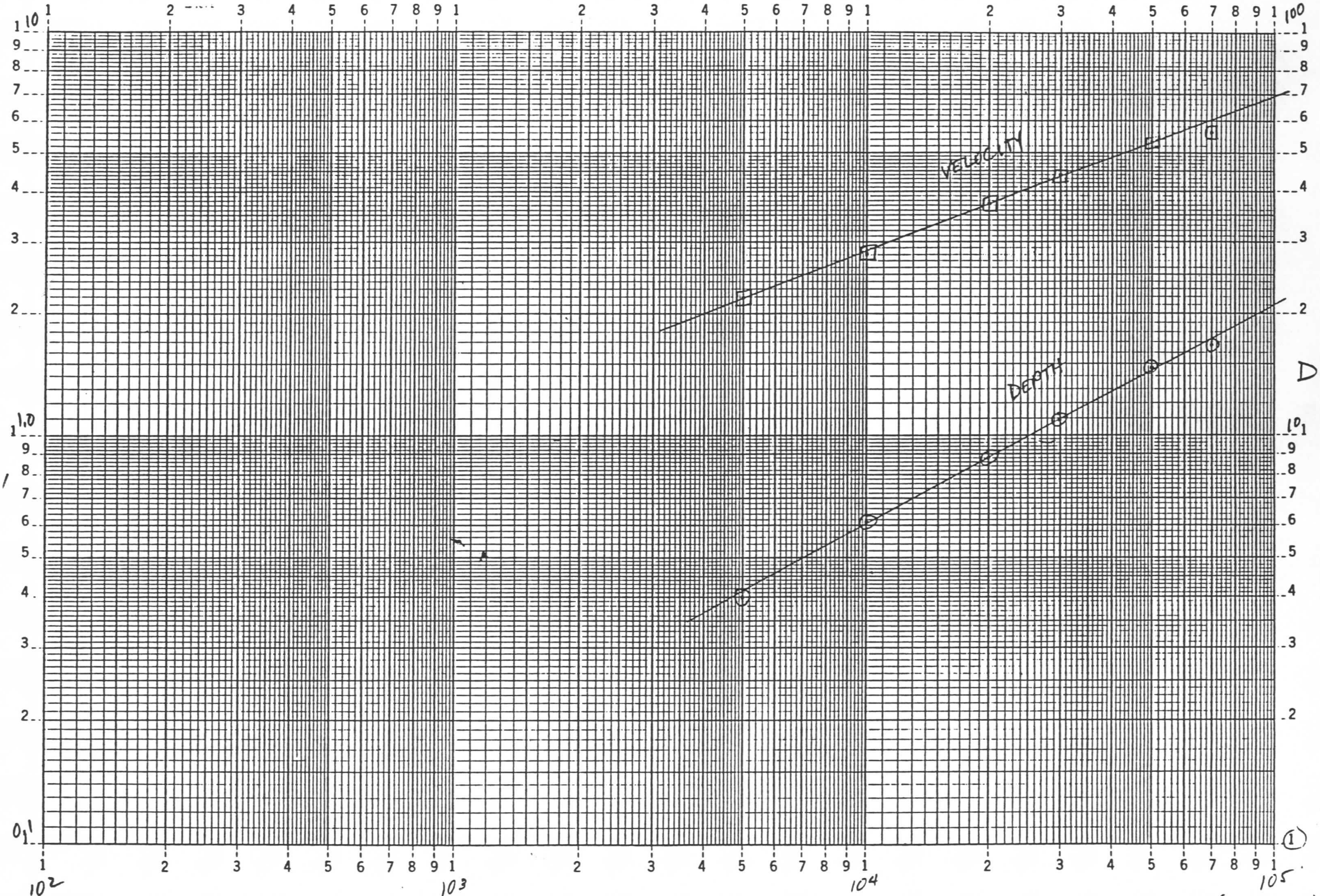


REACH 5
(RIVER MILE 271.2)
4-13-87


VELOCITY
DEPTH
10
1.0
0.1
10^0
10
10^2
10^3
10^4
10^5
REACH 6
JKB 4-18-87

K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

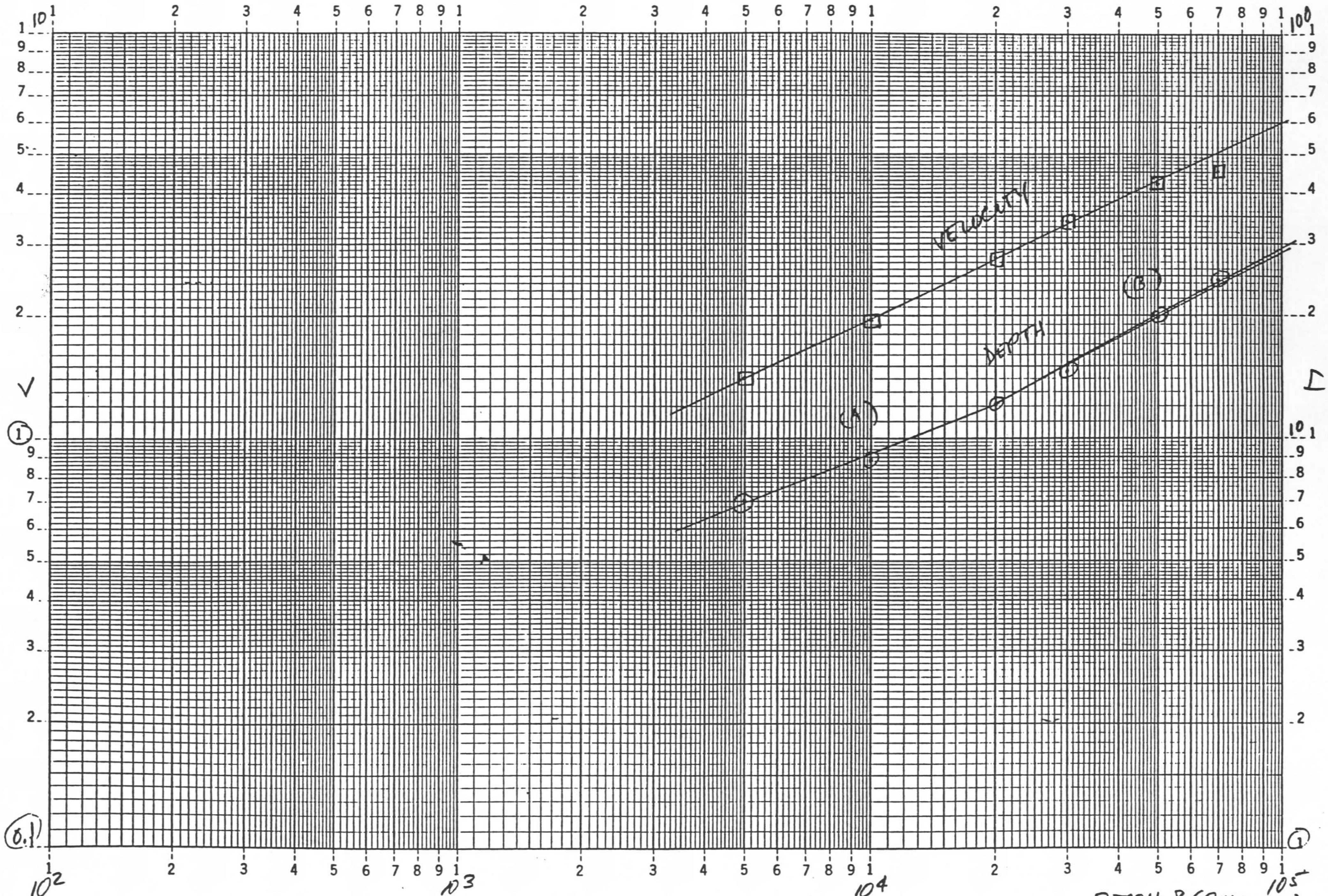
46 7320



REACH 7 (RM 289.5)

K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

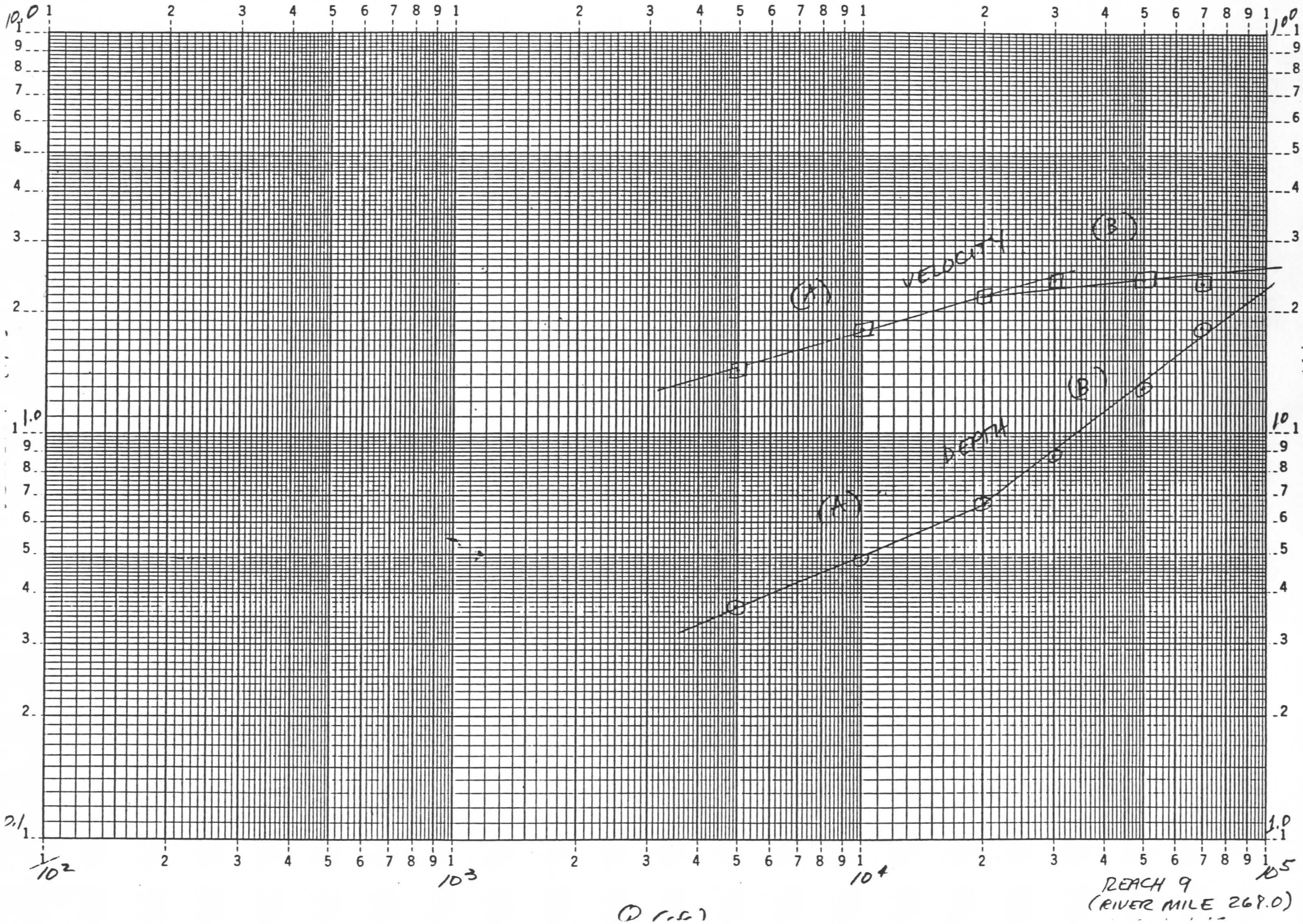
46 7320



REACH 8 (RM 269.0)
JCR 4-18-87

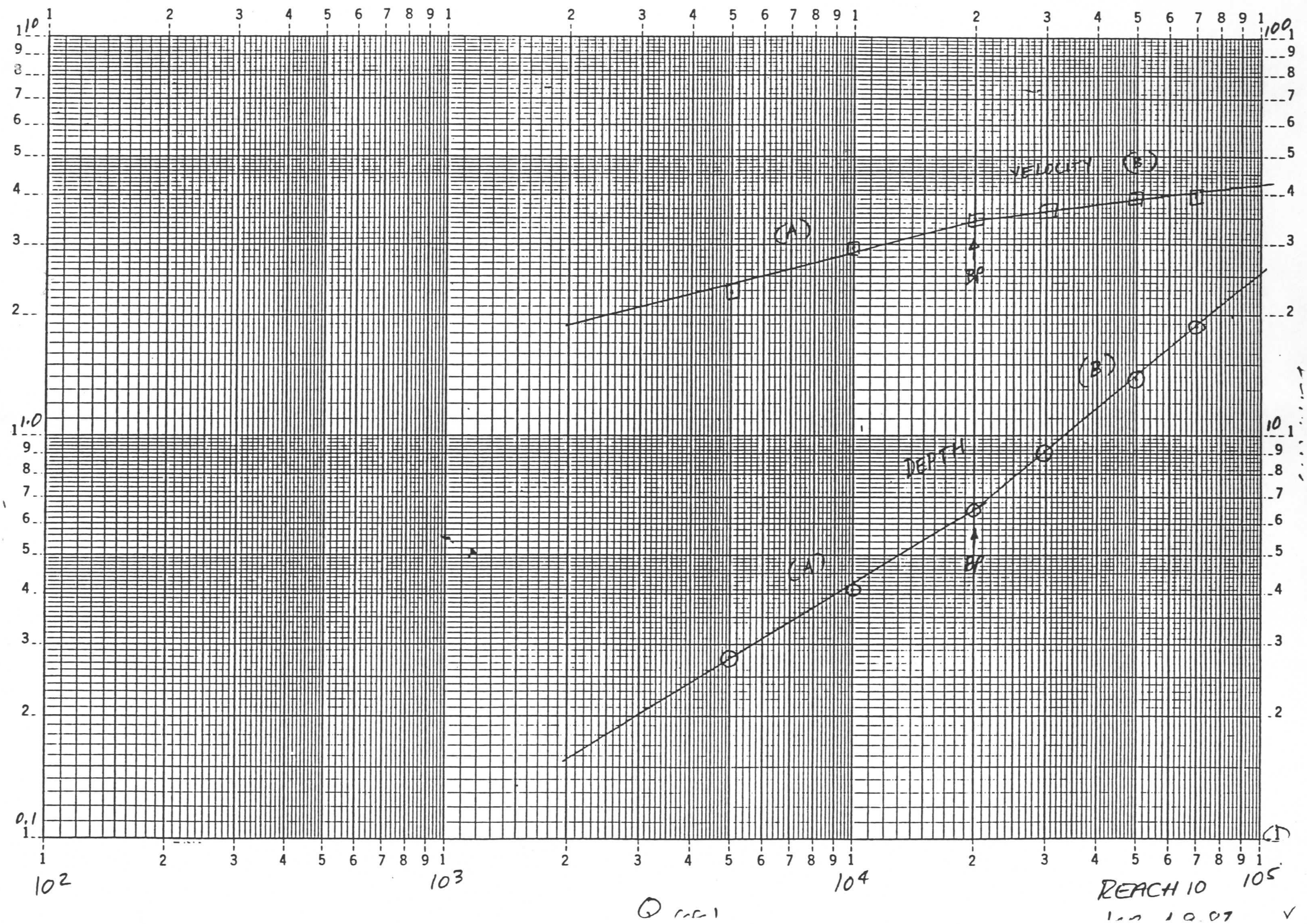
K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7320



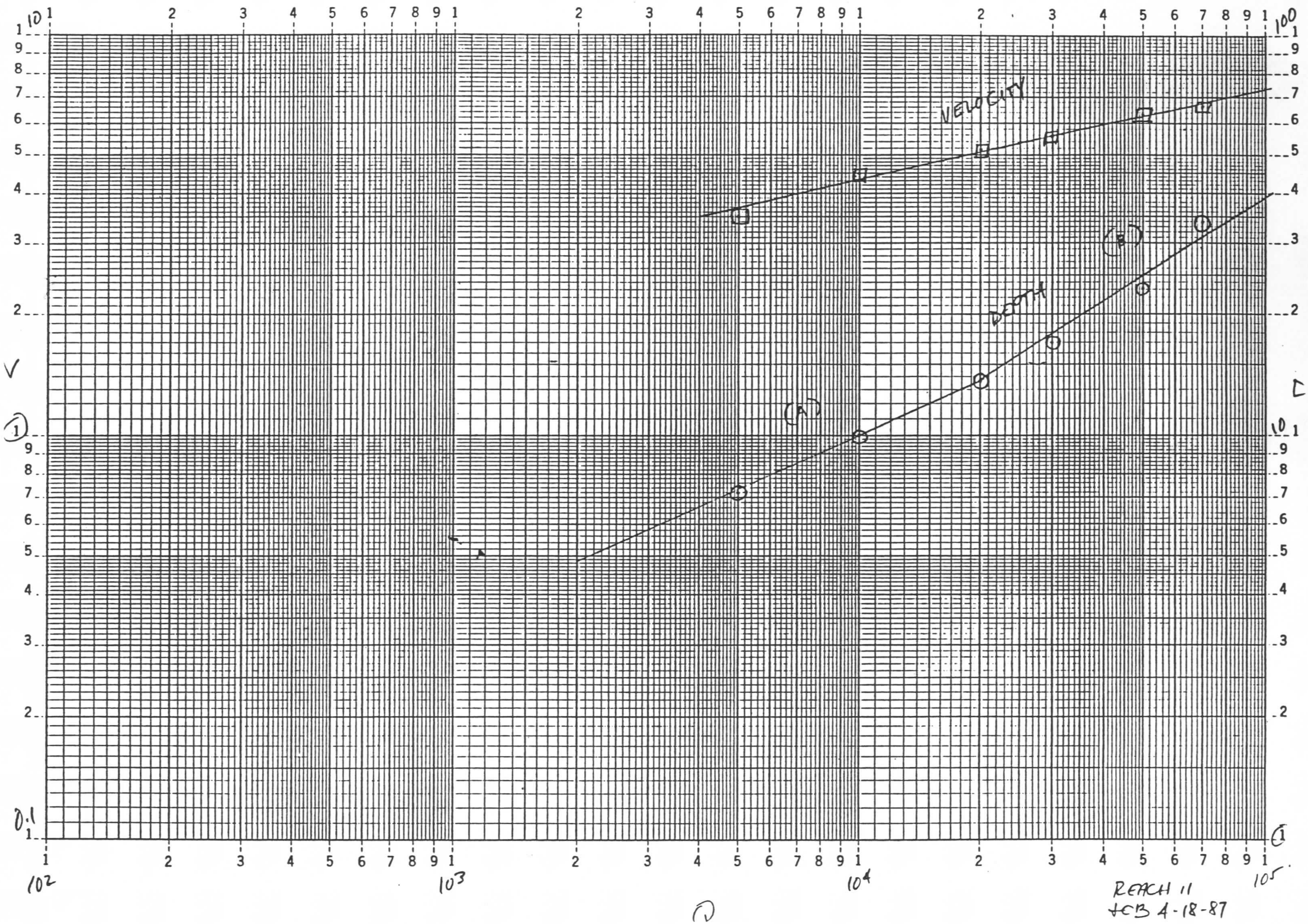
K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7320



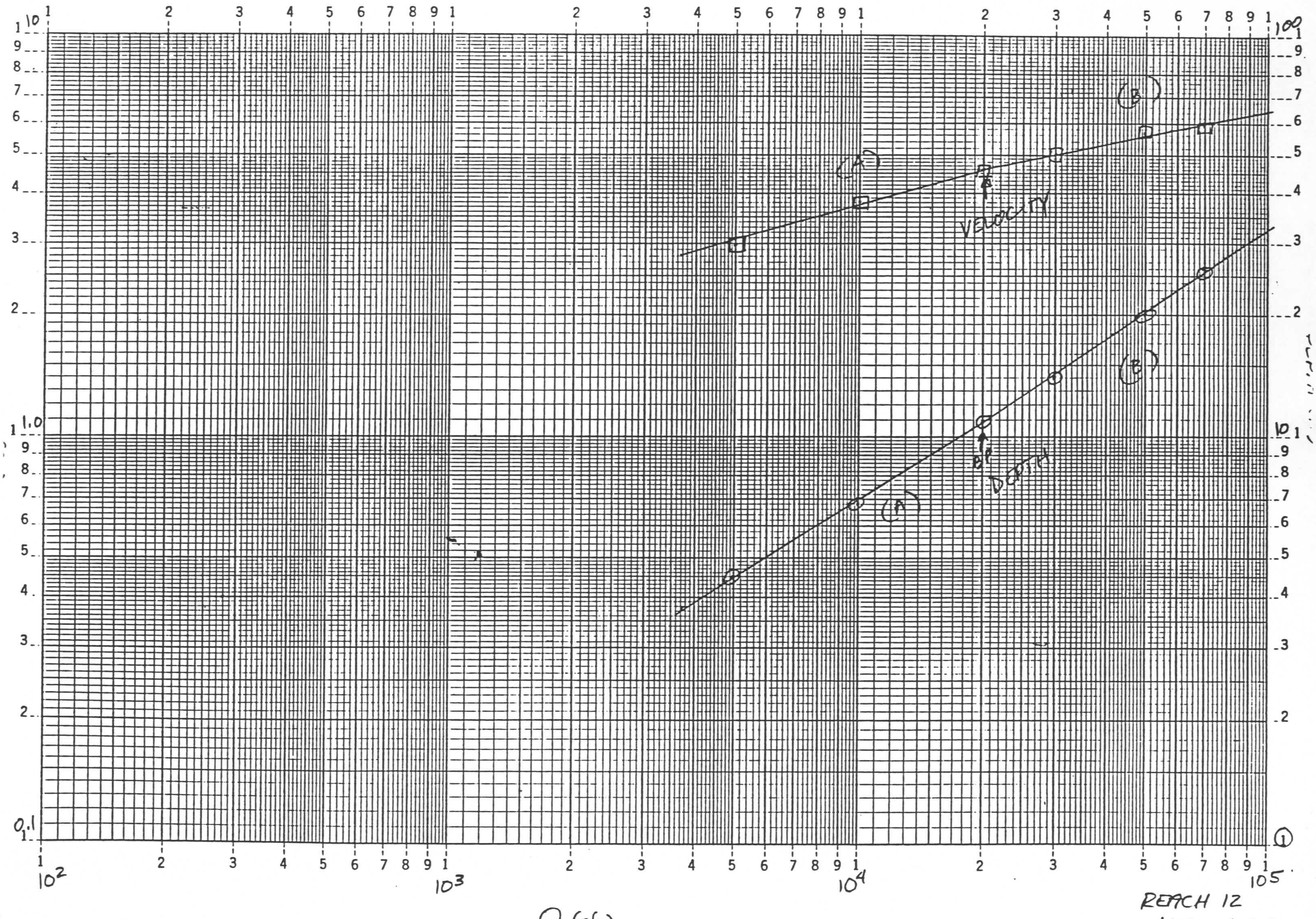
K+E LOGARITHMIC 2 X 3 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7320



