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CanonieEnvironmental

NRC Request for Information

Atlas Corporation Reclamation Plan Uranium Mill and Tailings Disposal Area

Moab, Utah

Submitted by:

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NRC Request for Information

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Canonie Environmental

RESPONSE TO NUCLEAR REGULATORY COMMISSION
REQUESTS FOR INFORMATION
NOVEMBER 29, 1993
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ENCLOSURE 2 - OTHER CONSIDERATIONS
JANUARY 3, 1994
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SURFACE WATER HYDROLOGY AND EROSION PROTECTION
RECLAMATION PLAN
URANIUM MILL TAILINGS SITE
MOAB, UTAH

INTRODUCTION

Canonie Environmental Services Corp. (Canonie) has prepared a response to the Nuclear Regulatory Commission's (NRC's) November 29, 1993, and January 3, 1994, requests for information. This response is a partial response to the information requested and completes our submittal requirements for these information requests. A previous partial response to the November 29, 1994, request for information submitted to NRC on January 28, 1994, addressed erosion protection at Moab Wash and the Lower Impoundment Drainage Channel, construction specifications, and settlement. The responses to Enclosure 1, the remainder of the responses to Enclosure 2, and the responses to the January 3, 1994, request for information are provided in this document. In the following pages, each request for information is restated verbatim and a response to each request is provided. Calculation briefs and other back-up data for these responses are included as appendices.

ENCLOSURE 1 - REQUEST FOR INFORMATION - FAULTING, SEISMIC AND GEOMORPHIC CONSIDERATIONS

A. Potential Faulting and Seismic Considerations

New geologic information brought to our attention requires a reassessment of the stability of the site. Please analyze the structural stability and liquefaction potential of the disposal area using current state-of-the-practice methodology by providing responses to the following:

Comment

1. There is evidence that a fault runs under the disposal site. Evaluate the extent of faulting under the disposal site and determine if there is capability for surface rupture.

Response

This response has been prepared by Woodward-Clyde Federal Services Corp., Oakland, California, under a consulting agreement with Canonie Environmental Services Corp. (Canonie) and is submitted under separate cover.

Comment

2. Evaluate the seismic potential for faults adjacent to the site, including the potential for fault movement due to salt dissolution and changes due to the development of oil resources.

Response

The response to the first part of this comment (i.e., seismic potential for faults adjacent to site and potential for fault movement due to salt dissolution) is provided with the response to Comment 1. The response to the second part of the comment concerning the development of oil resources is provided below.

The nearest oil production to the Atlas mill and tailings area is near Dead Horse State Park, approximately 12 miles southwest of the Atlas mill (Hunt, 1994). The production in this area comes from several fields that produce from the "Cane Creek" zone of the Paradox formation (Morgan, 1992a). The Cane Creek zone is a shale zone with production coming from depths ranging from 7,000 to 8,000 feet in the vicinity of Dead Horse State Park (Mathews, 1994).

The nearest oil exploration activity to the Atlas mill was just west of Arches National Park at a field designated the Coors West Moab Valley Unit (Morgan, 1992a). This area is about five miles northwest of the Atlas mill. Several test wells were drilled in this area. Morgan (1992a) and other investigators in the region do not designate this area as a viable field, even though oil shows were indicated in a couple of units.

One test well (Embar Oil Well) was drilled on the Atlas mill site. Available information indicates that the well was drilled into the Paradox formation of the Hermosa Group; however, no information is available with respect to oil and gas shows. Morgan (1993) indicated that the "Cane Creek" shale is highly contorted in the area of large salt-cored anticlines making identification and correlation extremely difficult and regional exploration unpractical at this time. As the Atlas mill is located in the vicinity of the collapsed crest of the Moab anticline, it is expected that the shale zones of the Paradox formation are quite contorted in this area and the area will not be targeted for oil exploration.