K+E LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

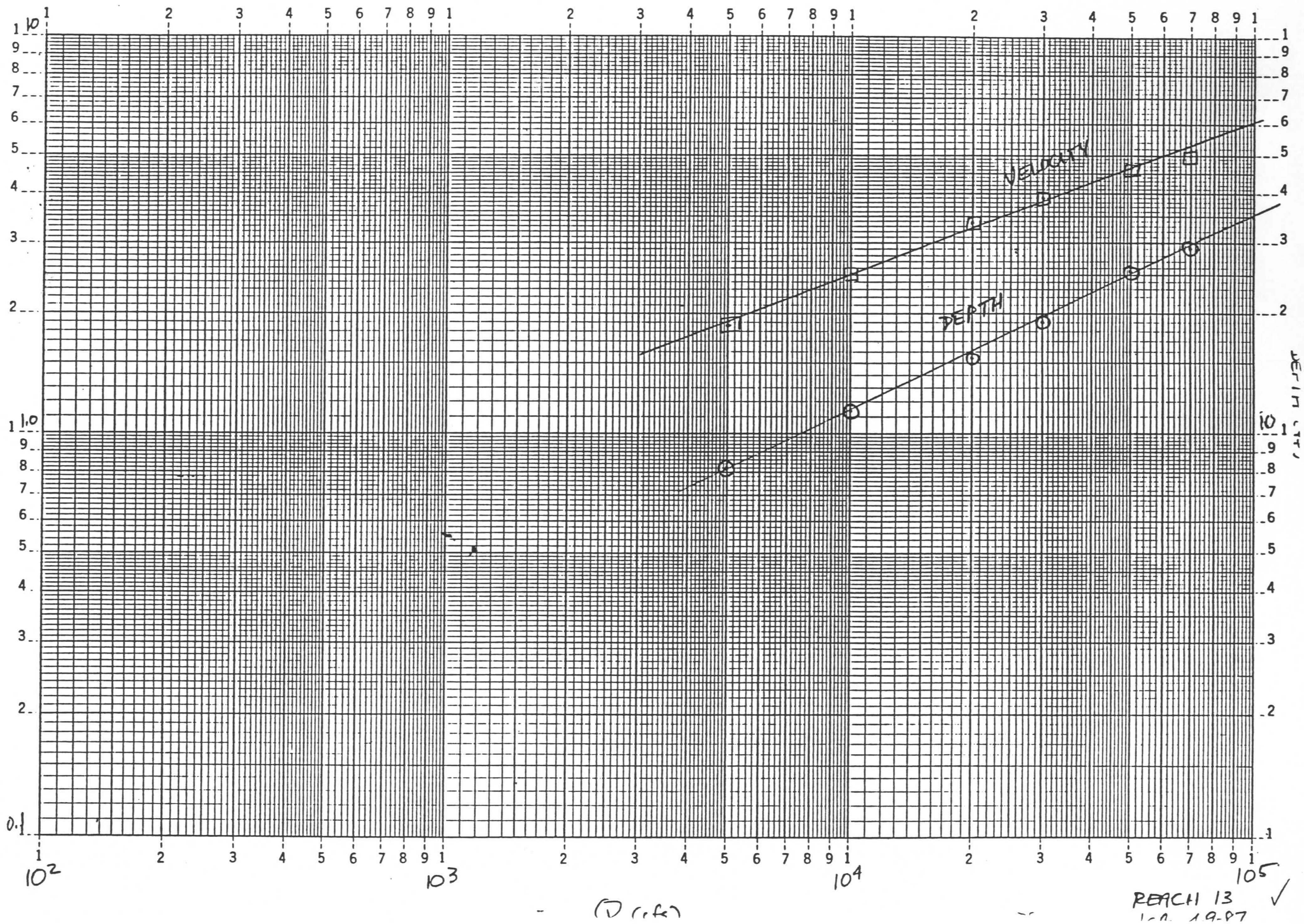
46 7320



REACH 12

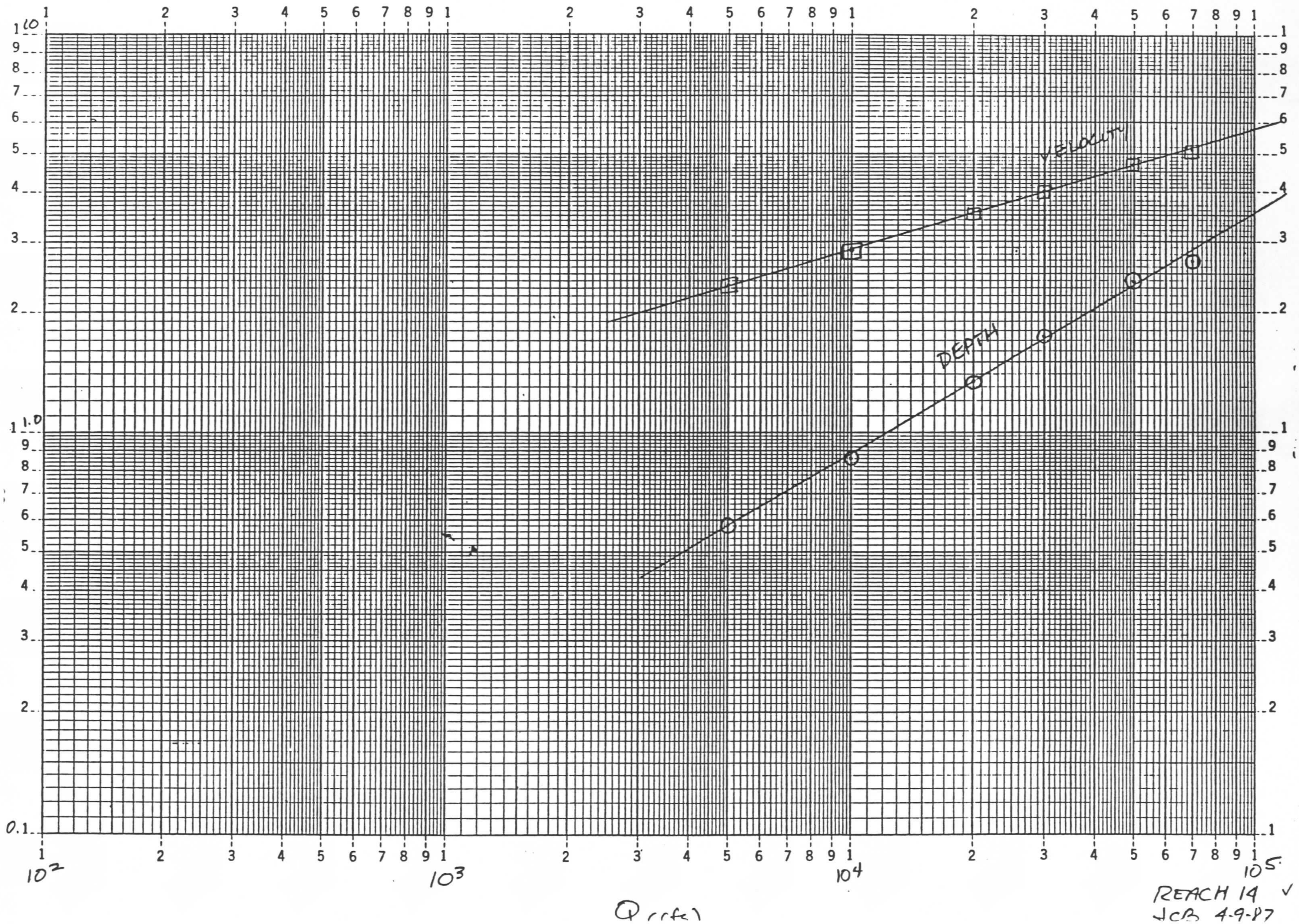
K•Σ LOGARITHMIC • 2 X 3 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7320



REACH 13 ✓

K+E LOGARITHMIC • 2 X 3 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 7320



REACH 14 ✓
JCB 4-9-87

ATTACHMENT E

TO

SECTION II

COLORADO RIVER MODEL

ATTACHMENT E

COMPUTER OUTPUT WITH RESULTS OF
MODEL VERIFICATION RUNS

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX UG/L	CHLA UG/L
1	1	54.00	540.00	53.00	70.00	10.40	1.50	.0500	.1999	.0100	.2600	.5200	.0120	.0080	.0200	17.92	.0000	1.00
1	2	54.00	540.00	53.00	70.00	10.40	1.50	.0500	.1999	.0101	.2600	.5200	.0120	.0080	.0200	17.83	.0000	1.00
1	3	54.00	540.00	53.00	70.00	10.40	1.50	.0500	.1998	.0101	.2600	.5200	.0120	.0080	.0200	17.75	.0000	1.00
1	4	54.00	540.00	53.00	70.00	10.40	1.50	.0500	.1998	.0102	.2600	.5200	.0120	.0090	.0200	17.67	.0000	1.00
1	5	54.00	540.00	53.00	70.00	10.40	1.50	.0500	.1997	.0102	.2601	.5200	.0120	.0080	.0200	17.59	.0000	1.00
2	1	54.00	540.00	53.00	70.00	10.39	1.50	.0500	.1997	.0103	.2601	.5200	.0120	.0080	.0200	17.50	.0000	1.00
2	2	54.00	540.00	53.00	70.00	10.39	1.50	.0500	.1996	.0103	.2601	.5200	.0120	.0080	.0200	17.42	.0000	1.00
2	3	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1996	.0103	.2601	.5200	.0120	.0080	.0200	17.33	.0000	1.00
2	4	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1995	.0104	.2601	.5200	.0120	.0080	.0200	17.24	.0000	1.00
2	5	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1995	.0104	.2601	.5200	.0120	.0080	.0200	17.15	.0000	1.00
2	6	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1994	.0105	.2601	.5200	.0120	.0080	.0200	17.06	.0000	1.00
3	1	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1994	.0105	.2601	.5200	.0120	.0080	.0200	16.97	.0000	1.00
3	2	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1993	.0106	.2601	.5200	.0120	.0080	.0200	16.88	.0000	1.00
3	3	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1992	.0106	.2602	.5200	.0120	.0080	.0200	16.79	.0000	1.00
3	4	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1992	.0107	.2602	.5200	.0120	.0080	.0200	16.71	.0000	1.00
3	5	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1991	.0107	.2602	.5200	.0120	.0080	.0200	16.62	.0000	1.00
4	1	54.00	540.00	53.00	70.00	10.39	1.49	.0500	.1990	.0108	.2602	.5200	.0120	.0080	.0200	16.50	.0000	1.00
4	2	54.00	540.00	53.00	70.00	10.38	1.49	.0500	.1989	.0109	.2602	.5200	.0120	.0080	.0200	16.35	.0000	1.00
4	3	54.00	540.00	53.00	70.00	10.38	1.48	.0500	.1988	.0109	.2602	.5200	.0120	.0080	.0200	16.20	.0000	1.00
4	4	54.00	540.00	53.00	70.00	10.38	1.48	.0500	.1987	.0110	.2603	.5200	.0120	.0080	.0200	16.05	.0000	1.00
4	5	54.00	540.00	53.00	70.00	10.38	1.48	.0500	.1986	.0111	.2603	.5200	.0120	.0080	.0200	15.91	.0000	1.00
5	1	54.00	540.00	53.00	70.00	10.37	1.48	.0500	.1986	.0112	.2603	.5200	.0120	.0080	.0200	15.79	.0000	1.00
5	2	54.00	540.00	53.00	70.00	10.37	1.48	.0500	.1985	.0112	.2603	.5200	.0120	.0090	.0200	15.71	.0000	1.00
5	3	54.00	540.00	53.00	70.00	10.37	1.48	.0500	.1984	.0113	.2603	.5200	.0120	.0080	.0200	15.63	.0000	1.00
6	1	54.00	540.00	53.00	70.00	10.37	1.48	.0500	.1984	.0113	.2603	.5200	.0120	.0080	.0200	15.56	.0000	1.00
6	2	54.00	540.00	53.00	70.00	10.37	1.48	.0500	.1984	.0113	.2604	.5200	.0120	.0080	.0200	15.50	.0000	1.00
6	3	54.00	540.00	53.00	70.00	10.37	1.48	.0500	.1983	.0114	.2604	.5200	.0120	.0080	.0200	15.45	.0000	1.00
6	4	54.00	540.00	53.00	70.00	10.37	1.48	.0499	.1983	.0114	.2604	.5200	.0120	.0080	.0200	15.39	.0000	1.00
7	1	54.00	540.00	53.00	70.00	10.37	1.48	.0499	.1982	.0114	.2604	.5200	.0120	.0080	.0200	15.33	.0000	1.00
7	2	54.00	540.00	53.00	70.00	10.37	1.48	.0499	.1982	.0115	.2604	.5200	.0120	.0080	.0200	15.26	.0000	1.00
7	3	54.00	540.00	53.00	70.00	10.37	1.47	.0499	.1981	.0115	.2604	.5200	.0120	.0080	.0200	15.19	.0000	1.00
7	4	54.00	540.00	53.00	70.00	10.37	1.47	.0499	.1981	.0115	.2604	.5200	.0120	.0080	.0200	15.12	.0000	1.00
8	1	54.00	540.00	53.00	70.00	10.37	1.47	.0499	.1980	.0116	.2604	.5200	.0120	.0080	.0200	15.04	.0000	1.00
8	2	54.00	540.00	53.00	70.00	10.37	1.47	.0499	.1980	.0116	.2605	.5200	.0120	.0080	.0200	14.95	.0000	1.00
8	3	54.00	540.00	53.00	70.00	10.37	1.47	.0499	.1979	.0117	.2605	.5200	.0120	.0080	.0200	14.86	.0000	1.00
8	4	54.00	540.00	53.00	70.00	10.37	1.47	.0499	.1978	.0117	.2605	.5200	.0120	.0080	.0200	14.77	.0000	1.00

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
9	1	65.30	541.21	56.48	70.37	7.67	1.92	.2288	.0405	.0104	.2839	.5636	.0119	.0088	.0207	12.30	.0002	2.23
9	2	65.38	541.21	56.48	70.37	7.69	1.92	.2288	.0405	.0104	.2839	.5636	.0119	.0088	.0207	12.11	.0002	2.24
9	3	65.45	541.21	56.48	70.37	7.72	1.92	.2287	.0405	.0104	.2839	.5635	.0119	.0088	.0207	11.92	.0002	2.24
9	4	65.52	541.21	56.48	70.37	7.75	1.91	.2287	.0405	.0104	.2838	.5634	.0119	.0088	.0207	11.74	.0002	2.25
9	5	65.59	541.21	56.48	70.37	7.77	1.91	.2287	.0405	.0104	.2838	.5634	.0119	.0088	.0207	11.56	.0002	2.26
10	1	65.66	541.21	56.48	70.37	7.80	1.91	.2286	.0405	.0104	.2838	.5633	.0119	.0088	.0207	11.41	.0002	2.26
10	2	65.71	541.21	56.48	70.37	7.83	1.91	.2286	.0405	.0104	.2838	.5633	.0119	.0088	.0207	11.30	.0002	2.27
10	3	65.77	541.21	56.48	70.37	7.86	1.90	.2286	.0405	.0104	.2838	.5633	.0119	.0088	.0207	11.20	.0002	2.27
10	4	65.83	541.21	56.48	70.37	7.89	1.90	.2286	.0405	.0104	.2838	.5632	.0119	.0088	.0207	11.09	.0002	2.28
10	5	65.89	541.21	56.48	70.37	7.92	1.90	.2285	.0405	.0105	.2837	.5632	.0119	.0088	.0207	10.98	.0002	2.28
10	6	65.95	541.21	56.48	70.37	7.95	1.90	.2285	.0405	.0105	.2837	.5632	.0119	.0087	.0207	10.88	.0002	2.29
10	7	66.01	541.21	56.48	70.37	7.98	1.90	.2285	.0405	.0105	.2838	.5632	.0119	.0088	.0207	10.78	.0002	2.29
10	8	66.07	541.37	56.55	70.41	8.01	1.90	.2284	.0405	.0105	.2872	.5666	.0119	.0097	.0216	10.71	.0008	2.29
11	1	66.09	541.37	56.55	70.41	8.02	1.90	.2284	.0405	.0105	.2872	.5666	.0119	.0097	.0216	10.62	.0008	2.30
11	2	66.11	541.37	56.55	70.41	8.02	1.90	.2284	.0405	.0105	.2872	.5665	.0119	.0097	.0216	10.55	.0008	2.30
11	3	66.12	541.37	56.55	70.41	8.03	1.90	.2284	.0405	.0105	.2871	.5665	.0119	.0097	.0216	10.49	.0008	2.30
11	4	66.13	541.37	56.55	70.41	8.03	1.89	.2284	.0405	.0105	.2871	.5665	.0119	.0097	.0216	10.42	.0008	2.31
11	5	66.15	541.37	56.55	70.41	8.04	1.89	.2283	.0405	.0105	.2871	.5665	.0119	.0097	.0216	10.36	.0008	2.31
11	6	66.16	541.37	56.55	70.41	8.04	1.89	.2283	.0405	.0105	.2871	.5664	.0119	.0097	.0216	10.29	.0008	2.31
11	7	66.17	541.37	56.55	70.41	8.04	1.89	.2283	.0405	.0105	.2871	.5664	.0119	.0097	.0216	10.23	.0008	2.32
11	8	66.19	541.37	56.55	70.41	8.05	1.89	.2283	.0405	.0105	.2871	.5664	.0119	.0097	.0216	10.17	.0008	2.32
11	9	66.20	541.37	56.55	70.41	8.05	1.89	.2283	.0405	.0105	.2871	.5663	.0119	.0097	.0216	10.10	.0008	2.33
11	10	66.21	541.37	56.55	70.41	8.05	1.89	.2283	.0405	.0105	.2870	.5663	.0119	.0097	.0216	10.04	.0008	2.33
12	1	66.23	541.37	56.55	70.41	8.06	1.89	.2283	.0405	.0105	.2870	.5663	.0119	.0097	.0216	9.97	.0008	2.33
12	2	66.26	541.37	56.55	70.41	8.07	1.88	.2282	.0405	.0105	.2870	.5663	.0119	.0097	.0216	9.90	.0008	2.34
12	3	66.29	541.37	56.55	70.41	8.08	1.88	.2282	.0405	.0105	.2870	.5662	.0119	.0097	.0216	9.82	.0008	2.34
12	4	66.31	541.37	56.55	70.41	8.09	1.88	.2282	.0405	.0105	.2870	.5662	.0119	.0097	.0216	9.75	.0008	2.34
12	5	66.34	541.37	56.55	70.41	8.10	1.88	.2282	.0405	.0105	.2870	.5662	.0119	.0097	.0215	9.67	.0008	2.35
12	6	66.37	541.37	56.55	70.41	8.11	1.88	.2282	.0405	.0105	.2870	.5661	.0119	.0097	.0215	9.60	.0008	2.35
12	7	66.39	541.37	56.55	70.41	8.12	1.88	.2281	.0405	.0105	.2869	.5661	.0119	.0097	.0215	9.53	.0008	2.36
13	1	66.42	541.37	56.55	70.41	8.12	1.88	.2281	.0405	.0105	.2869	.5660	.0119	.0096	.0215	9.43	.0008	2.36
13	2	66.44	541.37	56.55	70.41	8.13	1.87	.2281	.0405	.0105	.2869	.5660	.0119	.0096	.0215	9.32	.0008	2.37
13	3	66.46	541.37	56.55	70.41	8.13	1.87	.2281	.0405	.0105	.2869	.5659	.0119	.0096	.0215	9.20	.0008	2.37
13	4	66.49	541.37	56.55	70.41	8.13	1.87	.2280	.0405	.0105	.2868	.5659	.0119	.0096	.0215	9.09	.0008	2.38
13	5	66.51	541.37	56.55	70.41	8.13	1.87	.2280	.0405	.0105	.2868	.5658	.0119	.0096	.0215	8.98	.0008	2.39
13	6	66.53	541.37	56.55	70.41	8.14	1.86	.2280	.0405	.0105	.2868	.5657	.0119	.0096	.0215	8.87	.0008	2.40
13	7	66.55	541.37	56.55	70.41	8.14	1.86	.2279	.0405	.0105	.2867	.5657	.0119	.0096	.0215	8.77	.0008	2.40
13	8	66.58	541.37	56.55	70.41	8.14	1.86	.2279	.0405	.0105	.2867	.5656	.0119	.0096	.0215	8.66	.0008	2.41
13	9	66.60	541.37	56.55	70.41	8.14	1.86	.2279	.0405	.0105	.2867	.5656	.0119	.0096	.0215	8.56	.0008	2.42
13	10	66.62	541.37	56.55	70.41	8.14	1.85	.2279	.0405	.0105	.2866	.5655	.0119	.0096	.0214	8.45	.0008	2.42
13	11	66.65	541.37	56.55	70.41	8.15	1.85	.2278	.0405	.0105	.2866	.5654	.0119	.0096	.0214	8.35	.0008	2.43
13	12	66.67	541.37	56.55	70.41	8.15	1.85	.2278	.0405	.0105	.2866	.5654	.0119	.0096	.0214	8.25	.0008	2.44
13	13	66.69	541.37	56.55	70.41	8.15	1.85	.2278	.0405	.0106	.2865	.5653	.0119	.0096	.0214	8.15	.0008	2.44
13	14	66.71	541.37	56.55	70.41	8.15	1.85	.2277	.0405	.0106	.2865	.5653	.0119	.0095	.0214	8.05	.0008	2.45
13	15	66.74	541.37	56.55	70.41	8.16	1.84	.2277	.0405	.0106	.2865	.5652	.0119	.0095	.0214	7.95	.0008	2.46
13	16	66.76	541.37	56.55	70.41	8.16	1.84	.2277	.0405	.0106	.2865	.5651	.0119	.0095	.0214	7.85	.0008	2.47

LAUGHLIN DISCHARGE STUDY - FEBRUARY FINAL VERIFICATION RUN
COLORADO RIVER - MOHAVE REACH (FINAL)

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX UG/L	CHLA UG/L
14	1	53.99	540.01	53.00	70.00	10.34	1.44	.0499	.1954	.0136	.2613	.5202	.0119	.0082	.0201	11.79	.0000	1.01
14	2	53.99	540.01	53.00	70.00	10.34	1.44	.0499	.1953	.0136	.2613	.5202	.0119	.0082	.0201	11.74	.0000	1.01
14	3	53.99	540.01	53.00	70.00	10.34	1.44	.0499	.1953	.0136	.2614	.5202	.0119	.0082	.0201	11.68	.0000	1.01
14	4	53.99	540.01	53.00	70.00	10.34	1.44	.0499	.1952	.0137	.2614	.5202	.0119	.0082	.0201	11.63	.0000	1.01
14	5	53.99	540.01	53.00	70.00	10.34	1.44	.0499	.1952	.0137	.2614	.5202	.0119	.0082	.0201	11.57	.0000	1.01
14	6	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1951	.0138	.2614	.5202	.0119	.0082	.0201	11.52	.0000	1.01
14	7	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1951	.0138	.2614	.5202	.0119	.0082	.0201	11.46	.0000	1.01
14	8	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1950	.0138	.2614	.5202	.0119	.0082	.0201	11.41	.0000	1.01
14	9	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1950	.0139	.2614	.5202	.0119	.0082	.0201	11.36	.0000	1.01
14	10	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1949	.0139	.2615	.5202	.0119	.0082	.0201	11.30	.0000	1.01
14	11	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1949	.0139	.2615	.5202	.0119	.0082	.0201	11.25	.0000	1.01
14	12	53.99	540.01	53.00	70.00	10.34	1.43	.0499	.1948	.0140	.2615	.5202	.0119	.0082	.0201	11.20	.0000	1.01

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX UG/L	CHLA UG/L
9	1	64.28	540.00	56.00	64.00	8.48	1.46	.0051	.0882	.0064	.2902	.3898	.0054	.0036	.0090	1.50	.0000	1.02
9	2	64.32	540.00	56.00	64.00	8.49	1.46	.0051	.0881	.0064	.2902	.3898	.0054	.0036	.0090	1.48	.0000	1.02
9	3	64.37	540.00	56.00	64.00	8.49	1.45	.0051	.0880	.0065	.2902	.3898	.0054	.0036	.0090	1.46	.0000	1.02
9	4	64.42	540.00	56.00	64.00	8.50	1.45	.0051	.0880	.0065	.2902	.3898	.0054	.0036	.0090	1.45	.0000	1.02
9	5	64.46	540.00	56.00	64.00	8.50	1.45	.0051	.0879	.0066	.2902	.3898	.0054	.0036	.0090	1.43	.0000	1.02
10	1	64.50	540.00	56.00	64.00	8.50	1.45	.0051	.0878	.0066	.2903	.3898	.0054	.0036	.0090	1.42	.0000	1.02
10	2	64.53	540.00	56.00	64.00	8.51	1.45	.0051	.0878	.0067	.2903	.3898	.0054	.0036	.0090	1.41	.0000	1.02
10	3	64.57	540.00	56.00	64.00	8.51	1.45	.0051	.0877	.0067	.2903	.3898	.0054	.0036	.0090	1.40	.0000	1.02
10	4	64.60	540.00	56.00	64.00	8.52	1.45	.0051	.0877	.0067	.2903	.3898	.0054	.0036	.0090	1.39	.0000	1.02
10	5	64.63	540.00	56.00	64.00	8.52	1.45	.0051	.0877	.0067	.2903	.3898	.0054	.0036	.0090	1.38	.0000	1.02
10	6	64.66	540.00	56.00	64.00	8.53	1.44	.0051	.0876	.0068	.2903	.3898	.0054	.0036	.0090	1.37	.0000	1.02
10	7	64.69	540.00	56.00	64.00	8.53	1.44	.0051	.0876	.0068	.2903	.3898	.0054	.0036	.0090	1.36	.0000	1.02
10	8	64.72	540.01	56.00	64.00	8.53	1.44	.0052	.0875	.0068	.2906	.3901	.0054	.0036	.0090	1.36	.0000	1.02
11	1	64.74	540.01	56.00	64.00	8.54	1.44	.0052	.0875	.0069	.2906	.3901	.0054	.0036	.0090	1.35	.0000	1.02
11	2	64.75	540.01	56.00	64.00	8.54	1.44	.0052	.0875	.0069	.2906	.3901	.0054	.0036	.0090	1.34	.0000	1.02
11	3	64.76	540.01	56.00	64.00	8.54	1.44	.0052	.0874	.0069	.2906	.3901	.0054	.0036	.0090	1.34	.0000	1.02
11	4	64.77	540.01	56.00	64.00	8.54	1.44	.0052	.0874	.0069	.2906	.3901	.0054	.0036	.0090	1.33	.0000	1.02
11	5	64.78	540.01	56.00	64.00	8.54	1.44	.0052	.0874	.0069	.2906	.3901	.0054	.0036	.0090	1.32	.0000	1.02
11	6	64.79	540.01	56.00	64.00	8.54	1.44	.0052	.0873	.0070	.2906	.3901	.0054	.0036	.0090	1.32	.0000	1.02
11	7	64.80	540.01	56.00	64.00	8.54	1.44	.0052	.0873	.0070	.2906	.3901	.0054	.0036	.0090	1.31	.0000	1.02
11	8	64.81	540.01	56.00	64.00	8.54	1.44	.0052	.0873	.0070	.2906	.3901	.0054	.0036	.0090	1.31	.0000	1.02
11	9	64.82	540.01	56.00	64.00	8.54	1.44	.0052	.0873	.0070	.2906	.3901	.0054	.0036	.0090	1.30	.0000	1.02
11	10	64.82	540.01	56.00	64.00	8.54	1.44	.0052	.0872	.0070	.2906	.3901	.0054	.0036	.0090	1.29	.0000	1.03
12	1	64.84	540.01	56.00	64.00	8.54	1.43	.0052	.0872	.0071	.2906	.3901	.0054	.0036	.0090	1.29	.0000	1.03
12	2	64.85	540.01	56.00	64.00	8.54	1.43	.0052	.0872	.0071	.2906	.3901	.0054	.0036	.0090	1.28	.0000	1.03
12	3	64.86	540.01	56.00	64.00	8.54	1.43	.0052	.0871	.0071	.2906	.3901	.0054	.0036	.0090	1.27	.0000	1.03
12	4	64.88	540.01	56.00	64.00	8.54	1.43	.0052	.0871	.0071	.2906	.3901	.0054	.0036	.0090	1.27	.0000	1.03
12	5	64.89	540.01	56.00	64.00	8.54	1.43	.0052	.0871	.0072	.2906	.3901	.0054	.0036	.0090	1.26	.0000	1.03
12	6	64.90	540.01	56.00	64.00	8.54	1.43	.0052	.0870	.0072	.2906	.3901	.0054	.0036	.0090	1.25	.0000	1.03
12	7	64.92	540.01	56.00	64.00	8.54	1.43	.0052	.0870	.0072	.2906	.3900	.0054	.0036	.0090	1.25	.0000	1.03
13	1	64.93	540.01	56.00	64.00	8.54	1.43	.0052	.0870	.0072	.2906	.3900	.0054	.0036	.0090	1.24	.0000	1.03
13	2	64.94	540.01	56.00	64.00	8.54	1.43	.0052	.0869	.0073	.2907	.3900	.0054	.0036	.0090	1.23	.0000	1.03
13	3	64.96	540.01	56.00	64.00	8.54	1.43	.0052	.0869	.0073	.2907	.3900	.0054	.0036	.0090	1.22	.0000	1.03
13	4	64.97	540.01	56.00	64.00	8.54	1.43	.0052	.0868	.0073	.2907	.3900	.0054	.0036	.0090	1.21	.0000	1.03
13	5	64.98	540.01	56.00	64.00	8.54	1.43	.0052	.0868	.0074	.2907	.3900	.0054	.0036	.0090	1.20	.0000	1.03
13	6	65.00	540.01	56.00	64.00	8.54	1.42	.0052	.0867	.0074	.2907	.3900	.0054	.0036	.0090	1.19	.0000	1.03
13	7	65.01	540.01	56.00	64.00	8.54	1.42	.0052	.0867	.0074	.2907	.3900	.0054	.0036	.0090	1.19	.0000	1.03
13	8	65.02	540.01	56.00	64.00	8.54	1.42	.0052	.0866	.0075	.2907	.3900	.0054	.0036	.0090	1.18	.0000	1.03
13	9	65.03	540.01	56.00	64.00	8.54	1.42	.0052	.0866	.0075	.2907	.3900	.0054	.0036	.0090	1.17	.0000	1.03
13	10	65.05	540.01	56.00	64.00	8.54	1.42	.0052	.0865	.0075	.2907	.3900	.0054	.0036	.0090	1.16	.0000	1.03
13	11	65.06	540.01	56.00	64.00	8.54	1.42	.0052	.0865	.0075	.2907	.3900	.0054	.0036	.0090	1.15	.0000	1.03
13	12	65.07	540.01	56.00	64.00	8.54	1.42	.0052	.0864	.0076	.2907	.3900	.0054	.0036	.0090	1.14	.0000	1.03
13	13	65.08	540.01	56.00	64.00	8.54	1.42	.0052	.0864	.0076	.2907	.3900	.0054	.0036	.0090	1.13	.0000	1.03
13	14	65.10	540.01	56.00	64.00	8.54	1.42	.0052	.0864	.0076	.2907	.3900	.0054	.0036	.0090	1.13	.0000	1.04
13	15	65.11	540.01	56.00	64.00	8.54	1.41	.0052	.0863	.0077	.2908	.3900	.0054	.0036	.0090	1.12	.0000	1.04
13	16	65.12	540.01	56.00	64.00	8.54	1.41	.0052	.0863	.0077	.2908	.3900	.0054	.0036	.0090	1.11	.0000	1.04

* * * QUAL-2 STREAM QUALITY ROUTING MODEL * * *
* * * EPA/NCASI VERSION * * *

(PROBLEM TITLES)

CARD TYPE		QUAL-2E PROGRAM TITLES
TITLE01		LAUGHLIN DISCHARGE STUDY - OCTOBER VERIFICATION RUN
TITLE02		COLORADO R. - MOHAVE REACH (FINAL)
TITLE03	YES	CONSERVATIVE MINERAL I TDS MG/L
TITLE04	YES	CONSERVATIVE MINERAL II CL MG/L
TITLE05	YES	CONSERVATIVE MINERAL III NA MG/L
TITLE06	YES	TEMPERATURE
TITLE07	YES	5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08	YES	ALGAE AS CHL-A IN UG/L
TITLE09	YES	PHOSPHORUS CYCLE AS P IN MG/L
TITLE10		(ORGANIC-P, DISSOLVED-P)
TITLE11	YES	NITROGEN CYCLE AS N IN MG/L
TITLE12		(ORGANIC-N, AMMONIA-N, NITRITE-N, NITRITE-N)
TITLE13	YES	DISOLVED OXYGEN IN MG/L
TITLE14	YES	FECAL COLIFORMS IN NO./100 ML
TITLE15	YES	ARBITRARY NON-CONSERVATIVE CTOX UG/L
ENDTITLE		

DATA TYPE 1 (CONTROL DATA)

CARD TYPE		CARD TYPE	
LIST DATA INPUT	.00000		.00000
WRITE OPTIONAL SUMMARY	.00000		.00000
NO FLOW AUGMENTATION	.00000		.00000
STEADY STATE	.00000		.00000
NO TRAPEZOIDAL X-SECTIONS	.00000		.00000
PRINT SOLAR/LCD DATA	.00000		.00000
DO NOT PLOT DO AND BOD	.00000		.00000
FIXED DNSTM COND (YES=1)=	.00000	5D-ULT BOD CONV K COEF =	.19000
INPUT METRIC (YES=1) =	.00000	OUTPUT METRIC (YES=1) =	.00000
NUMBER OF REACHES =	14.00000	NUMBER OF JUNCTIONS =	.00000
NUM OF HEADWATERS =	1.00000	NUMBER OF POINT LOADS =	3.00000
TIME STEP (HOURS) =	.00000	LNTH COMP ELEMENT (DX)=	.20000
MAXIMUM ITERATIONS =	30.00000	TIME INC. FOR RPT2 (HRS)=	.00000
LATITUDE OF BASIN (DEG) =	35.17000	LONGITUDE OF BASIC (DEG)=	114.57000
STANDARD MERIDIAN (DEG) =	75.00000	DAY OF YEAR START TIME =	290.00000
EVAP. COEFF. (AE) =	.00068	EVAP. COEF. (BE) =	.00027
ELEV. OF BASIN (ELEV) =	480.00000	DUST ATTENUATION COEF. =	.00000
ENDATA1	.00000		.00000

DATA TYPE 1A (ALGAE PRODUCTION AND NITROGEN OXIDATION CONSTANTS)

CARD TYPE		CARD TYPE	
O UPTAKE BY NH3 OXID(MG O/MG N)=	3.4300	O UPTAKE BY NO2 XOID(MG O/MG N)=	1.1400
O PROD BY ALGAE (MG O/MG A) =	1.4000	O UPTAKE BY ALGAE (MG O/MG A) =	1.6000
N CONTENT OF ALGAE (MG N/MG A) =	.0850	P CONTENT OF ALGAE (MG P/MG A) =	.0140
ALG MAX SPEC GROWTH RATE(1/DAY)=	3.0000	ALGAE RESPRIATION RATE (1/DAY) =	.1000
N HALF SATURATION CONST (MG/L) =	.0250	P HALF SATURATION CONST (MG/L)=	.0100
LIN ALG SHADE CO (1/FT-UGCHA/L=)	.0000	NLIN SHADE(1/FT-(UGCHA/L)**2/3)=	.0000
LIGHT FUNCTION OPTION (LFNOPT) =	3.0000	LIGHT SAT'N COEF (BTU/FT2-MIN) =	1.0200
DAILY AVERAGING OPTION (LAVOPT)=	2.0000	TOTAL DAILY SOLAR RADTN (INT) =	.9200
NUMBER OF DAYLIGHT HOURS (DLH) =	12.0000	TOTAL DAILY SOLR RAD (BTU/FT-2)=	1520.0000
ALGY GROWTH CALC OPTION(LGROPT)=	1.0000	ALGAL PREF FOR NH3-N (PREFN) =	.5000

DATA TYPE 5 (HYDRAULIC DATA FOR DETERMINING VE[illegible]TY AND DEPTH)

CARD TYPE	REACH	COEF-DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1.	60.00	.021	.520	.321	.391	.030
HYDRAULICS	2.	60.00	.549	.181	.096	.464	.030
HYDRAULICS	3.	60.00	.129	.325	.079	.527	.030
HYDRAULICS	4.	60.00	.005	.590	.850	.320	.030
HYDRAULICS	5.	60.00	.015	.540	.250	.400	.030
HYDRAULICS	6.	60.00	.040	.480	.088	.477	.030
HYDRAULICS	7.	60.00	.083	.384	.042	.540	.030
HYDRAULICS	8.	60.00	.022	.488	.224	.402	.030
HYDRAULICS	9.	60.00	.123	.290	.105	.418	.030
HYDRAULICS	10.	60.00	.254	.264	.014	.617	.030
HYDRAULICS	11.	60.00	.547	.225	.159	.449	.030
HYDRAULICS	12.	60.00	.257	.291	.019	.640	.030
HYDRAULICS	13.	60.00	.073	.384	.131	.486	.030
HYDRAULICS	14.	60.00	.179	.302	.033	.606	.030
ENDATA5	0.	.00	.000	.000	.000	.000	.000

DATA TYPE 6 (REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION)

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF OR FOR OPT 8	EXPQK2 SLOPE FOR OPT 8
REACT COEF	1.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	2.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	3.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	4.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	5.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	6.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	7.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	8.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	9.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	10.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	11.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	12.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	13.	.20	.00	.000	3.	.00	.000	.00000
REACT COEF	14.	.20	.00	.000	3.	.00	.000	.00000
ENDATA6	0.	.00	.00	.000	0.	.00	.000	.00000

DATA TYPE 6A (NITROGEN AND PHOSPHORUS CONSTANTS)

CARD TYPE	REACH	CKNH2	SETNH2	CKNH3	SNH3	CKNO2	CKPORG	SETPORG	SPO4
N AND P COEF	1.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	2.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	3.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	4.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	5.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	6.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	7.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	8.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	9.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	10.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	11.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	12.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	13.	.03	.00	.15	.00	.50	.05	.00	.00
N AND P COEF	14.	.03	.00	.15	.00	.50	.05	.00	.00
ENDATA6A	0.	.00	.00	.00	.00	.00	.00	.00	.00

DATA TYPE 8 (INCREMENTAL INFLOW CONDITIONS)

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	2.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	3.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	4.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	5.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	6.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	7.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	8.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	9.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	10.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	11.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	12.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	13.	.000	.00	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-1	14.	.000	.00	.00	.00	.00	.00	.00	.00	.00
ENDATA8	0.	.000	.00	.00	.00	.00	.00	.00	.00	.00

DATA TYPE 8A (INCREMENTAL INFLOW CONDITIONS FOR CHLOROPHYLL A, NITROGEN, AND PHOSPHORUS)

CARD TYPE	REACH	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
INCR INFLOW-2	1.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	2.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	3.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	4.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	5.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	6.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	7.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	8.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	9.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	10.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	11.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	12.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	13.	.00	.00	.00	.00	.00	.00	.00
INCR INFLOW-2	14.	.00	.00	.00	.00	.00	.00	.00
ENDATA8A	0.	.00	.00	.00	.00	.00	.00	.00

DATA TYPE 9 (STREAM JUNCTIONS)

CARD TYPE	JUNCTION ORDER AND IDENT	UPSTRM	JUNCTION	TRIB
ENDATA9	0.	0.	0.	0.

DATA TYPE 10 (HEADWATER SOURCES)

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR-1	1.	HDW= DAVIS DAM	9870.00	63.70	7.30	2.00	486.00	57.00	76.00
ENDATA10	0.		.00	.00	.00	.00	.00	.00	.00

DATA TYPE 10A (HEADWATER CONDITIONS FOR CHLOROPHYLL, NITROGEN, PHOSPHORUS,
COLIFORM AND SELECTED NON-CONSERVATIVE CONSTITUENT)

CARD TYPE	HDWTR ORDER	ANC	COLI	CHL-A	ORG-N	NH3-N	NO2-N	NO3-N	ORG-P	DIS-P
HEADWTR-2	1.	20.00	20.00	2.00	.23	.04	.01	1.10	.01	.01

S.// STATE TEMPERATURE SIMULATION; CONVERGENCE SUMMARY

ITERATION	NUMBER OF NONCONVERGENT ELEMENTS
1	35
2	0

SUMMARY OF VALUES FOR STEADY STATE TEMPERATURE CALCULATIONS (SUBROUTINE HEATER):

DAILY NET SOLAR RADIATION = 1699.503 BTU/FT-2 (461.195 LANGLEYS)
NUMBER OF DAYLIGHT HOURS = 11.0

HOURLY VALUES OF SOLAR RADIATION (BTU/FT-2)

1	.00	9	.00	17	203.41
2	.00	10	31.47	18	151.52
3	.00	11	101.54	19	87.21
4	.00	12	163.71	20	17.03
5	.00	13	212.27	21	.00
6	.00	14	242.41	22	.00
7	.00	15	251.19	23	.00
8	.00	16	237.76	24	.00

TEMPERATURE — ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	63.71	63.73	63.74	63.76	63.77															
2	63.79	63.81	63.83	63.85	63.87	63.89														
3	63.91	63.93	63.95	63.96	63.98															
4	64.00	64.02	64.04	64.06	64.08															
5	64.10	64.12	64.14																	
6	64.16	64.18	64.20	64.21																
7	64.23	64.26	64.28	64.31																
8	64.33	64.35	64.38	64.40																
9	64.43	64.48	64.52	64.57	64.62															
10	64.66	64.69	64.73	64.76	64.80	64.83	64.86	64.90												
11	64.91	64.92	64.93	64.94	64.95	64.96	64.97	64.98	64.99	65.00										
12	65.01	65.02	65.04	65.06	65.07	65.09	65.10													
13	65.12	65.13	65.14	65.16	65.17	65.18	65.20	65.21	65.23	65.24	65.25	65.27	65.28	65.29	65.31	65.32				
14	65.34	65.35	65.37	65.38	65.40	65.41	65.43	65.44	65.46	65.47	65.49	65.50								

DISOLVED OXYGEN IN MG/L — ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7.30	7.31	7.31	7.31	7.31															
2	7.32	7.33	7.34	7.35	7.36	7.37														
3	7.37	7.38	7.38	7.38	7.39															
4	7.39	7.39	7.39	7.39	7.39															
5	7.39	7.40	7.40																	
6	7.41	7.41	7.42	7.43																
7	7.44	7.45	7.46	7.47																
8	7.48	7.48	7.49	7.49																
9	7.50	7.52	7.54	7.56	7.57															
10	7.59	7.61	7.63	7.64	7.66	7.68	7.70	7.71												
11	7.72	7.72	7.73	7.73	7.73	7.73	7.74	7.74	7.74	7.75										
12	7.75	7.76	7.76	7.77	7.77	7.78	7.78													
13	7.79	7.79	7.79	7.79	7.79	7.80	7.80	7.80	7.80	7.80	7.81	7.81	7.81	7.81	7.81	7.81				
14	7.82	7.82	7.82	7.83	7.83	7.83	7.84	7.84	7.85	7.85	7.85	7.86								

5-DAY BIOCHEMICAL OXYGEN DEMAND — ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2.00	2.00	1.99	1.99	1.99															
2	1.99	1.99	1.99	1.99	1.98	1.98														
3	1.98	1.98	1.98	1.98	1.97															
4	1.97	1.97	1.96	1.96	1.96															
5	1.95	1.95	1.95																	
6	1.95	1.95	1.95	1.94																
7	1.94	1.94	1.94	1.94																
8	1.94	1.93	1.93	1.93																
9	1.93	1.93	1.92	1.92	1.92															
10	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.91												
11	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90										
12	1.89	1.89	1.89	1.89	1.89	1.89	1.89													
13	1.89	1.88	1.88	1.88	1.88	1.88	1.88	1.87	1.87	1.87	1.87	1.87	1.87	1.86	1.86	1.86				
14	1.86	1.86	1.86	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.84	1.84								