Expanded development of the hydrocarbon resources at the oil fields in the vicinity of Dead Horse State Park (12 or more miles from the site) would not create a potential for affecting the integrity of the Atlas tailings embankment. Drilling operations conducted in this area are far removed from the embankment. Theoretically, withdrawal of hydrocarbons from reservoir horizons through wells can lead to subsidence. However, as the production zones in this area are generally below a depth of 7,000 feet and at a considerable distance from the Atlas mill, subsidence related to this production will not affect the Atlas site.

Even if production were to occur in the vicinity of the Atlas Mill site, it is expected that subsidence would not be noted at the surface. The "Cane Creek" shale is naturally fractured (as a result of folding and salt flowage) and is characterized by large "vertical" fractures with related microfractures (Morgan, 1993). The microfractures provide most of the fracture porosity in the reservoir. The "Cane Creek," having no available pore space and sealed above and below by salt, had to self-fracture to make room for hydrocarbons (Morgan, 1993). The result of this is that the "Cane Creek" shale is overpressured. The high fluid pressure helps to hold the formation fractures open (Morgan, 1993). A rapid drop in fluid pressure could cause closure of the fracture network around a borehole (Morgan, 1992b); however, the "plastic" nature of salt and its ability to creep and flow due to overburden pressures would only result in creep deformation of the overburden salt and would not be transmitted through the more rigid cap rock and the alluvium to the surface.

It is unlikely that the process of drilling an exploration hole and development of a production well could enhance dissolution of the salt. Steel casings are set into the salt and cemented in place from the surface to the salt. This prevents the upward or downward flow of fluids along the annular space of the borehole. Also, as mentioned above, the fluids in the salt are overpressured, creating an upward hydraulic gradient, so it unlikely that fresh water occurring in the alluvial aquifers will come in contact with salt formations.

Comment

3. Include in your analyses the earthquake loading considering the more recent information on Maximum Credible Earthquakes for the Colorado Plateau, which appears to require a value larger than you have used in the past. Consider in your reevaluation the information on geologic and geologic hazards for the Moab area that the State of Utah is currently preparing.

Response

The reclaimed embankment was analyzed under seismic loadings with both dry and partially saturated tailings. Factors of safety for the reclaimed embankment were computed using the computer program PCSTABL5 (Carpenter, 1986). Stability of the reclaimed embankment under the following scenarios was analyzed:

1. Critical circular failure surface with 250-year earthquake loading without phreatic surface in coarse tailings

2. Critical circular failure surface with 250-year earthquake loading with phreatic surface in coarse tailings

3. Critical circular failure surface with earthquake loading corresponding to the Maximum Credible Earthquake (MCE) for the Colorado Plateau without phreatic surface in coarse tailings

4. Critical circular failure surface with earthquake loading corresponding to the MCE for the Colorado Plateau with phreatic surface in coarse tailings

5. Trial failure surface between sand and tailings on embankment with earthquake loading

6. Same conditions as Scenario 1, but maximum earthquake loading under which the reclaimed embankment is stable is determined

7. Same conditions as Scenario 2, but maximum earthquake loading under which the reclaimed embankment is stable is determined

Dewatering of the existing tailings pile is currently ongoing. In the event that water is present in the tailings a phreatic surface is assumed for Scenarios 2, 4, 5, and 7 as a short term condition. The phreatic surface is assumed based on water level readings in piezometers at the tailings pile recorded on October 30, 1993, and provided to Canonie by Atlas Corporation (Atlas). Using the piezometers nearest the critical cross section, the phreatic surface has been extrapolated on Figure 1.

The longest return period for which horizontal earthquake acceleration maps are available is 250 years. United States Geological Survey Map MF-2120 (Algermissen, et al., 1990) is the most current map showing the mean horizontal earthquake acceleration which has a 90% probability of nonexceedance. For Moab, Utah, the 250-year horizontal acceleration is approximately 0.05 gravity (g). The 0.05 g value was confirmed by Utah Geological Survey personnel (Low, 1993).