NITRATE AS N IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.10	1.10	1.10	1.10	1.10															
2	1.10	1.10	1.10	1.10	1.10	1.10														
3	1.10	1.10	1.10	1.10	1.10															
4	1.10	1.10	1.10	1.10	1.10															
5	1.10	1.10	1.10																	
6	1.10	1.10	1.10	1.10																
7	1.10	1.10	1.10	1.10																
8	1.10	1.10	1.10	1.10																
9	1.10	1.10	1.10	1.10	1.10															
10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10												
11	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10										
12	1.10	1.10	1.10	1.10	1.10	1.10	1.10													
13	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10				
14	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10								

ORGANIC PHOSPHORUS AS P IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.01	.01	.01	.01	.01															
2	.01	.01	.01	.01	.01	.01														
3	.01	.01	.01	.01	.01															
4	.01	.01	.01	.01	.01															
5	.01	.01	.01																	
6	.01	.01	.01	.01																
7	.01	.01	.01	.01																
8	.01	.01	.01	.01																
9	.01	.01	.01	.01	.01															
10	.01	.01	.01	.01	.01	.01	.01	.01												
11	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01										
12	.01	.01	.01	.01	.01	.01	.01													
13	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01				
14	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01								

DISSOLVED PHOSPHORUS AS P IN MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.01	.01	.01	.01	.01															
2	.01	.01	.01	.01	.01	.01														
3	.01	.01	.01	.01	.01															
4	.01	.01	.01	.01	.01															
5	.01	.01	.01																	
6	.01	.01	.01	.01																
7	.01	.01	.01	.01																
8	.01	.01	.01	.01																
9	.01	.01	.01	.01	.01															
10	.01	.01	.01	.01	.01	.01	.01	.01												
11	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01										
12	.01	.01	.01	.01	.01	.01	.01													
13	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01				
14	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01								

CONSERVATIVE MINERAL I TDS M ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	486.00	486.00	486.00	486.00	486.00															
2	486.00	486.00	486.00	486.00	488.00	486.00														
3	486.00	486.00	486.00	486.00	486.00															
4	486.00	486.00	486.00	486.00	486.00															
5	486.00	486.00	486.00																	
6	486.00	486.00	486.00	486.00																
7	486.00	486.00	486.00	486.00																
8	486.00	486.00	486.00	486.00																
9	486.00	486.00	486.00	486.00	486.00															
10	486.00	486.00	486.00	486.00	486.00	486.00	486.00	486.01												
11	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01										
12	486.01	486.01	486.01	486.01	486.01	486.01	486.01													
13	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01				
14	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01	486.01								

CONSERVATIVE MINERAL II CL MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	57.00	57.00	57.00	57.00	57.00															
2	57.00	57.00	57.00	57.00	57.00	57.00														
3	57.00	57.00	57.00	57.00	57.00															
4	57.00	57.00	57.00	57.00	57.00															
5	57.00	57.00	57.00																	
6	57.00	57.00	57.00	57.00																
7	57.00	57.00	57.00	57.00																
8	57.00	57.00	57.00	57.00																
9	57.00	57.00	57.00	57.00	57.00															
10	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00												
11	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00										
12	57.00	57.00	57.00	57.00	57.00	57.00	57.00													
13	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00				
14	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00								

CONSERVATIVE MINERAL III NA MG/L ITERATION 7

RCH/CL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	76.00	76.00	76.00	76.00	76.00															
2	76.00	76.00	76.00	76.00	76.00	76.00														
3	76.00	76.00	76.00	76.00	76.00															
4	76.00	76.00	76.00	76.00	76.00															
5	76.00	76.00	76.00																	
6	76.00	76.00	76.00	76.00																
7	76.00	76.00	76.00	76.00																
8	76.00	76.00	76.00	76.00																
9	76.00	76.00	76.00	76.00	76.00															
10	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00												
11	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00										
12	76.00	76.00	76.00	76.00	76.00	76.00	76.00													
13	76.00	76.00	76.00	76.00	76.00	76.00	76:00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00				
14	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00								

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME FT-3	BOTTOM AREA FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
1	1	1	275.70	275.50	9870.00	.00	.00	2.508	.005	11.703	336.333	4156396.0	379883.9	3935.98	133.81
2	1	2	275.50	275.30	9870.00	.00	.00	2.508	.005	11.703	336.333	4156396.0	379883.9	3935.98	133.81
3	1	3	275.30	275.10	9870.00	.00	.00	2.508	.005	11.703	336.333	4156396.0	379883.9	3935.98	133.81
4	1	4	275.10	274.90	9870.00	.00	.00	2.508	.005	11.703	336.333	4156396.0	379883.9	3935.98	133.81
5	1	5	274.90	274.70	9870.00	.00	.00	2.508	.005	11.703	336.333	4156396.0	379883.9	3935.98	133.81
6	2	1	274.70	274.50	9870.00	.00	.00	2.901	.004	6.821	498.830	3592836.0	541169.4	3402.31	98.73
7	2	2	274.50	274.30	9870.00	.00	.00	2.901	.004	6.821	498.830	3592836.0	541169.4	3402.31	98.73
8	2	3	274.30	274.10	9870.00	.00	.00	2.901	.004	6.821	498.830	3592836.0	541169.4	3402.31	98.73
9	2	4	274.10	273.90	9870.00	.00	.00	2.901	.004	6.821	498.830	3592836.0	541169.4	3402.31	98.73
10	2	5	273.90	273.70	9870.00	.00	.00	2.901	.004	6.821	498.830	3592836.0	541169.4	3402.31	98.73
11	2	6	273.70	273.50	9870.00	.00	.00	2.901	.004	6.821	498.830	3592836.0	541169.4	3402.31	98.73
12	3	1	273.50	273.30	9870.00	.00	.00	2.563	.005	10.112	380.845	4066665.0	423528.8	3851.01	121.09
13	3	2	273.30	273.10	9870.00	.00	.00	2.563	.005	10.112	380.845	4066665.0	423528.8	3851.01	121.09
14	3	3	273.10	272.90	9870.00	.00	.00	2.563	.005	10.112	380.845	4066665.0	423528.8	3851.01	121.09
15	3	4	272.90	272.70	9870.00	.00	.00	2.563	.005	10.112	380.845	4066665.0	423528.8	3851.01	121.09
16	3	5	272.70	272.50	9852.00	-18.00	.00	2.561	.005	10.102	380.743	4061657.0	423399.6	3846.27	120.92
17	4	1	272.50	272.30	9852.00	.00	.00	1.204	.010	16.119	507.835	8644367.0	570317.7	8185.95	83.85
18	4	2	272.30	272.10	9852.00	.00	.00	1.204	.010	16.119	507.835	8644367.0	570317.7	8185.95	83.85
19	4	3	272.10	271.90	9852.00	.00	.00	1.204	.010	16.119	507.835	8644367.0	570317.7	8185.95	83.85
20	4	4	271.90	271.70	9852.00	.00	.00	1.204	.010	16.119	507.835	8644367.0	570317.7	8185.95	83.85
21	4	5	271.70	271.50	9852.00	.00	.00	1.204	.010	16.119	507.835	8644367.0	570317.7	8185.95	83.85
22	5	1	271.50	271.30	9852.00	.00	.00	2.151	.006	9.893	462.999	4837198.0	509822.1	4580.68	99.78
23	5	2	271.30	271.10	9852.00	.00	.00	2.151	.006	9.893	462.999	4837198.0	509822.1	4580.68	99.78
24	5	3	271.10	270.90	9852.00	.00	.00	2.151	.006	9.893	462.999	4837198.0	509822.1	4580.68	99.78
25	6	1	270.90	270.70	9852.00	.00	.00	3.303	.004	7.070	421.870	3149464.0	460426.0	2982.45	115.83
26	6	2	270.70	270.50	9852.00	.00	.00	3.303	.004	7.070	421.870	3149464.0	460426.0	2982.45	115.83
27	6	3	270.50	270.30	9852.00	.00	.00	3.303	.004	7.070	421.870	3149464.0	460426.0	2982.45	115.83
28	6	4	270.30	270.10	9852.00	.00	.00	3.303	.004	7.070	421.870	3149464.0	460426.0	2982.45	115.83
29	7	1	270.10	269.90	9852.00	.00	.00	2.835	.004	5.979	581.157	3669415.0	626329.9	3474.82	86.47
30	7	2	269.90	269.70	9852.00	.00	.00	2.835	.004	5.979	581.157	3669415.0	626329.9	3474.82	86.47
31	7	3	269.70	269.50	9852.00	.00	.00	2.835	.004	5.979	581.157	3669415.0	626329.9	3474.82	86.47
32	7	4	269.50	269.30	9852.00	.00	.00	2.835	.004	5.979	581.157	3669415.0	626329.9	3474.82	86.47
33	8	1	269.30	269.10	9852.00	.00	.00	1.956	.006	9.029	557.978	5320173.0	608294.0	5038.04	84.07
34	8	2	269.10	268.90	9852.00	.00	.00	1.956	.006	9.029	557.978	5320173.0	608294.0	5038.04	84.07
35	8	3	268.90	268.70	9852.00	.00	.00	1.956	.006	9.029	557.978	5320173.0	608294.0	5038.04	84.07
36	8	4	268.70	268.50	9852.00	.00	.00	1.956	.006	9.029	557.978	5320173.0	608294.0	5038.04	84.07

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
1	1	9.57	3	.48	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.79	.00	.00	.00
1	2	9.57	3	.48	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.79	.00	.00	.00
1	3	9.57	3	.48	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.79	.00	.00	.00
1	4	9.57	3	.48	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.79	.00	.00	.00
1	5	9.57	3	.48	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.80	.00	.00	.00
2	1	9.57	3	.83	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.80	.00	.00	.00
2	2	9.56	3	1.17	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.80	.00	.00	.00
2	3	9.56	3	1.17	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.80	.00	.00	.00
2	4	9.56	3	1.17	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.80	.00	.00	.00
2	5	9.56	3	1.17	.18	.00	.00	.03	.00	.12	.00	.45	.04	.00	.00	1.80	.00	.00	.00
2	6	9.55	3	1.17	.18	.00	.00	.03	.00	.12	.00	.45	.05	.00	.00	1.80	.00	.00	.00
3	1	9.55	3	.89	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.80	.00	.00	.00
3	2	9.55	3	.61	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.80	.00	.00	.00
3	3	9.55	3	.61	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.80	.00	.00	.00
3	4	9.55	3	.61	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.80	.00	.00	.00
3	5	9.54	3	.61	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.80	.00	.00	.00
4	1	9.54	3	.41	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
4	2	9.54	3	.21	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
4	3	9.54	3	.21	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
4	4	9.54	3	.21	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
4	5	9.53	3	.21	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
5	1	9.53	3	.39	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
5	2	9.53	3	.58	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
5	3	9.53	3	.58	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
6	1	9.53	3	.89	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
6	2	9.52	3	1.19	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
6	3	9.52	3	1.19	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.81	.00	.00	.00
6	4	9.52	3	1.19	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.82	.00	.00	.00
7	1	9.52	3	1.31	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.82	.00	.00	.00
7	2	9.51	3	1.42	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.82	.00	.00	.00
7	3	9.51	3	1.42	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.82	.00	.00	.00
7	4	9.51	3	1.42	.18	.00	.00	.03	.00	.13	.00	.45	.05	.00	.00	1.82	.00	.00	.00
8	1	9.51	3	1.03	.18	.00	.00	.03	.00	.13	.00	.46	.05	.00	.00	1.82	.00	.00	.00
8	2	9.50	3	.64	.18	.00	.00	.03	.00	.13	.00	.46	.05	.00	.00	1.82	.00	.00	.00
8	3	9.50	3	.64	.18	.00	.00	.03	.00	.13	.00	.46	.05	.00	.00	1.82	.00	.00	.00
8	4	9.50	3	.64	.18	.00	.00	.03	.00	.13	.00	.46	.05	.00	.00	1.82	.00	.00	.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX UG/L	CHLA UG/L
1	1	63.71	486.00	57.00	76.00	7.30	2.00	.2300	.0400	.0100	1.1000	1.3800	.0090	.0080	.0170	19.8320	.0000	2.00
1	2	63.73	486.00	57.00	76.00	7.31	2.00	.2300	.0400	.0100	1.1000	1.3799	.0090	.0080	.0170	19.6620	.0000	2.01
1	3	63.74	486.00	57.00	76.00	7.31	1.99	.2299	.0400	.0100	1.0999	1.3799	.0090	.0080	.0170	19.4820	.0000	2.01
1	4	63.76	486.00	57.00	76.00	7.31	1.99	.2299	.0400	.0100	1.0999	1.3799	.0090	.0080	.0170	19.3220	.0000	2.02
1	5	63.77	486.00	57.00	76.00	7.31	1.99	.2299	.0400	.0100	1.0999	1.3798	.0090	.0080	.0170	19.1520	.0000	2.02
2	1	63.79	486.00	57.00	76.00	7.32	1.99	.2299	.0400	.0100	1.0999	1.3798	.0090	.0080	.0170	19.0020	.0000	2.02
2	2	63.81	486.00	57.00	76.00	7.33	1.99	.2298	.0400	.0100	1.0999	1.3798	.0090	.0080	.0170	18.8520	.0000	2.03
2	3	63.83	486.00	57.00	76.00	7.34	1.99	.2298	.0400	.0100	1.0999	1.3797	.0090	.0080	.0170	18.7120	.0000	2.03
2	4	63.85	486.00	57.00	76.00	7.35	1.99	.2298	.0400	.0100	1.0998	1.3797	.0090	.0080	.0170	18.5720	.0000	2.03
2	5	63.87	486.00	57.00	76.00	7.36	1.98	.2298	.0400	.0100	1.0998	1.3797	.0090	.0080	.0169	18.4320	.0000	2.04
2	6	63.89	486.00	57.00	76.00	7.37	1.98	.2298	.0400	.0100	1.0998	1.3797	.0090	.0080	.0169	18.2320	.0000	2.04
3	1	63.91	486.00	57.00	76.00	7.37	1.98	.2297	.0400	.0100	1.0998	1.3796	.0090	.0079	.0169	18.1420	.0000	2.04
3	2	63.93	486.00	57.00	76.00	7.38	1.98	.2297	.0401	.0100	1.0998	1.3796	.0090	.0079	.0169	17.9920	.0000	2.05
3	3	63.95	486.00	57.00	76.00	7.38	1.98	.2297	.0401	.0100	1.0998	1.3796	.0090	.0079	.0169	17.8420	.0000	2.05
3	4	63.96	486.00	57.00	76.00	7.38	1.98	.2297	.0401	.0100	1.0997	1.3795	.0090	.0079	.0169	17.6820	.0000	2.06
3	5	63.98	486.00	57.00	76.00	7.39	1.97	.2297	.0401	.0100	1.0997	1.3795	.0090	.0079	.0169	17.5320	.0000	2.06
4	1	64.00	486.00	57.00	76.00	7.39	1.97	.2296	.0401	.0100	1.0997	1.3794	.0090	.0079	.0169	17.3020	.0000	2.07
4	2	64.02	486.00	57.00	76.00	7.39	1.97	.2296	.0401	.0100	1.0997	1.3794	.0090	.0079	.0169	16.9920	.0000	2.07
4	3	64.04	486.00	57.00	76.00	7.39	1.96	.2295	.0401	.0100	1.0996	1.3793	.0090	.0079	.0169	16.6820	.0000	2.08
4	4	64.06	486.00	57.00	76.00	7.39	1.96	.2295	.0401	.0101	1.0996	1.3792	.0090	.0079	.0169	16.3820	.0000	2.09
4	5	64.08	486.00	57.00	76.00	7.39	1.96	.2294	.0401	.0101	1.0995	1.3792	.0090	.0079	.0169	16.0920	.0000	2.10
5	1	64.10	486.00	57.00	76.00	7.39	1.95	.2294	.0401	.0101	1.0995	1.3791	.0090	.0079	.0169	15.8620	.0000	2.11
5	2	64.12	486.00	57.00	76.00	7.40	1.95	.2294	.0401	.0101	1.0995	1.3791	.0090	.0079	.0168	15.7020	.0000	2.11
5	3	64.14	486.00	57.00	76.00	7.40	1.95	.2293	.0401	.0101	1.0995	1.3790	.0090	.0079	.0168	15.5420	.0000	2.12
6	1	64.16	486.00	57.00	76.00	7.41	1.95	.2293	.0401	.0101	1.0994	1.3790	.0090	.0079	.0168	15.4120	.0000	2.12
6	2	64.18	486.00	57.00	76.00	7.41	1.95	.2293	.0401	.0101	1.0994	1.3790	.0090	.0078	.0168	15.3120	.0000	2.12
6	3	64.20	486.00	57.00	76.00	7.42	1.95	.2293	.0401	.0101	1.0994	1.3789	.0090	.0078	.0168	15.2120	.0000	2.13
6	4	64.21	486.00	57.00	76.00	7.43	1.94	.2293	.0401	.0101	1.0994	1.3789	.0090	.0078	.0168	15.1120	.0000	2.13
7	1	64.23	486.00	57.00	76.00	7.44	1.94	.2293	.0401	.0101	1.0994	1.3789	.0090	.0078	.0168	15.0020	.0000	2.13
7	2	64.26	486.00	57.00	76.00	7.45	1.94	.2292	.0401	.0101	1.0994	1.3788	.0090	.0078	.0168	14.8820	.0000	2.14
7	3	64.28	486.00	57.00	76.00	7.46	1.94	.2292	.0401	.0101	1.0994	1.3788	.0090	.0078	.0168	14.7620	.0000	2.14
7	4	64.31	486.00	57.00	76.00	7.47	1.94	.2292	.0402	.0101	1.0993	1.3788	.0090	.0078	.0168	14.6520	.0000	2.14
8	1	64.33	486.00	57.00	76.00	7.48	1.94	.2292	.0402	.0101	1.0993	1.3787	.0090	.0078	.0168	14.5120	.0000	2.15
8	2	64.35	486.00	57.00	76.00	7.48	1.93	.2291	.0402	.0101	1.0993	1.3787	.0090	.0078	.0168	14.3520	.0000	2.15
8	3	64.38	486.00	57.00	76.00	7.49	1.93	.2291	.0402	.0101	1.0993	1.3786	.0090	.0078	.0168	14.1820	.0000	2.16
8	4	64.40	486.00	57.00	76.00	7.49	1.93	.2291	.0402	.0101	1.0992	1.3786	.0090	.0078	.0168	14.0220	.0000	2.16

***** STEADY STATE SIMULATION *****

** ALGAE DATA **

ELE ORD	RCH NUM	ELE NUM	CHLA UG/L	ALGY GRWTH 1/DAY	ALGY RESP 1/DAY	ALGY SETT FT/DA	A P/R RATIO *	NET P-R MG/L-D	NH3 PREF *	NH3-N FRACT N-UPTKE *	LIGHT EXTCO 1/FT	ALGAE GROWTH RATE ATTEN FACTORS LIGHT *	NITRGN *	PHSPRS *
1	1	1	2.00	.50	.09	.00	4.88	.11	.50	.04	.10	.43	.98	.44
2	1	2	2.01	.50	.09	.00	4.87	.11	.50	.04	.10	.43	.98	.44
3	1	3	2.01	.50	.09	.00	4.87	.11	.50	.04	.10	.43	.98	.44
4	1	4	2.02	.50	.09	.00	4.87	.11	.50	.04	.10	.43	.98	.44
5	1	5	2.02	.50	.09	.00	4.87	.11	.50	.04	.10	.43	.98	.44
6	2	1	2.02	.48	.09	.00	4.70	.11	.50	.04	.10	.41	.98	.44
7	2	2	2.03	.48	.09	.00	4.70	.11	.50	.04	.10	.41	.98	.44
8	2	3	2.03	.48	.09	.00	4.70	.11	.50	.04	.10	.41	.98	.44
9	2	4	2.03	.48	.09	.00	4.69	.11	.50	.04	.10	.41	.98	.44
10	2	5	2.04	.48	.09	.00	4.69	.11	.50	.04	.10	.41	.98	.44
11	2	6	2.04	.48	.09	.00	4.69	.11	.50	.04	.10	.41	.98	.44
12	3	1	2.04	.50	.09	.00	4.85	.11	.50	.04	.10	.43	.98	.44
13	3	2	2.05	.50	.09	.00	4.85	.11	.50	.04	.10	.43	.98	.44
14	3	3	2.05	.50	.09	.00	4.84	.11	.50	.04	.10	.43	.98	.44
15	3	4	2.06	.50	.09	.00	4.84	.11	.50	.04	.10	.43	.98	.44
16	3	5	2.06	.50	.09	.00	4.84	.11	.50	.04	.10	.43	.98	.44
17	4	1	2.07	.49	.09	.00	4.71	.11	.50	.04	.10	.42	.98	.44
18	4	2	2.07	.49	.09	.00	4.71	.11	.50	.04	.10	.42	.98	.44
19	4	3	2.08	.49	.09	.00	4.71	.11	.50	.04	.10	.42	.98	.44
20	4	4	2.09	.49	.09	.00	4.70	.11	.50	.04	.10	.42	.98	.44
21	4	5	2.10	.49	.09	.00	4.70	.11	.50	.04	.10	.42	.98	.44
22	5	1	2.11	.50	.09	.00	4.82	.12	.50	.04	.10	.43	.98	.44
23	5	2	2.11	.50	.09	.00	4.82	.12	.50	.04	.10	.43	.98	.44
24	5	3	2.12	.50	.09	.00	4.81	.12	.50	.04	.10	.43	.98	.44
25	6	1	2.12	.48	.09	.00	4.68	.11	.50	.04	.10	.41	.98	.44
26	6	2	2.12	.48	.09	.00	4.68	.11	.50	.04	.10	.41	.98	.44
27	6	3	2.13	.48	.09	.00	4.68	.11	.50	.04	.10	.41	.98	.44
28	6	4	2.13	.48	.09	.00	4.67	.11	.50	.04	.10	.41	.98	.44
29	7	1	2.13	.48	.09	.00	4.58	.11	.50	.04	.10	.41	.98	.44
30	7	2	2.14	.48	.09	.00	4.58	.11	.50	.04	.10	.41	.98	.44
31	7	3	2.14	.48	.09	.00	4.58	.11	.50	.04	.10	.41	.98	.44
32	7	4	2.14	.48	.09	.00	4.58	.11	.50	.04	.10	.41	.98	.44
33	8	1	2.15	.50	.09	.00	4.77	.12	.50	.04	.10	.42	.98	.44
34	8	2	2.15	.50	.09	.00	4.77	.12	.50	.04	.10	.42	.98	.44
35	8	3	2.16	.50	.09	.00	4.77	.12	.50	.04	.10	.42	.98	.44
36	8	4	2.16	.50	.09	.00	4.77	.12	.50	.04	.10	.42	.98	.44