The reclaimed embankment design life is a minimum of 1000 years. During this period an earthquake of larger magnitude could potentially occur. In discussions with Joel Grimm, Project Manager with the NRC on December 28, 1993, the MCE used for a nearby Colorado Plateau Green River Title 1 site was 6.2 on the Richter scale, corresponding to a horizontal earthquake acceleration of 0.21 g (Department of Energy, 1989). This value is used for Scenarios 3, 4, and 5 along with a vertical earthquake acceleration of 0.05 g. The purpose of Scenarios 6 and 7 is to account for a potential earthquake of even greater magnitude during the design life of the reclaimed embankment. Under these scenarios, the maximum horizontal earthquake acceleration under which the reclaimed embankment is stable was determined.

Failure surfaces predicted by PCSTABL5 for the scenarios listed above are shown graphically on Figure 1. Soil properties and strength properties used in the analysis are also presented on Figure 1. Details of the stability evaluation are provided in Appendix A. Appendix A also contains the piezometer coordinates and the most current water level information.

The factor of safety against slope failure is greater than 1 for Scenarios 1, 2, and 3. For worst case Scenarios 6 and 7, the impoundment could withstand an earthquake with a horizontal earthquake acceleration of 0.25 g. This is 400 percent larger than the 250-year earthquake acceleration predicted for Moab, Utah, and 19 percent larger than the MCE loading. Based on the results of the stability analysis and the low probability of the MCE being exceeded, the reclaimed embankment design will provide an adequate factor of safety against shear failure.

B. Geomorphic Stability

Comment

1. From the available data and our observations, there appears to be no basis to conclude that the Colorado River cannot erode in the direction of the tailings pile. There is also insufficient information currently available to us to determine the rate of erosion. We therefore conclude that this erosion could adversely affect the stability of the tailings pile during the project design life.

   Accordingly, provide information to show that the Colorado River will not erode and migrate to the tailings embankment, or substantiate that your proposed design has considered and accounted for the potential for long-term bank erosion and changes in the river's position in the valley. Include consideration of both structural stability and erosion protection.

If you cannot substantiate that the river will not migrate toward the tailings or that your design accommodated this condition, provide a revised design for our review and approval that considers a complete range of river conditions and positions that could be experienced in the project design life.

Include in your substantiation or redesign the estimated location, depth, and dimensions of the channel and any revised designs and analyses of the riprap to be placed along the sides of the toe of the pile. Also consider potential future channel locations, estimated depth of the channel, depth of scour, Probable Maximum Flood (PMF) water surface elevation, and other factors which enter into the erosion protection design. Since a new channel could possibly occur in a number of locations along the face of the pile, address in detail the areal extent of the erosion protection for the pile side slopes and toes. Include information to demonstrate that erosion protection is adequate to the scour depth that could be expected for the conditions described above.

Note

Additional comments concerning surface water hydrology and erosion protection were submitted to Atlas on January 3, 1994. The comment is repeated below.

Comment

2. It appears that the cross-sections and other estimated hydraulic parameters used in your water surface profile analyses to assess flooding on the Colorado River may not be appropriate. Preliminary review of your data and analyses indicates that the computations presented may not reflect actual conditions, as indicated by direct staff observations of the Colorado River. We have questions and concerns in the following areas:

- Topographic and Colorado River cross-section data
- Underprediction of flow velocities in the river channel
- Changes to river channel cross-sections during flood events
- Use of Manning's 'n' values