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
									COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)						
1	1	1	63.71	9.57	7.30	2.27	.00	1.00	1497.74	1.10	-.36	.00	.11	-.02	-.01
2	1	2	63.73	9.57	7.31	2.27	.00	1.00	.00	1.10	-.36	.00	.11	-.02	-.01
3	1	3	63.74	9.57	7.31	2.26	.00	1.00	.00	1.10	-.36	.00	.11	-.02	-.01
4	1	4	63.76	9.57	7.31	2.26	.00	1.00	.00	1.09	-.36	.00	.11	-.02	-.01
5	1	5	63.77	9.57	7.31	2.25	.00	1.00	.00	1.09	-.36	.00	.11	-.02	-.01
6	2	1	63.79	9.57	7.32	2.24	.00	1.00	.00	1.86	-.36	.00	.11	-.02	-.01
7	2	2	63.81	9.56	7.33	2.23	.00	1.00	.00	2.62	-.36	.00	.11	-.02	-.01
8	2	3	63.83	9.56	7.34	2.22	.00	1.00	.00	2.61	-.36	.00	.11	-.02	-.01
9	2	4	63.85	9.56	7.35	2.21	.00	1.00	.00	2.59	-.36	.00	.11	-.02	-.01
10	2	5	63.87	9.56	7.36	2.20	.00	1.00	.00	2.58	-.36	.00	.11	-.02	-.01
11	2	6	63.89	9.55	7.37	2.19	.00	1.00	.00	2.57	-.36	.00	.11	-.02	-.01
12	3	1	63.91	9.55	7.37	2.18	.00	1.00	.00	1.95	-.36	.00	.11	-.02	-.01
13	3	2	63.93	9.55	7.38	2.17	.00	1.00	.00	1.33	-.36	.00	.11	-.02	-.01
14	3	3	63.95	9.55	7.38	2.17	.00	1.00	.00	1.33	-.36	.00	.11	-.02	-.01
15	3	4	63.96	9.55	7.38	2.16	.00	1.00	.00	1.32	-.36	.00	.11	-.02	-.01
16	3	5	63.98	9.54	7.39	2.16	.00	1.00	-2.83	1.32	-.36	.00	.11	-.02	-.01
17	4	1	64.00	9.54	7.39	2.15	.00	1.00	.00	.88	-.36	.00	.11	-.02	-.01
18	4	2	64.02	9.54	7.39	2.15	.00	1.00	.00	.45	-.36	.00	.11	-.02	-.01
19	4	3	64.04	9.54	7.39	2.15	.00	1.00	.00	.45	-.35	.00	.11	-.02	-.01
20	4	4	64.06	9.54	7.39	2.15	.00	1.00	.00	.45	-.35	.00	.11	-.02	-.01
21	4	5	64.08	9.53	7.39	2.14	.00	1.00	.00	.45	-.35	.00	.11	-.02	-.01
22	5	1	64.10	9.53	7.39	2.14	.00	1.00	.00	.84	-.35	.00	.12	-.02	-.01
23	5	2	64.12	9.53	7.40	2.13	.00	1.00	.00	1.24	-.35	.00	.12	-.02	-.01
24	5	3	64.14	9.53	7.40	2.13	.00	1.00	.00	1.23	-.35	.00	.12	-.02	-.01
25	6	1	64.16	9.53	7.41	2.12	.00	1.00	.00	1.88	-.35	.00	.11	-.02	-.01
26	6	2	64.18	9.52	7.41	2.11	.00	1.00	.00	2.51	-.35	.00	.11	-.02	-.01
27	6	3	64.20	9.52	7.42	2.10	.00	1.00	.00	2.50	-.35	.00	.11	-.02	-.01
28	6	4	64.21	9.52	7.43	2.09	.00	1.00	.00	2.49	-.35	.00	.11	-.02	-.01
29	7	1	64.23	9.52	7.44	2.08	.00	1.00	.00	2.72	-.35	.00	.11	-.02	-.01
30	7	2	64.26	9.51	7.45	2.07	.00	1.00	.00	2.93	-.35	.00	.11	-.02	-.01
31	7	3	64.28	9.51	7.46	2.05	.00	1.00	.00	2.92	-.35	.00	.11	-.02	-.01
32	7	4	64.31	9.51	7.47	2.04	.00	1.00	.00	2.90	-.35	.00	.11	-.02	-.01
33	8	1	64.33	9.51	7.48	2.03	.00	1.00	.00	2.09	-.35	.00	.12	-.02	-.01
34	8	2	64.35	9.50	7.48	2.02	.00	1.00	.00	1.29	-.35	.00	.12	-.02	-.01
35	8	3	64.38	9.50	7.49	2.01	.00	1.00	.00	1.28	-.35	.00	.12	-.02	-.01
36	8	4	64.40	9.50	7.49	2.01	.00	1.00	.00	1.28	-.35	.00	.12	-.02	-.01

ATTACHMENT F

TO

SECTION II

COLORADO RIVER MODEL

ATTACHMENT F

COMPUTER OUTPUT WITH RESULTS OF MODEL PROJECTION RUNS

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
1	1	64.03	540.00	56.00	70.00	7.31	2.00	.2300	.0400	.0100	.2400	.5200	.0120	.0080	.0200	19.75	.0000	2.01
1	2	64.05	540.00	56.00	70.00	7.31	1.99	.2299	.0400	.0100	.2400	.5199	.0120	.0080	.0200	19.51	.0000	2.01
1	3	64.08	540.00	56.00	70.00	7.32	1.99	.2299	.0400	.0100	.2400	.5199	.0120	.0080	.0200	19.27	.0000	2.02
1	4	64.11	540.00	56.00	70.00	7.32	1.99	.2299	.0400	.0100	.2399	.5198	.0120	.0080	.0200	19.03	.0000	2.02
1	5	64.13	540.00	56.00	70.00	7.33	1.99	.2298	.0400	.0100	.2399	.5198	.0120	.0080	.0200	18.79	.0000	2.03
2	1	64.16	540.00	56.00	70.00	7.34	1.99	.2298	.0400	.0100	.2399	.5197	.0120	.0080	.0200	18.60	.0000	2.03
2	2	64.19	540.00	56.00	70.00	7.36	1.98	.2298	.0400	.0100	.2399	.5197	.0120	.0080	.0200	18.44	.0000	2.03
2	3	64.22	540.00	56.00	70.00	7.37	1.98	.2298	.0400	.0100	.2399	.5197	.0120	.0080	.0199	18.28	.0000	2.04
2	4	64.26	540.00	56.00	70.00	7.39	1.98	.2297	.0400	.0100	.2399	.5197	.0120	.0080	.0199	18.12	.0000	2.04
2	5	64.29	540.00	56.00	70.00	7.40	1.98	.2297	.0400	.0100	.2399	.5196	.0120	.0080	.0199	17.97	.0000	2.04
2	6	64.32	540.00	56.00	70.00	7.42	1.98	.2297	.0400	.0100	.2399	.5196	.0120	.0080	.0199	17.81	.0000	2.05
3	1	64.35	540.00	56.00	70.00	7.43	1.97	.2297	.0400	.0100	.2398	.5196	.0120	.0079	.0199	17.64	.0000	2.05
3	2	64.38	540.00	56.00	70.00	7.44	1.97	.2296	.0400	.0100	.2398	.5195	.0120	.0079	.0199	17.45	.0000	2.06
3	3	64.41	540.00	56.00	70.00	7.45	1.97	.2296	.0400	.0100	.2398	.5195	.0120	.0079	.0199	17.26	.0000	2.06
3	4	64.43	540.00	56.00	70.00	7.46	1.97	.2296	.0400	.0100	.2398	.5194	.0120	.0079	.0199	17.08	.0000	2.07
3	5	64.46	540.00	56.00	70.00	7.47	1.97	.2296	.0400	.0100	.2398	.5194	.0120	.0079	.0199	16.89	.0000	2.07
4	1	64.50	540.00	56.00	70.00	7.47	1.96	.2295	.0400	.0101	.2398	.5193	.0120	.0079	.0199	16.57	.0000	2.08
4	2	64.54	540.00	56.00	70.00	7.47	1.96	.2294	.0400	.0101	.2397	.5192	.0120	.0079	.0199	16.12	.0000	2.09
4	3	64.58	540.00	56.00	70.00	7.47	1.95	.2294	.0400	.0101	.2397	.5191	.0120	.0079	.0199	15.69	.0000	2.10
4	4	64.61	540.00	56.00	70.00	7.47	1.95	.2293	.0400	.0101	.2396	.5190	.0120	.0079	.0198	15.26	.0000	2.11
4	5	64.65	540.00	56.00	70.00	7.47	1.94	.2292	.0400	.0101	.2396	.5189	.0120	.0079	.0198	14.85	.0000	2.13
5	1	64.69	540.00	56.00	70.00	7.48	1.94	.2292	.0400	.0101	.2396	.5188	.0120	.0079	.0198	14.54	.0000	2.14
5	2	64.73	540.00	56.00	70.00	7.49	1.93	.2291	.0400	.0101	.2396	.5188	.0119	.0079	.0198	14.33	.0000	2.14
5	3	64.76	540.00	56.00	70.00	7.49	1.93	.2291	.0400	.0101	.2395	.5187	.0119	.0078	.0198	14.11	.0000	2.15
6	1	64.80	540.00	56.00	70.00	7.51	1.93	.2291	.0400	.0101	.2395	.5187	.0119	.0078	.0198	13.94	.0000	2.15
6	2	64.83	540.00	56.00	70.00	7.52	1.93	.2290	.0400	.0101	.2395	.5187	.0119	.0078	.0198	13.81	.0000	2.16
6	3	64.86	540.00	56.00	70.00	7.53	1.92	.2290	.0400	.0101	.2395	.5186	.0119	.0078	.0198	13.68	.0000	2.16
6	4	64.89	540.00	56.00	70.00	7.55	1.92	.2290	.0400	.0101	.2395	.5186	.0119	.0078	.0198	13.56	.0000	2.17
7	1	64.93	540.00	56.00	70.00	7.56	1.92	.2290	.0400	.0101	.2395	.5186	.0119	.0078	.0198	13.42	.0000	2.17
7	2	64.98	540.00	56.00	70.00	7.58	1.92	.2289	.0400	.0101	.2395	.5185	.0119	.0078	.0198	13.28	.0000	2.17
7	3	65.02	540.00	56.00	70.00	7.60	1.92	.2289	.0400	.0101	.2394	.5185	.0119	.0078	.0198	13.15	.0000	2.18
7	4	65.06	540.00	56.00	70.00	7.62	1.92	.2289	.0400	.0101	.2394	.5184	.0119	.0078	.0197	13.01	.0000	2.18
8	1	65.11	540.00	56.00	70.00	7.64	1.91	.2289	.0400	.0101	.2394	.5184	.0119	.0078	.0197	12.84	.0000	2.19
8	2	65.15	540.00	56.00	70.00	7.65	1.91	.2288	.0400	.0101	.2394	.5183	.0119	.0078	.0197	12.64	.0000	2.20
8	3	65.19	540.00	56.00	70.00	7.65	1.91	.2288	.0400	.0101	.2394	.5183	.0119	.0078	.0197	12.43	.0000	2.20
8	4	65.23	540.00	56.00	70.00	7.66	1.90	.2287	.0400	.0101	.2393	.5182	.0119	.0078	.0197	12.24	.0000	2.21

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
14	1	66.76	540.04	56.02	70.01	8.17	1.81	.2276	.0399	.0103	.2395	.5173	.0119	.0078	.0197	7.59	.0002	2.42
14	2	66.79	540.04	56.02	70.01	8.18	1.81	.2275	.0399	.0103	.2395	.5173	.0119	.0078	.0197	7.51	.0002	2.43
14	3	66.81	540.04	56.02	70.01	8.18	1.81	.2275	.0399	.0103	.2395	.5173	.0119	.0078	.0197	7.44	.0002	2.43
14	4	66.84	540.04	56.02	70.01	8.19	1.81	.2275	.0399	.0103	.2395	.5172	.0119	.0078	.0197	7.36	.0002	2.44
14	5	66.87	540.04	56.02	70.01	8.19	1.81	.2275	.0399	.0103	.2395	.5172	.0119	.0078	.0196	7.29	.0002	2.44
14	6	66.89	540.04	56.02	70.01	8.20	1.81	.2274	.0399	.0103	.2395	.5171	.0119	.0078	.0196	7.21	.0002	2.45
14	7	66.92	540.04	56.02	70.01	8.20	1.80	.2274	.0399	.0103	.2394	.5171	.0119	.0078	.0196	7.14	.0002	2.45
14	8	66.94	540.04	56.02	70.01	8.21	1.80	.2274	.0399	.0103	.2394	.5171	.0119	.0078	.0196	7.07	.0002	2.46
14	9	66.97	540.04	56.02	70.01	8.21	1.80	.2274	.0399	.0103	.2394	.5170	.0118	.0078	.0196	7.00	.0002	2.46
14	10	67.00	540.04	56.02	70.01	8.22	1.80	.2273	.0399	.0103	.2394	.5170	.0118	.0078	.0196	6.93	.0002	2.47
14	11	67.02	540.04	56.02	70.01	8.22	1.80	.2273	.0399	.0103	.2394	.5169	.0118	.0078	.0196	6.86	.0002	2.47
14	12	67.05	540.04	56.02	70.01	8.23	1.79	.2273	.0399	.0104	.2393	.5169	.0118	.0078	.0196	6.79	.0002	2.48

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
9	1	65.30	541.21	56.48	70.37	7.68	1.92	.2306	.0404	.0104	.2831	.5644	.0119	.0205	.0324	12.30	.0065	2.35
9	2	65.38	541.21	56.48	70.37	7.71	1.92	.2305	.0404	.0104	.2830	.5643	.0119	.0205	.0324	12.11	.0065	2.36
9	3	65.45	541.21	56.48	70.37	7.74	1.92	.2305	.0403	.0104	.2829	.5642	.0119	.0205	.0324	11.92	.0065	2.37
9	4	65.52	541.21	56.48	70.37	7.76	1.91	.2305	.0403	.0104	.2829	.5641	.0119	.0205	.0324	11.74	.0065	2.38
9	5	65.59	541.21	56.48	70.37	7.79	1.91	.2304	.0403	.0104	.2828	.5640	.0119	.0204	.0324	11.56	.0065	2.39
10	1	65.66	541.21	56.48	70.37	7.82	1.91	.2304	.0403	.0104	.2828	.5639	.0119	.0204	.0323	11.41	.0065	2.40
10	2	65.71	541.21	56.48	70.37	7.85	1.91	.2304	.0403	.0104	.2827	.5639	.0119	.0204	.0323	11.30	.0065	2.41
10	3	65.77	541.21	56.48	70.37	7.88	1.90	.2303	.0403	.0104	.2827	.5638	.0119	.0204	.0323	11.20	.0065	2.41
10	4	65.83	541.21	56.48	70.37	7.91	1.90	.2303	.0403	.0104	.2827	.5638	.0119	.0204	.0323	11.09	.0065	2.42
10	5	65.89	541.21	56.48	70.37	7.94	1.90	.2303	.0403	.0104	.2826	.5637	.0119	.0204	.0323	10.98	.0065	2.43
10	6	65.95	541.21	56.48	70.37	7.97	1.90	.2303	.0403	.0105	.2826	.5636	.0119	.0204	.0323	10.88	.0065	2.43
10	7	66.01	541.21	56.48	70.37	8.00	1.90	.2302	.0403	.0105	.2826	.5636	.0119	.0204	.0323	10.78	.0065	2.44
10	8	66.06	541.25	56.50	70.38	8.02	1.90	.2302	.0403	.0105	.2835	.5645	.0119	.0206	.0325	10.68	.0066	2.45
11	1	66.09	541.25	56.50	70.38	8.04	1.90	.2302	.0403	.0105	.2834	.5644	.0119	.0206	.0325	10.60	.0066	2.46
11	2	66.10	541.25	56.50	70.38	8.04	1.89	.2302	.0403	.0105	.2834	.5644	.0119	.0206	.0325	10.53	.0066	2.46
11	3	66.12	541.25	56.50	70.38	8.05	1.89	.2302	.0403	.0105	.2834	.5643	.0119	.0206	.0325	10.46	.0066	2.47
11	4	66.13	541.25	56.50	70.38	8.05	1.89	.2302	.0403	.0105	.2834	.5643	.0119	.0206	.0325	10.40	.0066	2.47
11	5	66.14	541.25	56.50	70.38	8.05	1.89	.2301	.0403	.0105	.2833	.5642	.0119	.0206	.0325	10.33	.0066	2.48
11	6	66.16	541.25	56.50	70.38	8.06	1.89	.2301	.0403	.0105	.2833	.5642	.0119	.0206	.0325	10.27	.0066	2.48
11	7	66.17	541.25	56.50	70.38	8.06	1.89	.2301	.0403	.0105	.2833	.5642	.0119	.0206	.0325	10.21	.0066	2.49
11	8	66.18	541.25	56.50	70.38	8.06	1.89	.2301	.0403	.0105	.2832	.5641	.0119	.0206	.0325	10.14	.0066	2.49
11	9	66.20	541.25	56.50	70.38	8.07	1.89	.2301	.0403	.0105	.2832	.5641	.0119	.0206	.0325	10.08	.0066	2.50
11	10	66.21	541.25	56.50	70.38	8.07	1.88	.2301	.0403	.0105	.2832	.5640	.0119	.0206	.0325	10.02	.0066	2.50
12	1	66.23	541.25	56.50	70.38	8.08	1.88	.2300	.0403	.0105	.2832	.5640	.0119	.0206	.0325	9.95	.0066	2.51
12	2	66.26	541.25	56.50	70.38	8.09	1.88	.2300	.0403	.0105	.2831	.5639	.0119	.0206	.0325	9.87	.0066	2.51
12	3	66.28	541.25	56.50	70.38	8.10	1.88	.2300	.0403	.0105	.2831	.5639	.0119	.0206	.0324	9.80	.0066	2.52
12	4	66.31	541.25	56.50	70.38	8.11	1.88	.2300	.0403	.0105	.2831	.5638	.0119	.0205	.0324	9.72	.0066	2.53
12	5	66.34	541.25	56.50	70.38	8.12	1.88	.2300	.0403	.0105	.2830	.5638	.0119	.0205	.0324	9.65	.0066	2.53
12	6	66.36	541.25	56.50	70.38	8.13	1.88	.2300	.0403	.0105	.2830	.5637	.0119	.0205	.0324	9.58	.0066	2.54
12	7	66.39	541.25	56.50	70.38	8.14	1.87	.2299	.0403	.0105	.2830	.5637	.0119	.0205	.0324	9.50	.0066	2.54
13	1	66.41	541.25	56.50	70.38	8.14	1.87	.2299	.0403	.0105	.2829	.5636	.0119	.0205	.0324	9.41	.0066	2.55
13	2	66.44	541.25	56.50	70.38	8.15	1.87	.2299	.0403	.0105	.2828	.5635	.0119	.0205	.0324	9.29	.0066	2.56
13	3	66.46	541.25	56.50	70.38	8.15	1.87	.2299	.0403	.0105	.2828	.5634	.0119	.0205	.0324	9.18	.0066	2.58
13	4	66.48	541.25	56.50	70.38	8.15	1.87	.2298	.0402	.0105	.2827	.5633	.0119	.0205	.0323	9.07	.0066	2.59
13	5	66.51	541.25	56.50	70.38	8.15	1.86	.2298	.0402	.0105	.2827	.5632	.0119	.0205	.0323	8.96	.0066	2.60
13	6	66.53	541.25	56.50	70.38	8.16	1.86	.2298	.0402	.0105	.2826	.5631	.0119	.0204	.0323	8.85	.0066	2.61
13	7	66.55	541.25	56.50	70.38	8.16	1.86	.2297	.0402	.0105	.2825	.5630	.0119	.0204	.0323	8.75	.0066	2.62
13	8	66.57	541.25	56.50	70.38	8.16	1.86	.2297	.0402	.0105	.2825	.5629	.0119	.0204	.0323	8.64	.0066	2.63
13	9	66.60	541.25	56.50	70.38	8.17	1.85	.2297	.0402	.0105	.2824	.5628	.0119	.0204	.0323	8.54	.0066	2.64
13	10	66.62	541.25	56.50	70.38	8.17	1.85	.2297	.0402	.0105	.2824	.5627	.0119	.0204	.0323	8.43	.0066	2.65
13	11	66.64	541.25	56.50	70.38	8.17	1.85	.2296	.0402	.0105	.2823	.5627	.0119	.0204	.0322	8.33	.0066	2.66
13	12	66.67	541.25	56.50	70.38	8.17	1.85	.2296	.0402	.0105	.2822	.5626	.0119	.0204	.0322	8.23	.0066	2.67
13	13	66.69	541.25	56.50	70.38	8.18	1.85	.2296	.0402	.0105	.2822	.5625	.0119	.0203	.0322	8.13	.0066	2.69
13	14	66.71	541.25	56.50	70.38	8.18	1.84	.2295	.0402	.0105	.2821	.5624	.0119	.0203	.0322	8.03	.0066	2.70
13	15	66.73	541.25	56.50	70.38	8.18	1.84	.2295	.0402	.0105	.2820	.5623	.0119	.0203	.0322	7.93	.0066	2.71
13	16	66.76	541.25	56.50	70.38	8.19	1.84	.2295	.0402	.0106	.2820	.5622	.0119	.0203	.0322	7.84	.0066	2.7