It appears that the topographic and cross-section data provided for determining water surface evaluations and velocities are not adequate for assessing flow velocities in the river channel. Based on an examination of the topographic and cross-section information provided, more detailed and correct cross-sections are required to correctly analyze the flows in the Colorado River, particularly with regard to determining flood velocities. For example, the cross-section data provided with the HEC-2 analyses (Appendix F) do not agree with topographic data provided in Drawing 88-067-E64 (Sheet 2 of 10). Specifically, cross-section 800 in the immediate site vicinity, does not reflect the elevations or channel widths indicated on the drawing. Further, direct observations and approximate staff measurements of the river depth indicate that the depths from the top of the bank to the channel bottom are greater than indicated in the HEC-2 data at cross-section 800 and at other cross-sections. These apparent errors could significantly affect the flow profiles computed using HEC-2, particularly if the channel bottom elevations and bottom slope are not well-defined. The calculations take on added significance if the river channel is assumed to migrate toward the pile (see previous questions on geomorphology, dated November 29, 1993). Additional evidence to substantiate that the cross-section data are not correct is provided by direct observations of the flow velocities in the river, which indicate that the maximum predicted PMF channel velocity of about two to three feet per second has apparently been underestimated. The staff observed surface velocities of two to three feet per second in November 1993 during a low-flow period in the river. Channel velocities are likely to increase significantly as the discharge increases during flood events.

In addition, based on map studies, this reach of the river is known to change geometry during and after major flood events, since erosion and deposition occur in various places. Therefore, the flood analyses should assume that changes will occur to the river geometry during a flood event. These changes would include erosion of channel bars and deepening of the channel during a large flood event. This assumption could be extremely important at cross-sections near the "portal" area, for example, where it appears that significant constriction of flows occur and backwater effects are produced by constricted cross-sections. These sections may not be a significantly constricted during the course of a flood event. In particular, cross-section 200 indicates the presence of a sandbar which constricts flows, but could be eroded by high velocities during a major flood event. In addition, it becomes very important to define stable channel bottom elevations in these constricted sections, since the bottom elevations and bottom slope can have a great effect on velocities and depth of flow.

Also, the Manning 'n' values should be more conservative than those assumed. For example, the channel and overbank 'n' values are assumed to be 0.03. It is likely, particularly during large floods, that channel 'n' values would be less than this. It is also likely, based on the presence of significant amounts of vegetation, that overbank 'n' values would be greater than 0.03. The overall net effect of using lower channel 'n' values would likely be to increase channel velocities and possibly lower water surface elevations. This is significant if the riprap on the pile side slopes needs to be designed for river channel velocities, if the river is assumed to migrate toward the pile (see staff questions on geomorphology). If the river is not assumed to migrate, use of overbank 'n' values of 0.03 is likely to be acceptable, but should be checked and verified using appropriate equations for estimating 'n' values.

During our field visit to the area in November, the National Park Service pointed out high-water marks at the Highway 191 bridge for floods which occurred in the early 1980s. You should attempt to duplicate these historic profiles by adjusting Manning 'n' values, expansion and contraction losses, river geometry, etc. for the flows which occurred. These high-water marks should be surveyed and provided in the analyses as justification for the HEC-2 input parameters selected.

Accordingly, please provide revised and accurate cross-sections to properly model flood flows in the Colorado River. The new data should include surveyed cross-sections which accurately portray river geometry. Also, submit revised HEC-2 analyses using these new data to substantiate the adequacy of the proposed erosion protection on the pile side slopes.

Alternately, it may be possible to conservatively estimate the river depth and velocities to be used for the design of erosion protection using a minimal amount of data. Such estimates could be developed for:

1. Overbank velocities for the case which the river channel is assumed to be stable and does not migrate toward the pile
2. Channel velocities for the case where the channel is assumed to migrate toward the pile

In preparing these "bounding" calculations however, a certain amount of new information will need to be developed. While some river channel widths and bank elevations could possibly be estimated from topographic maps already available, the slope and elevation of the river bottom will need to be accurately determined by surveys. It may be possible to use such measured river slopes and overbank/channel geometry taken from maps in a worst-case analysis to estimate velocities in the vicinity of the pile using simple slope-area methods and conservative estimates of Manning 'n' values for the channel and overbank. This type of worst-case calculation could possible be acceptable, if adequately justified as being appropriate and/or conservative, using sensitivity analyses, for example. This analysis should also attempt to duplicate historic profiles and high water marks.