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
1	1	64.03	540.00	56.00	70.00	7.31	2.00	.2300	.0400	.0100	.2400	.5200	.0120	.0080	.0200	19.75	.0000	2.01
1	2	64.05	540.00	56.00	70.00	7.31	1.99	.2299	.0400	.0100	.2400	.5199	.0120	.0080	.0200	19.51	.0000	2.01
1	3	64.08	540.00	56.00	70.00	7.32	1.99	.2299	.0400	.0100	.2400	.5199	.0120	.0080	.0200	19.27	.0000	2.02
1	4	64.11	540.00	56.00	70.00	7.32	1.99	.2299	.0400	.0100	.2399	.5198	.0120	.0080	.0200	19.03	.0000	2.02
1	5	64.13	540.00	56.00	70.00	7.33	1.99	.2298	.0400	.0100	.2399	.5198	.0120	.0080	.0200	18.79	.0000	2.03
2	1	64.16	540.00	56.00	70.00	7.34	1.99	.2298	.0400	.0100	.2399	.5198	.0120	.0080	.0200	18.60	.0000	2.03
2	2	64.19	540.03	56.01	70.01	7.36	1.98	.2298	.0400	.0100	.2410	.5208	.0120	.0080	.0200	18.45	.0000	2.03
2	3	64.25	541.21	56.48	70.37	7.36	2.01	.2299	.0405	.0103	.2846	.5653	.0120	.0090	.0210	18.67	.0002	2.03
2	4	64.28	541.21	56.48	70.37	7.37	2.00	.2299	.0405	.0103	.2846	.5653	.0120	.0090	.0210	18.51	.0002	2.04
2	5	64.32	541.21	56.48	70.37	7.39	2.00	.2298	.0405	.0103	.2846	.5652	.0120	.0090	.0210	18.35	.0002	2.04
2	6	64.35	541.21	56.48	70.37	7.41	2.00	.2298	.0405	.0103	.2846	.5652	.0120	.0090	.0210	18.19	.0002	2.04
3	1	64.38	541.21	56.48	70.37	7.42	2.00	.2298	.0405	.0103	.2846	.5652	.0120	.0090	.0210	18.01	.0002	2.05
3	2	64.41	541.21	56.48	70.37	7.43	2.00	.2298	.0405	.0103	.2846	.5651	.0120	.0090	.0210	17.82	.0002	2.05
3	3	64.43	541.21	56.48	70.37	7.43	1.99	.2297	.0405	.0103	.2845	.5651	.0120	.0090	.0210	17.63	.0002	2.06
3	4	64.46	541.21	56.48	70.37	7.44	1.99	.2297	.0405	.0103	.2845	.5650	.0120	.0090	.0210	17.44	.0002	2.06
3	5	64.49	541.21	56.48	70.37	7.45	1.99	.2297	.0405	.0103	.2845	.5650	.0120	.0090	.0210	17.25	.0002	2.07
4	1	64.52	541.21	56.48	70.37	7.46	1.99	.2296	.0405	.0103	.2845	.5649	.0120	.0090	.0209	16.92	.0002	2.08
4	2	64.56	541.21	56.48	70.37	7.46	1.98	.2295	.0405	.0103	.2844	.5648	.0120	.0090	.0209	16.46	.0002	2.09
4	3	64.60	541.21	56.48	70.37	7.46	1.98	.2295	.0405	.0103	.2844	.5647	.0120	.0089	.0209	16.02	.0002	2.11
4	4	64.64	541.21	56.48	70.37	7.46	1.97	.2294	.0405	.0104	.2843	.5646	.0120	.0089	.0209	15.59	.0002	2.12
4	5	64.68	541.21	56.48	70.37	7.46	1.96	.2293	.0405	.0104	.2843	.5645	.0119	.0089	.0209	15.17	.0002	2.13
5	1	64.72	541.21	56.48	70.37	7.46	1.96	.2293	.0405	.0104	.2842	.5644	.0119	.0089	.0209	14.85	.0002	2.14
5	2	64.75	541.21	56.48	70.37	7.47	1.96	.2292	.0405	.0104	.2842	.5643	.0119	.0089	.0208	14.63	.0002	2.15
5	3	64.79	541.21	56.48	70.37	7.48	1.95	.2292	.0405	.0104	.2842	.5642	.0119	.0089	.0208	14.42	.0002	2.16
6	1	64.82	541.21	56.48	70.37	7.49	1.95	.2292	.0405	.0104	.2842	.5642	.0119	.0089	.0208	14.24	.0002	2.16
6	2	64.85	541.21	56.48	70.37	7.51	1.95	.2292	.0405	.0104	.2842	.5642	.0119	.0089	.0208	14.11	.0002	2.17
6	3	64.89	541.21	56.48	70.37	7.52	1.95	.2291	.0405	.0104	.2841	.5641	.0119	.0089	.0208	13.98	.0002	2.17
6	4	64.92	541.21	56.48	70.37	7.53	1.95	.2291	.0405	.0104	.2841	.5641	.0119	.0089	.0208	13.84	.0002	2.18
7	1	64.96	541.21	56.48	70.37	7.55	1.94	.2291	.0405	.0104	.2841	.5640	.0119	.0089	.0208	13.71	.0002	2.18
7	2	65.00	541.21	56.48	70.37	7.57	1.94	.2291	.0405	.0104	.2841	.5640	.0119	.0089	.0208	13.57	.0002	2.18
7	3	65.04	541.21	56.48	70.37	7.59	1.94	.2290	.0405	.0104	.2841	.5640	.0119	.0089	.0208	13.43	.0002	2.19
7	4	65.09	541.21	56.48	70.37	7.61	1.94	.2290	.0405	.0104	.2841	.5639	.0119	.0088	.0208	13.29	.0002	2.19
8	1	65.13	541.21	56.48	70.37	7.63	1.94	.2290	.0405	.0104	.2840	.5639	.0119	.0088	.0208	13.11	.0002	2.20
8	2	65.17	541.21	56.48	70.37	7.63	1.93	.2289	.0405	.0104	.2840	.5638	.0119	.0088	.0208	12.91	.0002	2.21
8	3	65.21	541.21	56.48	70.37	7.64	1.93	.2289	.0405	.0104	.2840	.5637	.0119	.0088	.0207	12.70	.0002	2.22
8	4	65.25	541.21	56.48	70.37	7.65	1.93	.2288	.0405	.0104	.2839	.5637	.0119	.0088	.0207	12.50	.0002	2.22

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
14	1	66.78	541.25	56.50	70.38	8.16	1.84	.2277	.0404	.0106	.2839	.5626	.0119	.0088	.0207	7.75	.0004	2.46
14	2	66.81	541.25	56.50	70.38	8.17	1.83	.2276	.0404	.0106	.2839	.5625	.0119	.0088	.0207	7.67	.0004	2.47
14	3	66.83	541.25	56.50	70.38	8.17	1.83	.2276	.0404	.0106	.2839	.5625	.0119	.0088	.0207	7.59	.0004	2.47
14	4	66.86	541.25	56.50	70.38	8.18	1.83	.2276	.0404	.0106	.2839	.5625	.0119	.0088	.0206	7.52	.0004	2.48
14	5	66.88	541.25	56.50	70.38	8.18	1.83	.2276	.0404	.0106	.2839	.5624	.0119	.0088	.0206	7.44	.0004	2.48
14	6	66.91	541.25	56.50	70.38	8.19	1.83	.2276	.0404	.0106	.2838	.5624	.0119	.0088	.0206	7.37	.0004	2.49
14	7	66.94	541.25	56.50	70.38	8.20	1.83	.2275	.0404	.0106	.2838	.5623	.0118	.0088	.0206	7.29	.0004	2.49
14	8	66.96	541.25	56.50	70.38	8.20	1.82	.2275	.0404	.0106	.2838	.5623	.0118	.0088	.0206	7.22	.0004	2.50
14	9	66.99	541.25	56.50	70.38	8.21	1.82	.2275	.0404	.0106	.2838	.5622	.0118	.0088	.0206	7.15	.0004	2.51
14	10	67.02	541.25	56.50	70.38	8.21	1.82	.2275	.0404	.0106	.2837	.5622	.0118	.0088	.0206	7.08	.0004	2.51
14	11	67.04	541.25	56.50	70.38	8.22	1.82	.2274	.0404	.0106	.2837	.5621	.0118	.0087	.0206	7.01	.0004	2.52
14	12	67.07	541.25	56.50	70.38	8.22	1.82	.2274	.0404	.0106	.2837	.5621	.0118	.0087	.0206	6.94	.0004	2.52

RCH NUM	ELE NUM	TEMP DEG-F	CM-1 TDS MG/L	CM-2 CL MG/L	CM-3 NA MG/L	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC CTOX MG/L	CHLA UG/L
9	1	65.30	541.21	56.48	70.37	7.67	1.92	.2288	.0405	.0104	.2839	.5636	.0119	.0088	.0207	12.30	.0002	2.23
9	2	65.38	541.21	56.48	70.37	7.69	1.92	.2288	.0405	.0104	.2839	.5636	.0119	.0088	.0207	12.11	.0002	2.24
9	3	65.45	541.21	56.48	70.37	7.72	1.92	.2287	.0405	.0104	.2839	.5635	.0119	.0088	.0207	11.92	.0002	2.24
9	4	65.52	541.21	56.48	70.37	7.75	1.91	.2287	.0405	.0104	.2838	.5634	.0119	.0088	.0207	11.74	.0002	2.25
9	5	65.59	541.21	56.48	70.37	7.77	1.91	.2287	.0405	.0104	.2838	.5634	.0119	.0088	.0207	11.56	.0002	2.26
10	1	65.66	541.21	56.48	70.37	7.80	1.91	.2286	.0405	.0104	.2838	.5633	.0119	.0088	.0207	11.41	.0002	2.26
10	2	65.71	541.21	56.48	70.37	7.83	1.91	.2286	.0405	.0104	.2838	.5633	.0119	.0088	.0207	11.30	.0002	2.27
10	3	65.77	541.21	56.48	70.37	7.86	1.90	.2286	.0405	.0104	.2838	.5633	.0119	.0088	.0207	11.20	.0002	2.27
10	4	65.83	541.21	56.48	70.37	7.89	1.90	.2286	.0405	.0104	.2838	.5632	.0119	.0088	.0207	11.09	.0002	2.28
10	5	65.89	541.21	56.48	70.37	7.92	1.90	.2285	.0405	.0105	.2837	.5632	.0119	.0088	.0207	10.98	.0002	2.28
10	6	65.95	541.21	56.48	70.37	7.95	1.90	.2285	.0405	.0105	.2837	.5632	.0119	.0087	.0207	10.88	.0002	2.29
10	7	66.01	541.21	56.48	70.37	7.98	1.90	.2285	.0405	.0105	.2838	.5632	.0119	.0088	.0207	10.78	.0002	2.29
10	8	66.07	541.37	56.55	70.41	8.01	1.90	.2284	.0405	.0105	.2872	.5666	.0119	.0097	.0216	10.71	.0008	2.29
11	1	66.09	541.37	56.55	70.41	8.02	1.90	.2284	.0405	.0105	.2872	.5666	.0119	.0097	.0216	10.62	.0008	2.30
11	2	66.11	541.37	56.55	70.41	8.02	1.90	.2284	.0405	.0105	.2872	.5665	.0119	.0097	.0216	10.55	.0008	2.30
11	3	66.12	541.37	56.55	70.41	8.03	1.90	.2284	.0405	.0105	.2871	.5665	.0119	.0097	.0216	10.49	.0008	2.30
11	4	66.13	541.37	56.55	70.41	8.03	1.89	.2284	.0405	.0105	.2871	.5665	.0119	.0097	.0216	10.42	.0008	2.31
11	5	66.15	541.37	56.55	70.41	8.04	1.89	.2283	.0405	.0105	.2871	.5665	.0119	.0097	.0216	10.36	.0008	2.31
11	6	66.16	541.37	56.55	70.41	8.04	1.89	.2283	.0405	.0105	.2871	.5664	.0119	.0097	.0216	10.29	.0008	2.31
11	7	66.17	541.37	56.55	70.41	8.04	1.89	.2283	.0405	.0105	.2871	.5664	.0119	.0097	.0216	10.23	.0008	2.32
11	8	66.19	541.37	56.55	70.41	8.05	1.89	.2283	.0405	.0105	.2871	.5664	.0119	.0097	.0216	10.17	.0008	2.32
11	9	66.20	541.37	56.55	70.41	8.05	1.89	.2283	.0405	.0105	.2871	.5663	.0119	.0097	.0216	10.10	.0008	2.33
11	10	66.21	541.37	56.55	70.41	8.05	1.89	.2283	.0405	.0105	.2870	.5663	.0119	.0097	.0216	10.04	.0008	2.33
12	1	66.23	541.37	56.55	70.41	8.06	1.89	.2283	.0405	.0105	.2870	.5663	.0119	.0097	.0216	9.97	.0008	2.33
12	2	66.26	541.37	56.55	70.41	8.07	1.88	.2282	.0405	.0105	.2870	.5663	.0119	.0097	.0216	9.90	.0008	2.34
12	3	66.29	541.37	56.55	70.41	8.08	1.88	.2282	.0405	.0105	.2870	.5662	.0119	.0097	.0216	9.82	.0008	2.34
12	4	66.31	541.37	56.55	70.41	8.09	1.88	.2282	.0405	.0105	.2870	.5662	.0119	.0097	.0216	9.75	.0008	2.34
12	5	66.34	541.37	56.55	70.41	8.10	1.88	.2282	.0405	.0105	.2870	.5662	.0119	.0097	.0215	9.67	.0008	2.35
12	6	66.37	541.37	56.55	70.41	8.11	1.88	.2282	.0405	.0105	.2870	.5661	.0119	.0097	.0215	9.60	.0008	2.35
12	7	66.39	541.37	56.55	70.41	8.12	1.88	.2281	.0405	.0105	.2869	.5661	.0119	.0097	.0215	9.53	.0008	2.36
13	1	66.42	541.37	56.55	70.41	8.12	1.88	.2281	.0405	.0105	.2869	.5660	.0119	.0096	.0215	9.43	.0008	2.36
13	2	66.44	541.37	56.55	70.41	8.13	1.87	.2281	.0405	.0105	.2869	.5660	.0119	.0096	.0215	9.32	.0008	2.37
13	3	66.46	541.37	56.55	70.41	8.13	1.87	.2281	.0405	.0105	.2869	.5659	.0119	.0096	.0215	9.20	.0008	2.37
13	4	66.49	541.37	56.55	70.41	8.13	1.87	.2280	.0405	.0105	.2868	.5659	.0119	.0096	.0215	9.09	.0008	2.38
13	5	66.51	541.37	56.55	70.41	8.13	1.87	.2280	.0405	.0105	.2868	.5658	.0119	.0096	.0215	8.98	.0008	2.39
13	6	66.53	541.37	56.55	70.41	8.14	1.86	.2280	.0405	.0105	.2868	.5657	.0119	.0096	.0215	8.87	.0008	2.40
13	7	66.55	541.37	56.55	70.41	8.14	1.86	.2279	.0405	.0105	.2867	.5657	.0119	.0096	.0215	8.77	.0008	2.40
13	8	66.58	541.37	56.55	70.41	8.14	1.86	.2279	.0405	.0105	.2867	.5656	.0119	.0096	.0215	8.66	.0008	2.41
13	9	66.60	541.37	56.55	70.41	8.14	1.86	.2279	.0405	.0105	.2867	.5656	.0119	.0096	.0215	8.56	.0008	2.42
13	10	66.62	541.37	56.55	70.41	8.14	1.85	.2279	.0405	.0105	.2866	.5655	.0119	.0096	.0214	8.45	.0008	2.42
13	11	66.65	541.37	56.55	70.41	8.15	1.85	.2278	.0405	.0105	.2866	.5654	.0119	.0096	.0214	8.35	.0008	2.43
13	12	66.67	541.37	56.55	70.41	8.15	1.85	.2278	.0405	.0105	.2866	.5654	.0119	.0096	.0214	8.25	.0008	2.44
13	13	66.69	541.37	56.55	70.41	8.15	1.85	.2278	.0405	.0106	.2865	.5653	.0119	.0096	.0214	8.15	.0008	2.44
13	14	66.71	541.37	56.55	70.41	8.15	1.85	.2277	.0405	.0106	.2865	.5653	.0119	.0095	.0214	8.05	.0008	2.45
13	15	66.74	541.37	56.55	70.41	8.16	1.84	.2277	.0405	.0106	.2865	.5652	.0119	.0095	.0214	7.95	.0008	2.46
13	16	66.76	541.37	56.55	70.41	8.16	1.84	.2277	.0405	.0106	.2865	.5651	.0119	.0095	.0214	7.85	.0008	2.47