<u>Response</u>

This response has been prepared by Mussetter Engineering, Inc., Fort Collins, Colorado, under a consulting agreement with Canonie and is provided under separate cover.

ENCLOSURE 2 - REQUEST FOR INFORMATION - OTHER CONSIDERATIONS

A. Erosion Protection

Comment

1. Based on examination of the design and observation of nearby cliffs, we consider that a potential exists for sediment and large rocks to block or severely restrict Southwest Runoff Drainage Channel, the lower reaches of the Upper Impoundment Drainage Channel, and the upper reaches of the Lower Impoundment Drainage Channel. This could reduce their flow capacity and result in increased water surface elevations and flow velocities in the channels. Critical areas of potential sedimentation are at locations where concentrated flows in relatively well-defined natural channels enter the drainage channels. Critical areas of potential rock falls and blockage occur throughout the length of the Southwest Runoff Drainage Channel, along the last several hundred feet of the Upper Impoundment Drainage Channel, and along the first several hundred feet of the Lower Impoundment Channel.

   Accordingly, provide a detailed analysis to demonstrate how the drainage channels will either safely store or flush out the expected rock falls and sediment load. If your analyses conclude that the channels will safely store the expected debris load, demonstrate that changes in the water surface profiles and flow velocities will not adversely affect the stability of the riprap in the channels or on the adjacent tailings pile side slopes. If your analyses conclude that channel velocities will naturally flush out the expected sediment and large rocks, you should demonstrate that flow velocities in the drainage channels will be high enough to accomplish this for a range of flood events.

   In your analyses, consider that rocks weighing several tons may enter the drainage channels from the cliffs to the west. Rocks of this size would probably not be moved out of the channels, even during a Probable Maximum Flood. In this case, the design of the drainage channels may need to be revised to accommodate the increased water surface elevations and velocities caused by these blockages. One possible design solution you may want to consider would be to eliminate the Southwest Drainage Channel and design the erosion protection on the tailings pile side slopes, assuming that large amounts of sediments and rocks are transported to areas immediately adjacent to the side slopes.

Response

Utah State Highway Number 279 (Highway 279) is located between the subject cliffs and the Atlas tailings embankment. To get a reasonable assessment of the frequency and size of rock falls from the cliffs, Canonie contacted the Utah Highway Department. Mr. Lloyd McKinley, Maintenance Supervisor for the Utah Highway Department, Moab District, was contacted with respect to the frequency of rock clearing operations along Highway 279 adjacent to the tailings embankment. Mr. McKinley indicated that he has worked in the Moab district for 28 years and has never cleaned rocks along this section of Highway 279. He indicated that they have only had to remove small rocks from the ditch along the cliff side of the highway. Mr. McKinley indicated that the talus slope generally stops at a bench or road cut in bedrock above the highway and most large rocks hang up above this point. A major portion of the cliff adjacent to the tailings embankment is covered with talus. The talus is composed of mostly large-sized material and is maintaining a fairly steep slope (i.e., approximately 25 to 35 degrees). The toe of the slope (at ditch on cliff side of the highway) is approximately 140 to 170 feet from the proposed Southwest Runoff Drainage Channel (SWRDC) and at a greater distance from the lower reaches of the Upper Impoundment Drainage Channel and upper reaches of the Lower Impoundment Drainage Channel. As rockfalls along this cliff are infrequent and the distance from the toe of the slope to the channel is such that rockfalls will probably not reach the channel, it is unlikely that rockfalls will reach the channel and restrict flow.

However, because of NRC's concerns that a potential exists for sediment and large rocks to block or severely restrict the SWRDC, the previously designed trapezoidal channel has been replaced by a natural drainage way. Riprap erosion protection along the base of the tailings pile side slopes has been redesigned to withstand flows down the natural drainage channel. Sheet 4 of 10 and Sheet 6 of 10 of the Reclamation Plan drawings have been revised to reflect the design changes to the SWRDC. These figures are included in the Figures section of this document. Appendix B of this document contains a detailed analysis on the redesign of the erosion protection on the tailings pile side slopes.

Sheet 4 of 10 of the drawings identifies the selected D_{50} riprap erosion protection and the location of the riprap erosion protection along the base of the tailings pile adjacent to the natural SWRDC. An actual (oversized for durability) D_{50} of 9 inches has been designed for the base of the tailings pile adjacent to the SWRDC from the beginning of the SWRDC to Station 10+00 and from Station 12+00 to Station 18+15 (beginning of the width transition). From SWRDC Station 10+00 to 12+00, an actual D_{50} of 17.4 inches has been designed. These D_{50} values are sized adequately to withstand a Probable Maximum Flood (PMF) event in the natural drainage channel. Furthermore, the D_{50} values are adequately sized for flow conditions resulting from a rock fall into the channel of a reasonable volume of rocks, based on engineering judgement.

As illustrated on Sheet 4 of 10, a natural drainage way from Station 18+15 to the end of the SWRDC was not considered because existing contours adjacent to the reclaimed tailings pile do not provide for adequate drainage nor does a natural channel provide adequate protection at the outlet of the SWRDC. The designed trapezoidal channel will be used from the start of the width transition to the end of the channel including the rock cutoff wall. Rocks or sediments entering the lower reach of the SWRDC should not severely restrict drainage because the lower reach is fairly wide (50 feet) and the slope is steep (7.5 percent).

Cross Section J-J' on Sheet 6 of 10 of the drawings illustrates the vertical extent of the riprap erosion protection. The riprap erosion protection extends sufficiently below the existing grade to account for scour depth and sufficiently above existing grade to account for the maximum expected PMF depth under flow conditions resulting from falling rocks entering the channel. The maximum predicted PMF depth under flow conditions resulting from rocks entering the channel is approximately 1.8 feet higher than the PMF depth with no rocks in the channel.

The U. S. Army Corps of Engineers (COE) riprap sizing method (Hydraulic Design of Flood Control Channels, EM 1110-2-1601, 1970) was selected to size the riprap erosion protection at the base of the tailings pile side slopes adjacent to the natural SWRDC. The depth of flow in the channel, required to apply the COE method, was determined through numerical modeling of the water surface profile using the COE HEC-2 Water Surface Profile computer program (September 1990 version). The redesigned channel was evaluated for both subcritical and supercritical flow using the HEC-2 computer program. Appendix B discusses in greater detail the COE method input and results.

Both initial conditions in the channel (i.e., following construction when no rocks or sediment may be blocking the channel) and future conditions (when sediment and rocks may have entered the channel) were evaluated as part of the redesign of the tailings embankment riprap erosion protection. For the initial channel conditions, the geometry of the natural side slope of the channel was determined from existing ground contours. The geometry of the tailings embankment side of the channel was determined by projecting upward from the channel invert to the top of the reclaimed tailings pile side slope.

For future conditions involving rocks or sediments entering the channel, approximately 500 cubic yards (cy) of rocks were distributed in the natural reach of the channel. This rock volume was determined by measuring boulders which are presently located in the vicinity of the southwest side of the tailings pile and north of Highway 279. The resulting volume was approximately 25 cy. It was assumed that the boulders and rocks had fallen in the past 50 years. To obtain a volume over the 1000-year design life of the tailings embankment, the 50-year volume of 25 cy was extrapolated to 1000 years.

The 500-cy rock volume was distributed over approximately 250 feet of the channel reach in areas of both subcritical and supercritical flow. Rocks were placed down the natural side slope of the channel to the channel invert. Placement of the rocks only on the natural side of the channel is consistent with currently observed rocks adjacent to the southwest portion of the tailings pile.