ATTACHMENT G

TO

SECTION II

COLORADO RIVER MODEL

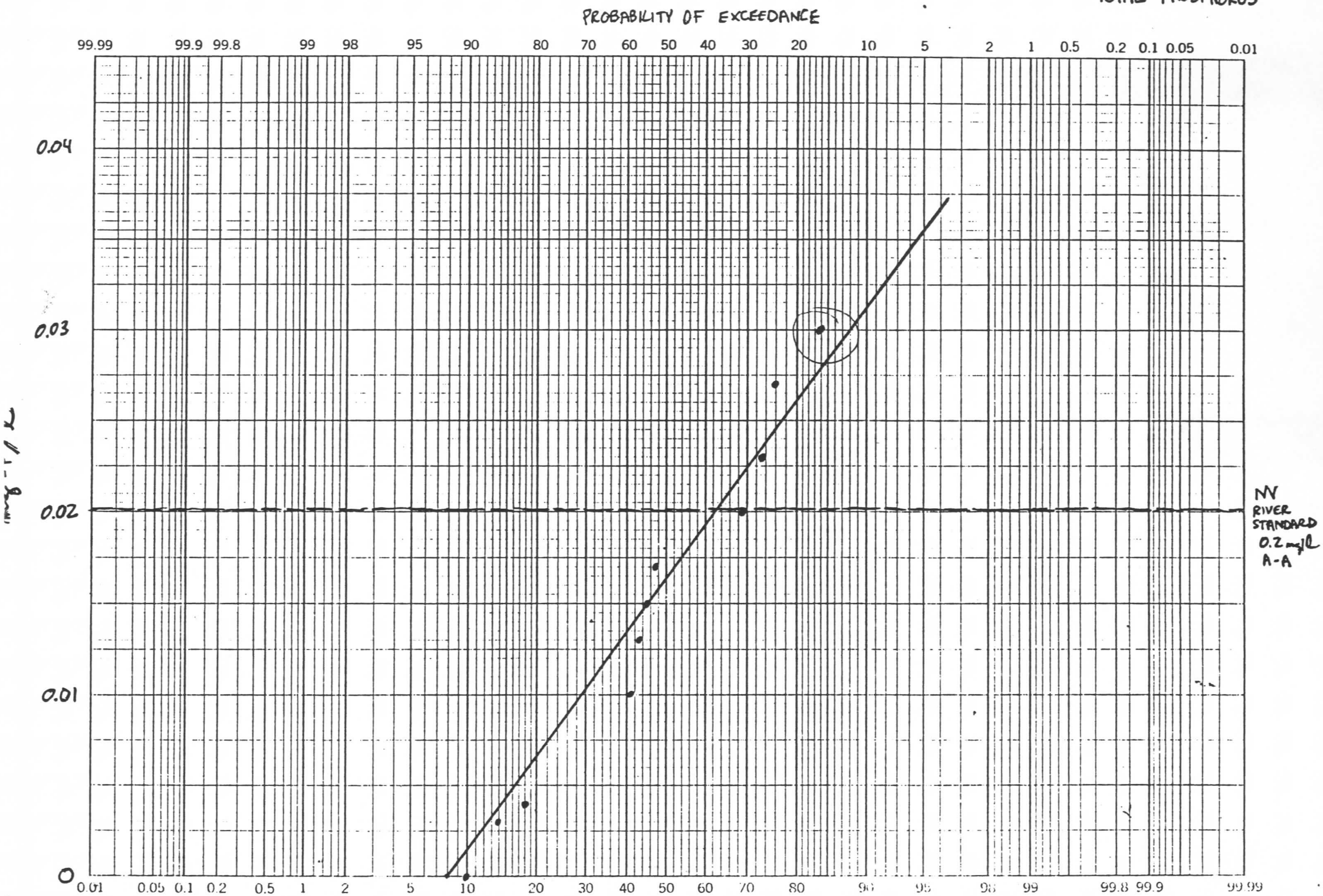
ATTACHMENT G

PROBABILITY PLOTS OF HISTORICAL WATER QUALITY DATA FOR THE COLORADO RIVER BELOW DAVIS DAM

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000

TOTAL PHOSPHORUS

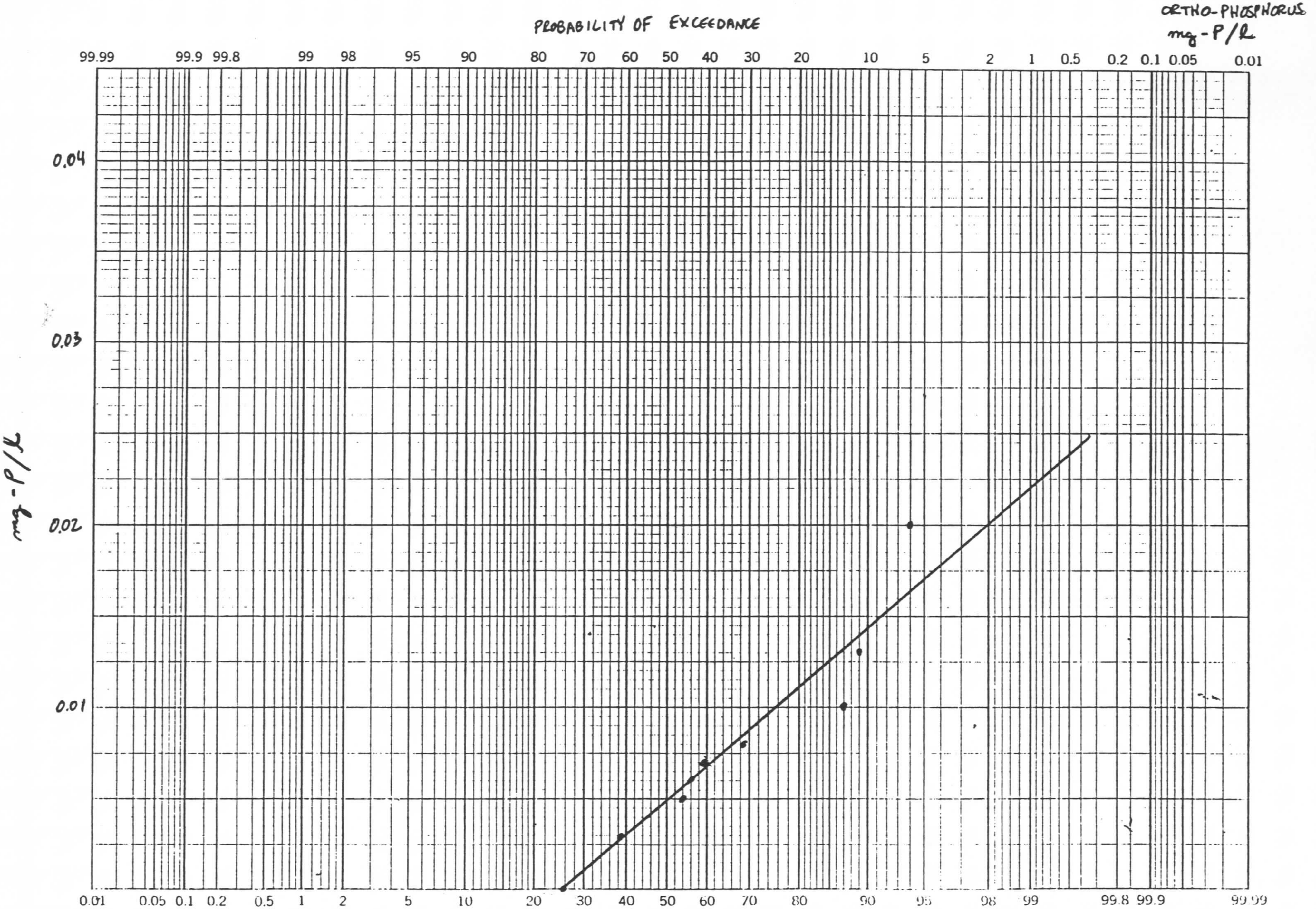


SOURCE: USBR STORET DATA BELOW DAVIS DAM 1967-1987
AND K/J/C SURVEY 1987

SAMPLE SIZE = 49
$\bar{x}$ = .018

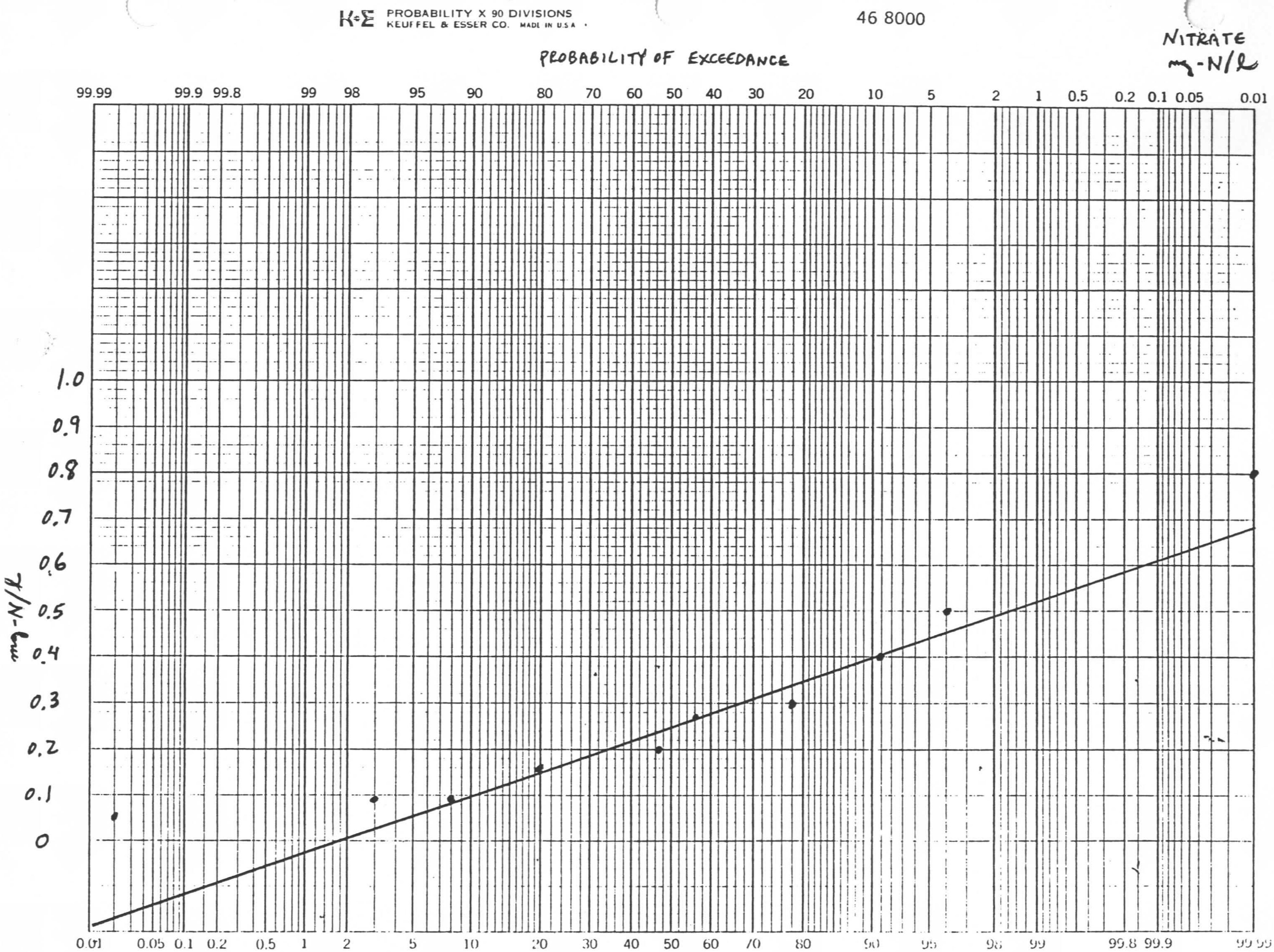
K+E PROBABILITY X 90 DIVISIONS
KLUFFEL & ESSER CO. MADE IN U.S.A.

46 8000



SOURCE : USBR STORET : BELOW DAVIS DAM 1967-1987
K/S/C SURVEY, 1987

SAMPLE SIZE = 54
S = .007



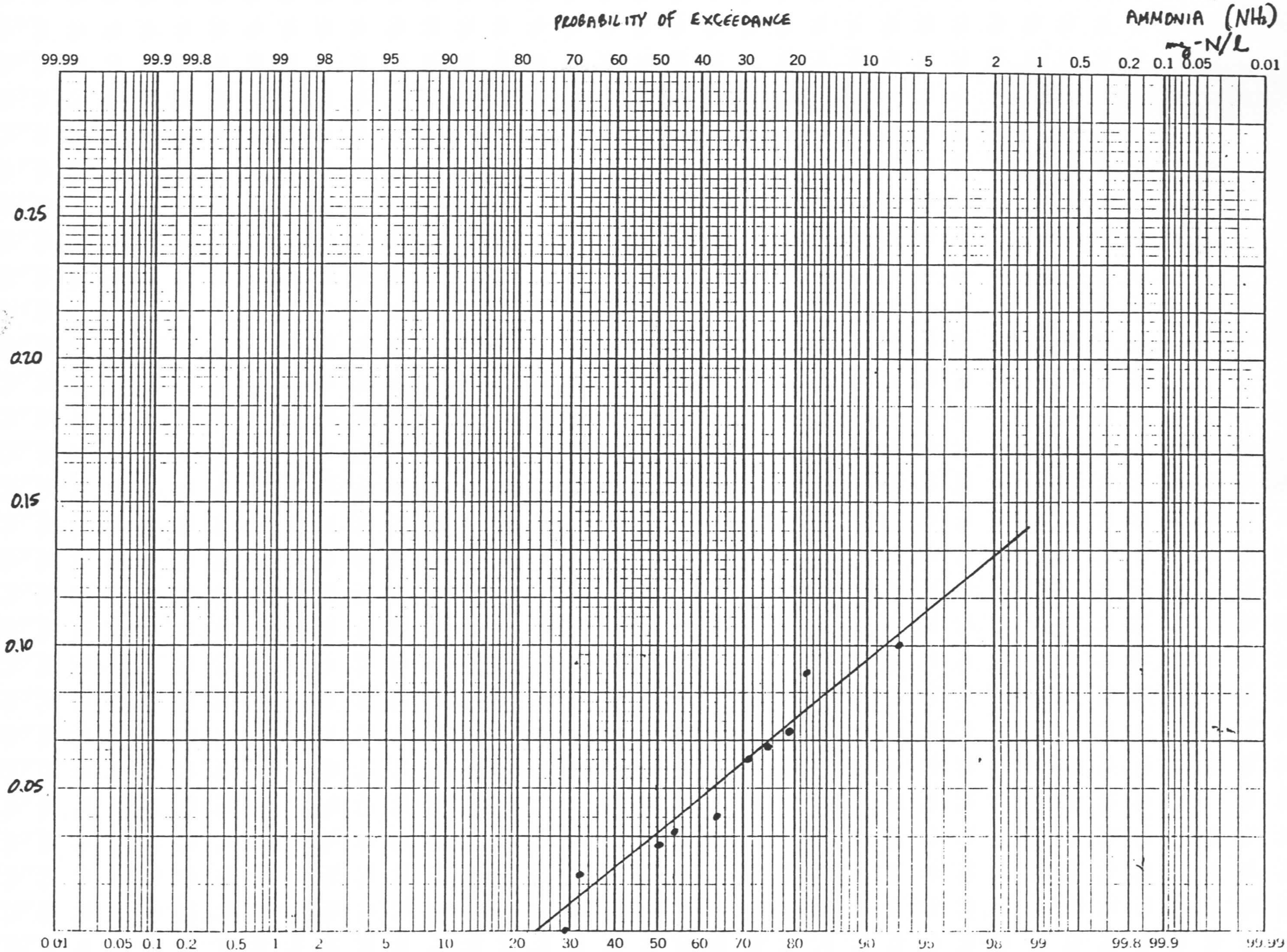
SOURCE: USBR STORET, 1967-1987

SAMPLE SIZE = 174

$\bar{x}$ = .27

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000

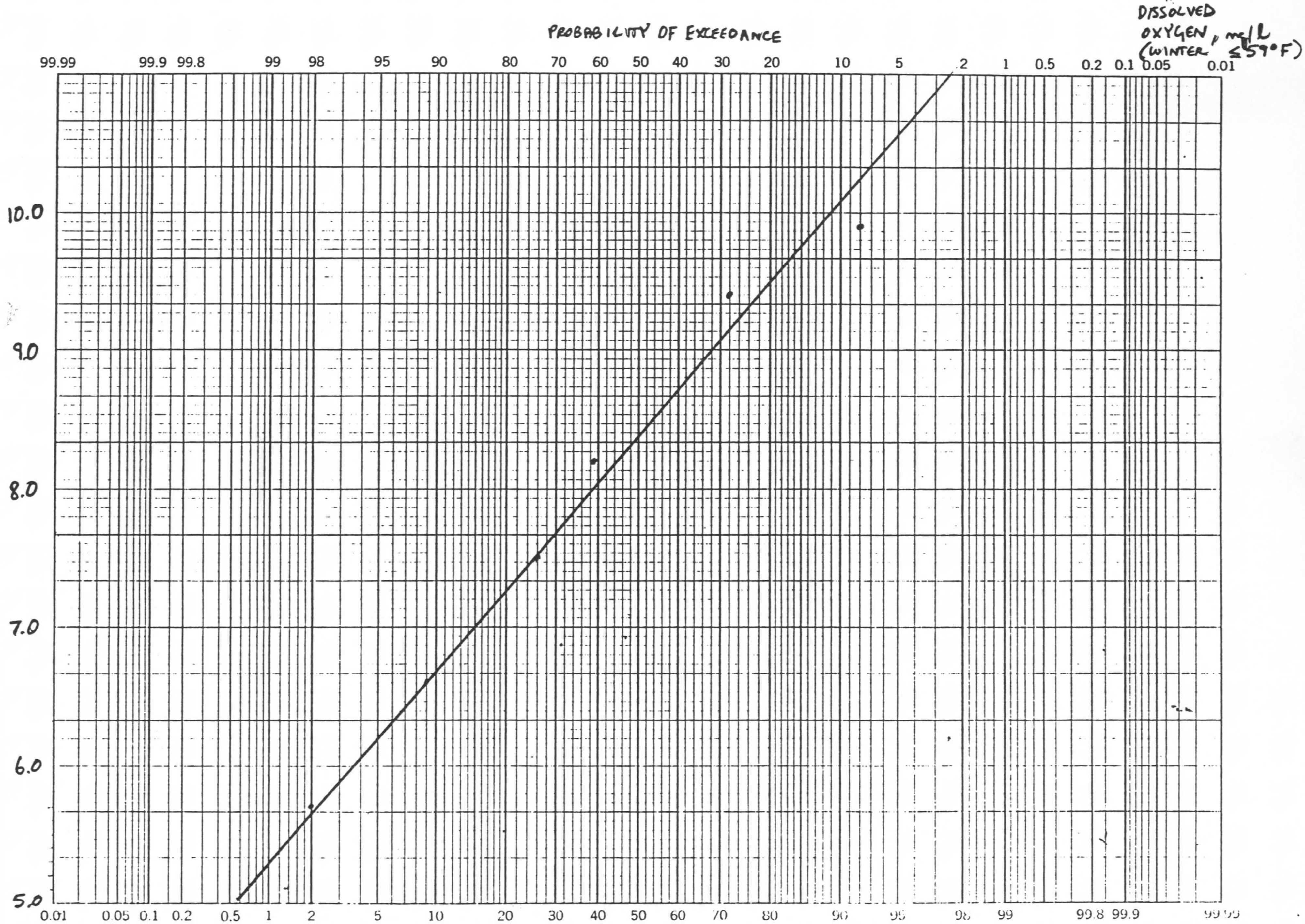


SOURCE: USBR STORET DATA, 1967-1987
K/J/C SURVEY 1987

SAMPLE SIZE = 28
$\bar{x}$ = .05

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000



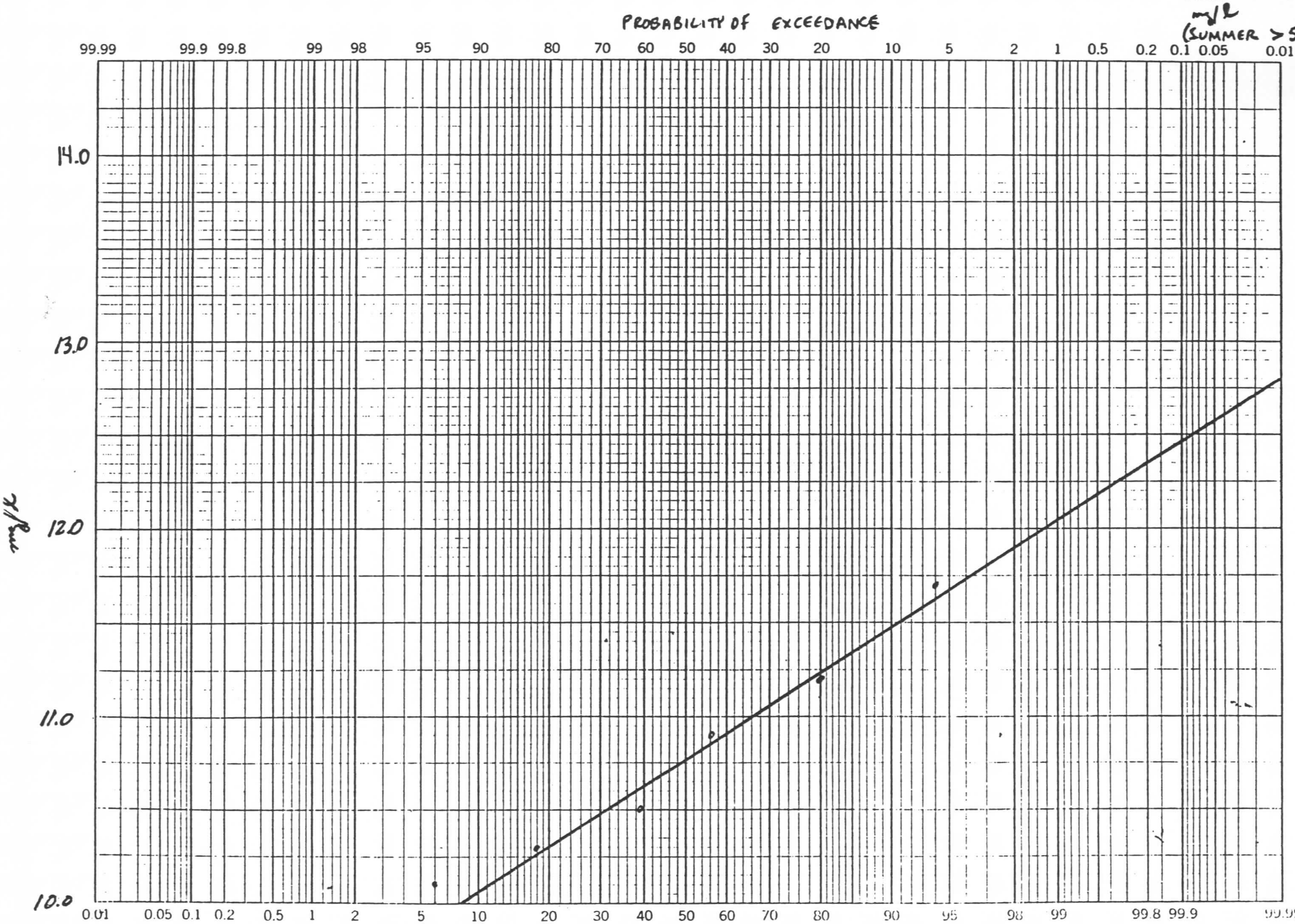
SOURCE : USBR STORET DATA, 1967-87
K/J/C SURVEY, 1987

SAMPLE SIZE = 88

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000

DISSOLVED OXYGEN, mg/l
(SUMMER >59°F)

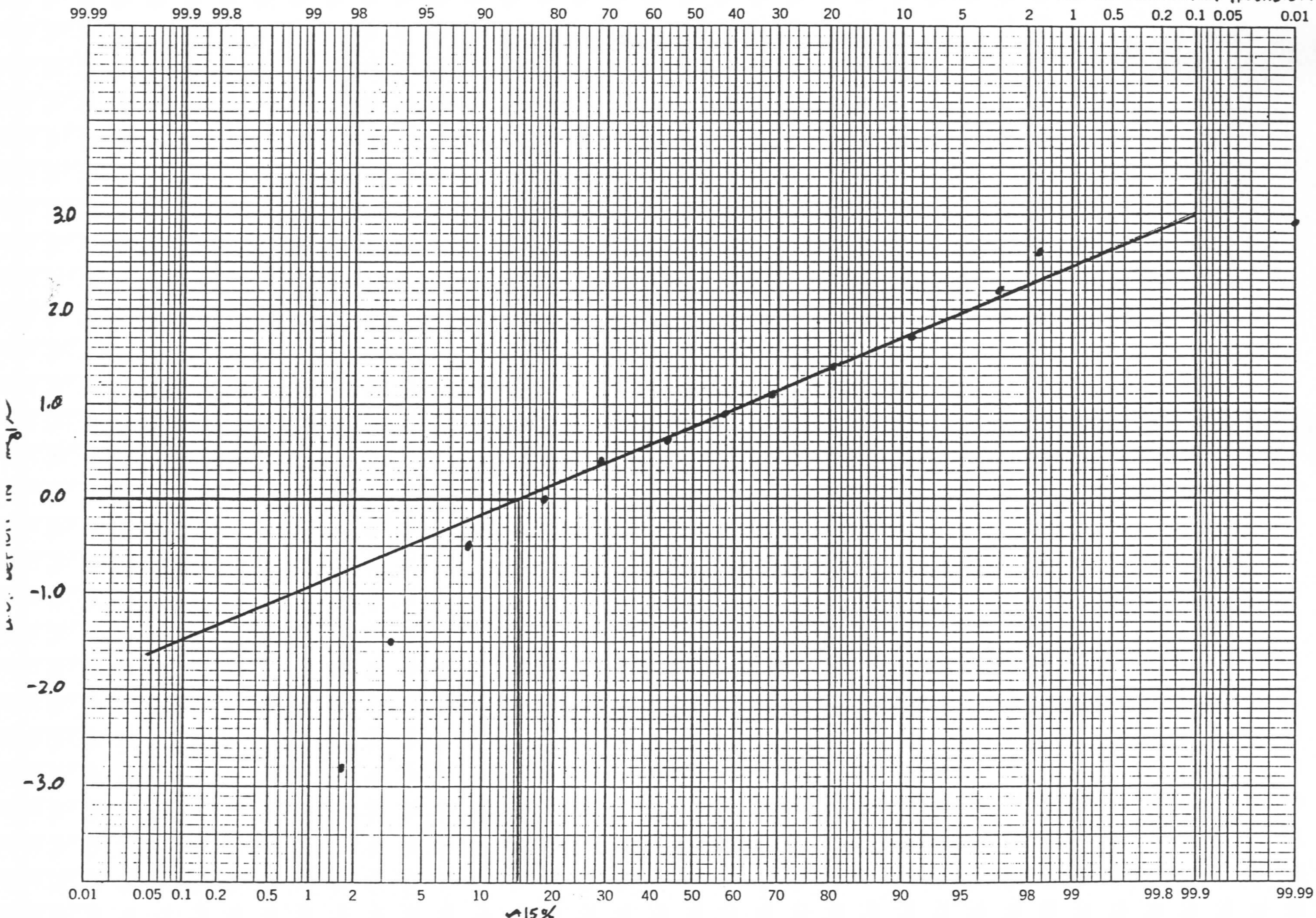


SOURCE: USBR, STORET, 1967-87
K/S/K SURVEY 1997

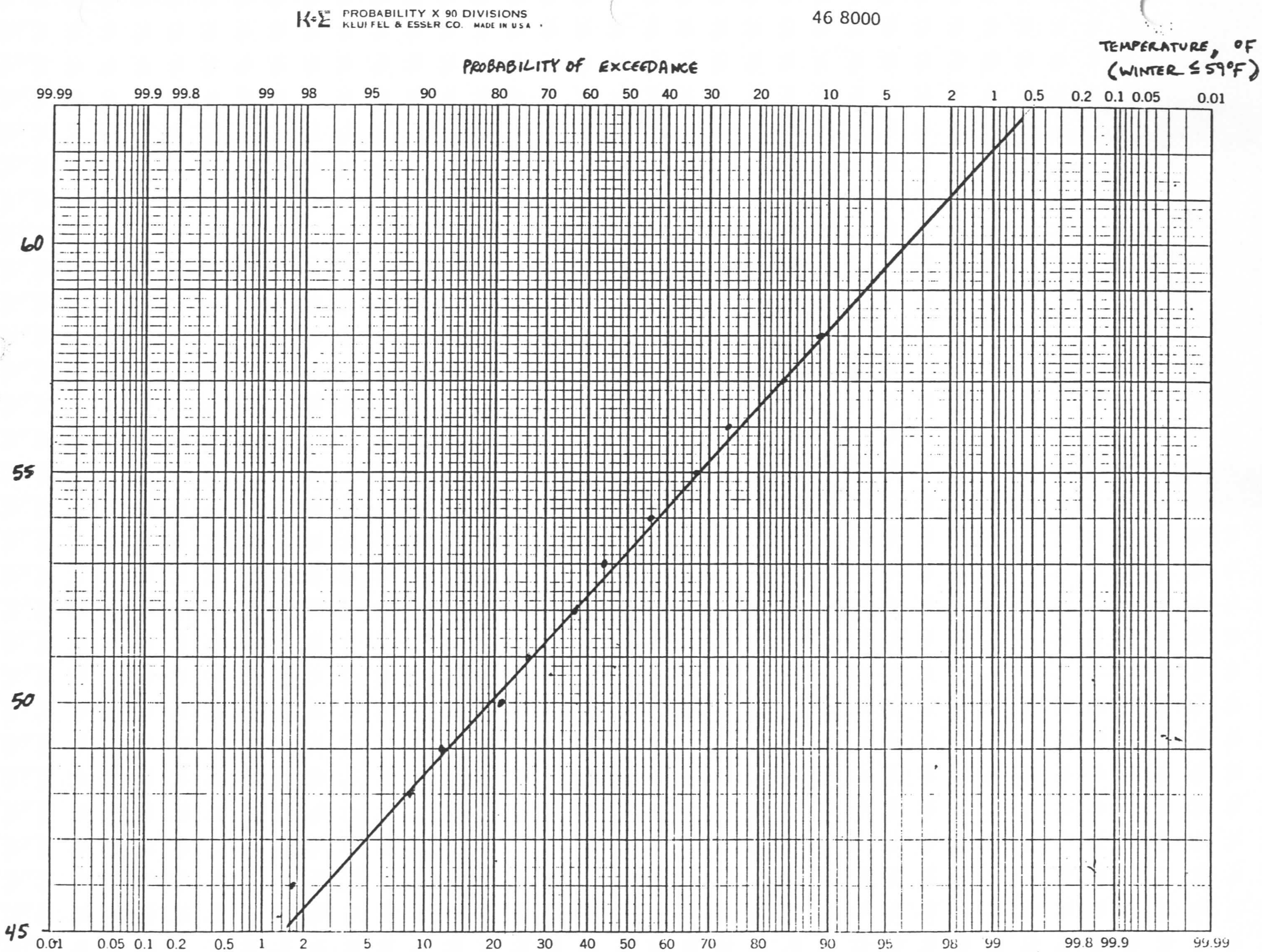
SAMPLE SIZE = 88
$\bar{x}$ = 10.8

DISSOLVED OXYGEN DEFICIT

NORMAL DISTRIBUTION PROBABILITY PLOT



SOURCE: USBR STORET DATA AND
K|J|C SURVEY-1987



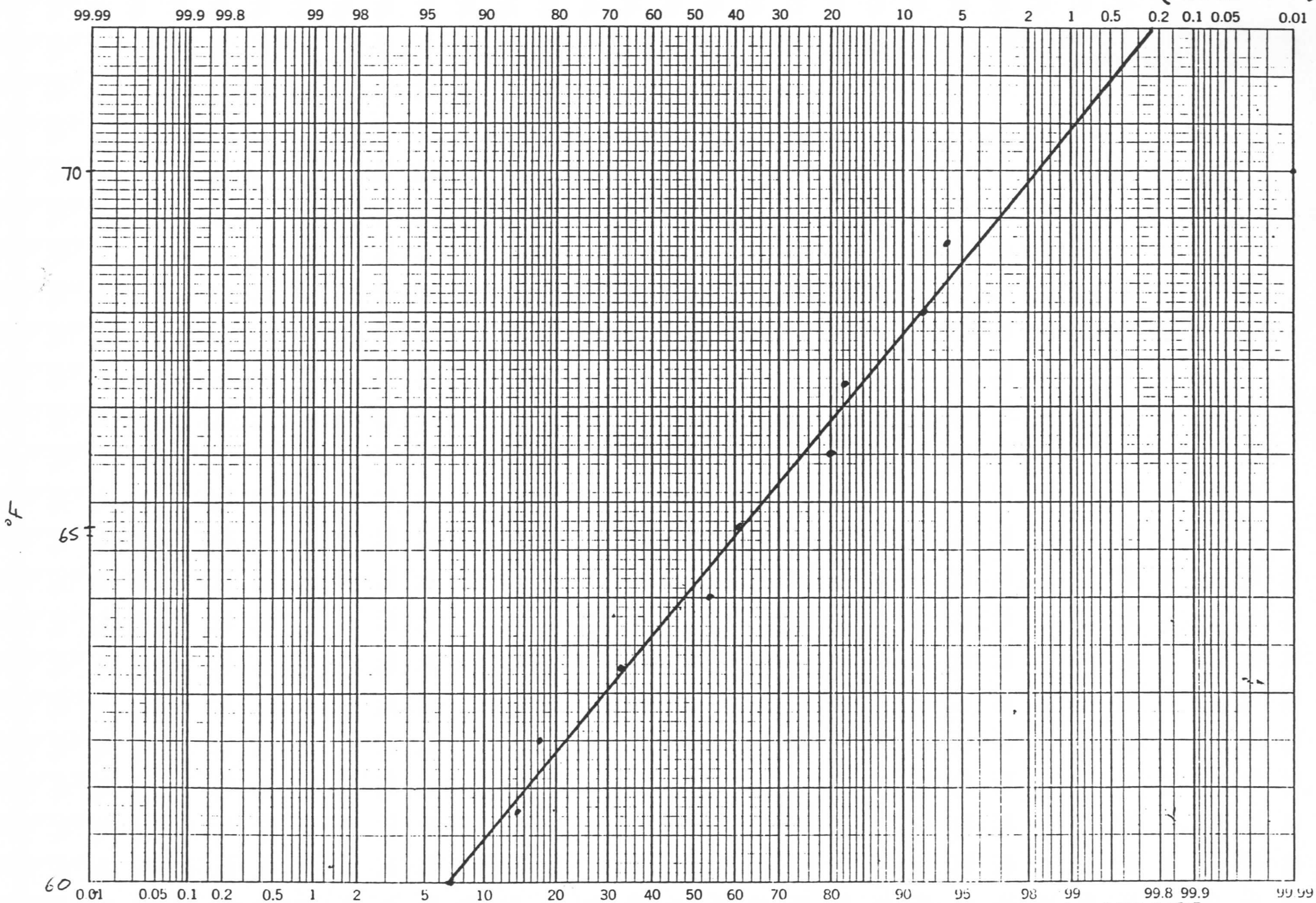
SOURCE = USBR STORET DATA, 1967-87
K/J/C SURVEY 1987

SAMPLE SIZE = 115

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000

TEMPERATURE, °F
(SUMMER > 59°F)

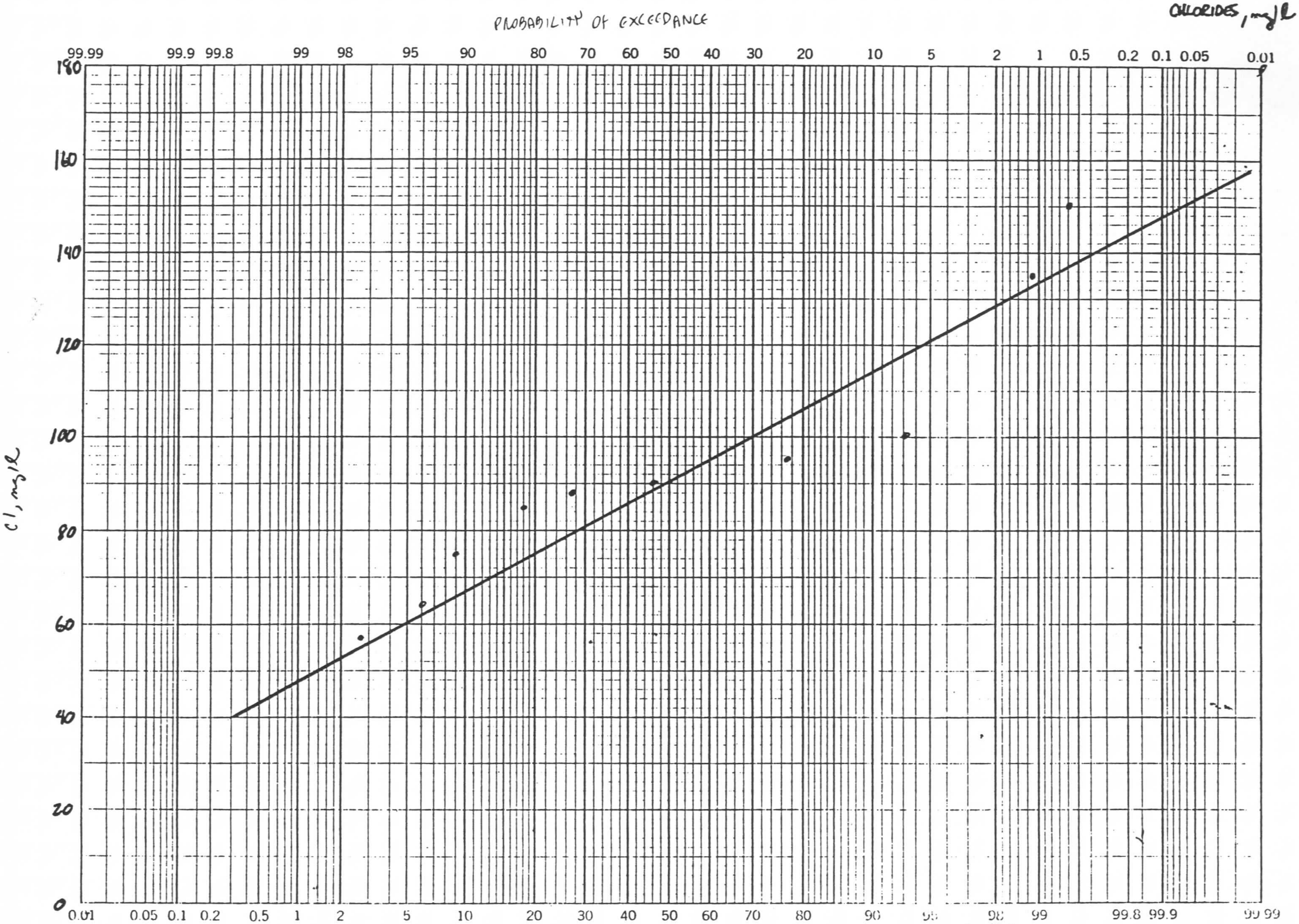


SAMPLE SIZE = 125
$\bar{x}$ = 63.7 , s = 2.64

SOURCE : USBR ST[illegible] DATA 1967-87
K/J/K S[illegible] 1987

K+E PROBABILITY X 90 DIVISIONS
KLUFFEL & ESSER CO. MADE IN U.S.A.

46 8000

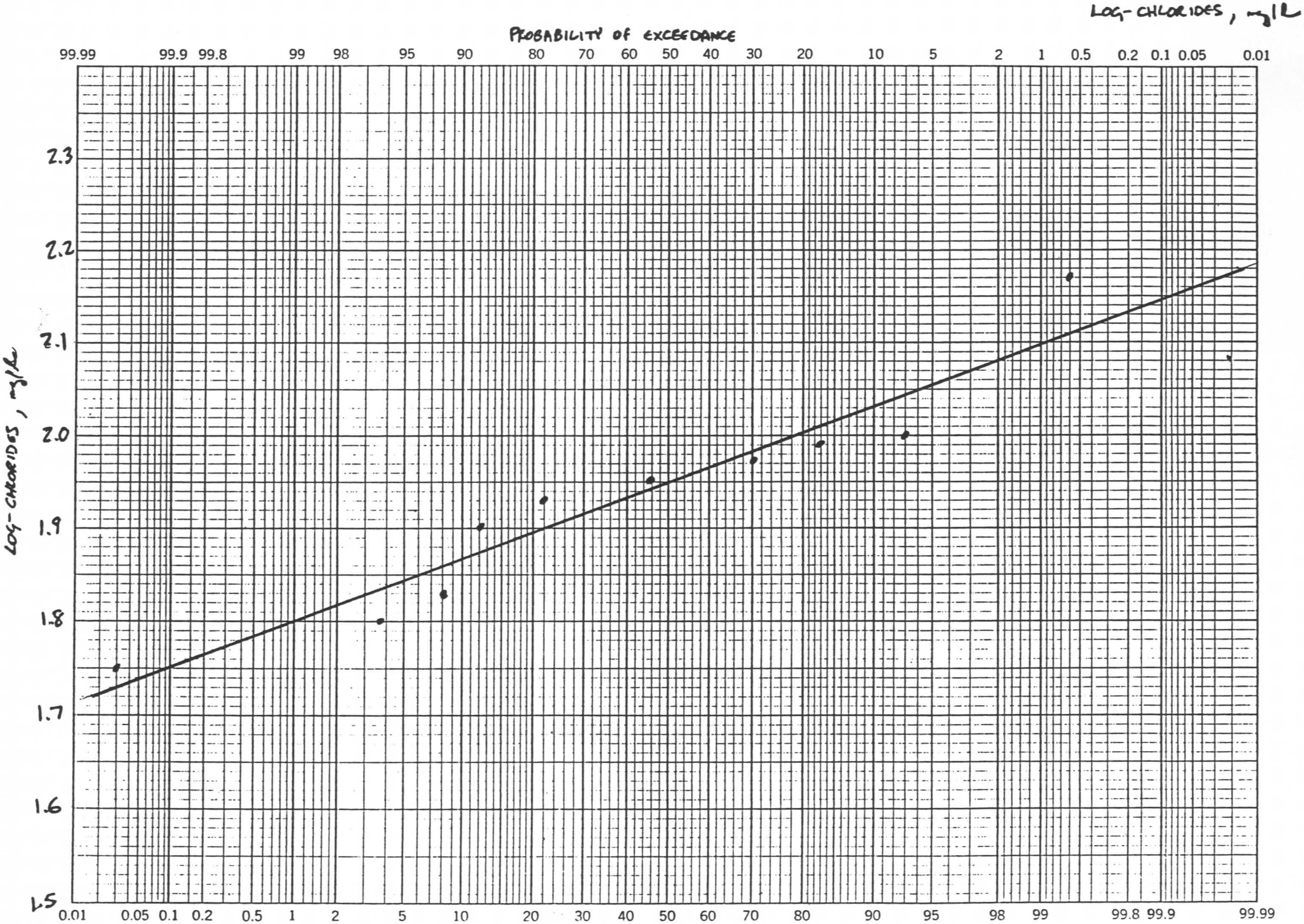


SAMPLE SIZE = 180
$\bar{X} = 89.7$, $S = 15.8$

SOURCE: USBR STORET, 1967-87
KLSYC SURVEY, 1987

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000

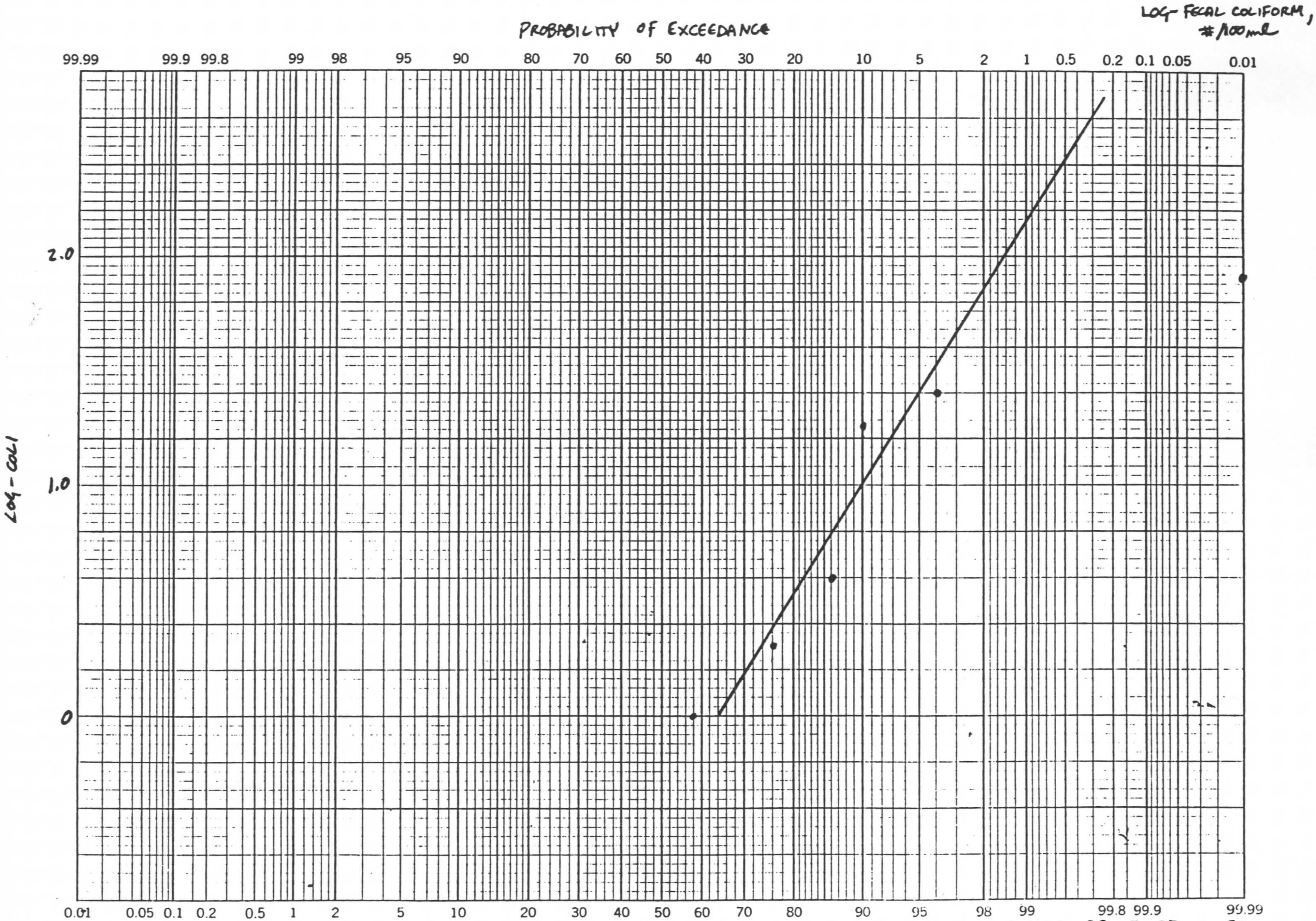


SOURCE: USBR STORET, 1967-87
K|J|C SURVEY

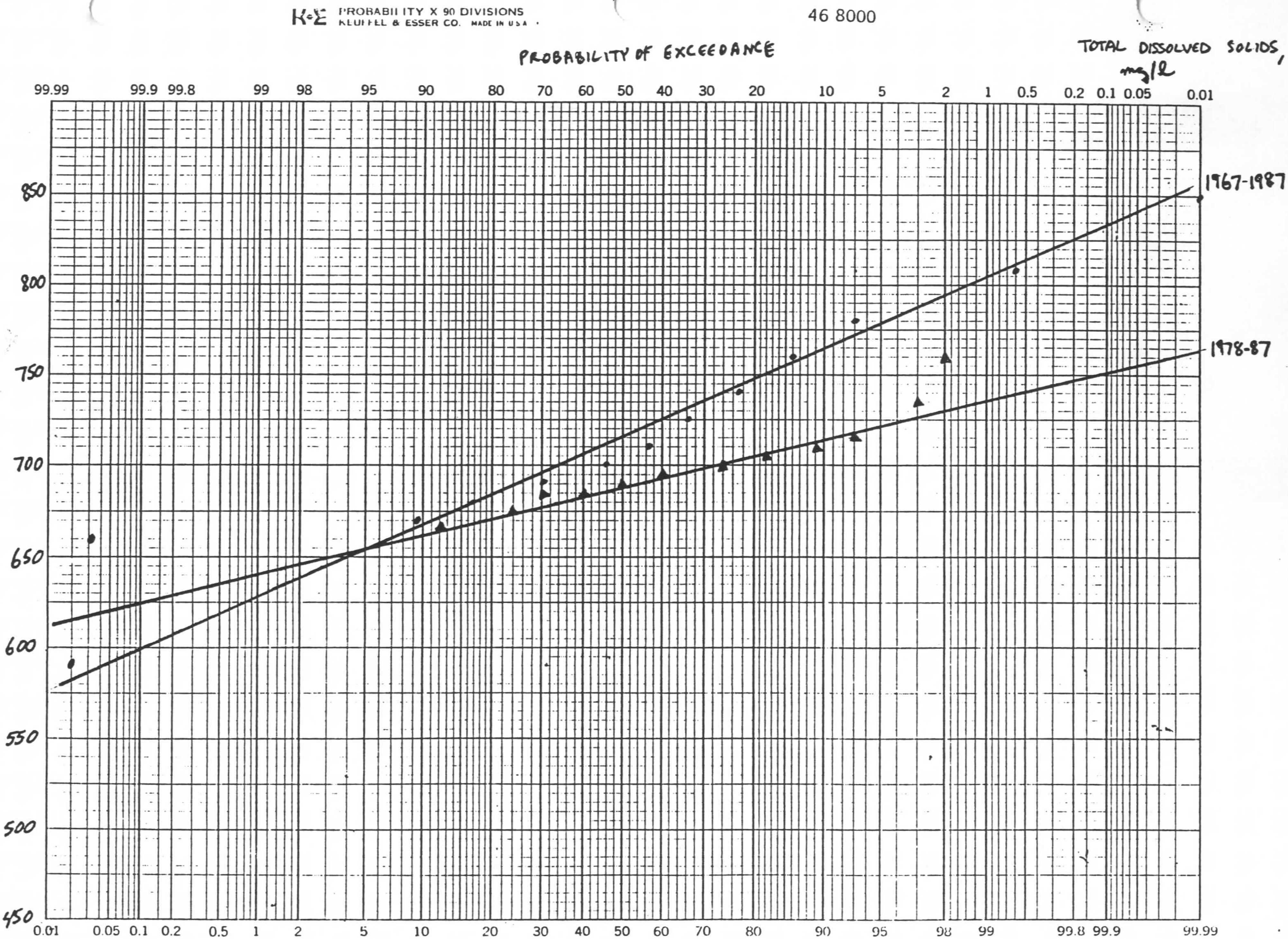
SAMPLESIZE = 180

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8000



SOURCE: USBR STORET 1967-87
K|J|C SURVEY 1987



SOURCE: USBR STORET, 1967-87
K/J/C SURVEY, 1987

SAMPLE SIZE = 167
$\bar{X}$ = 711.2, S = 46.2