The final selected D_{50} sizes are recommended based on comparing evaluations of both the initial conditions (i.e., no rocks or sediment) and future conditions (i.e., with rocks and sediment) in the channel. As shown in Appendix B, placement of rocks in the channel resulted in a larger D_{50} at certain locations in the channel than the D_{50} required for the designed trapezoidal channel. However, in other channel cross sections, the D_{50} actually decreased depending on the distribution of the rocks. The D_{50} sizes finally selected are a conservative recommendation due to uncertainties in how and where rocks may enter the channel.

Between SWRDC Stations 10+00 and 12+00, a larger D_{50} is required because, in both the initial conditions and future conditions scenarios, the HEC-2 model predicted supercritical flow between these stations. As a result of the supercritical flow conditions, velocities are higher than those encountered under subcritical flow and the local boundary shear is increased. Therefore, a large D_{50} was required between these stations.

B. Radon Attenuation

Comment

1. Please substantiate that your exploration and laboratory testing program produced representative parameters that were used to model the radon attenuation. In particular, the parameters associated with the ore and the radiological parameters of all contaminated materials may not be representative, considering the number of samples tested. Address the activity of the coarse tailings that currently comprise the upper 10 feet of the embankment sideslopes which will be relocated over the fine tailings. If you cannot demonstrate that your procedures resulted in statistically valid representative values, propose a program of additional data collection and analyses, and submit the resultant revisions to the radon barrier design for review and approval.

Response

General Response

The collection and analysis of three composite samples for each material in the tailings area (i.e., fine tailings, coarse tailings and ore) to determine engineering design parameters is justified because each material is relatively homogenous in composition, having been produced by identical processes or from similar sources. This homogeneity within each material type is confirmed by the laboratory results from the sampling program. Although the samples for each waste type were collected at test pits located large distances apart, the laboratory data for each sample show only a small variability for the parameters tested.

The radium concentrations reported by the laboratory are further validated by calculating the radium concentration for the tailings area using the average ore grade processed through the mill. This calculation results in an average radium concentration which is consistent with the laboratory results used in the model for radon attenuation design. Based on the tailings homogeneity and the ore grade calculations, additional sampling would not be expected to produce results that would significantly alter the design parameters or the proposed reclamation design. Additional details of the mill and tailings processes, the 1992 sampling and testing program, and the ore grade calculations are provided below.

Mill and Tailings Processes

The tailings produced by the Atlas mill resulted exclusively from the processing of blended ore. The ore was blended to achieve a uniform feed into the mill, both in terms of ore grade and physical characteristics. Table 1 presents a summary of the ore processed at the mill from 1978 to 1984. Based on an average dry tailings density of 90 pounds per cubic foot and a tailings area of approximately 100 acres, the two million tons of ore processed during this period represent the top 10 feet of the tailings in the tailings impoundment. As shown in Table 1, the combined ore grade ranged between 0.157 wt percent U_3O_8 and 0.394 wt percent U_3O_8 with an average grade of 0.228 wt percent U_3O_8 for the seven-year period.

The tailings waste was divided by natural processes within the tailings area into two components:

1. The coarse fraction located around the perimeter of the tailings area and closest to the discharge points

2. The finer fraction located in the center of the tailings area

The areal extents of the fine and coarse tailings were delineated in 1988 by a combination of visual observation at the site and a review of topographical maps of the tailings area. The fine tailings, due to their fine-grained nature and high moisture content, have a much lower angle of repose than the coarse tailings and consequently, there is a clear topographical demarcation between the coarse and the fine tailings. Based on this survey, the area of the coarse tailings was determined to be 62.2 acres, representing 68 percent of the tailings area, and the area of the fine tailings was determined to be 28.7 acres, representing 32 percent of the tailings area.

This natural division according to size of the tailings material was not completely uniform, hence there is some variability in physical and chemical characteristics within each of the two tailings areas. This variability is, however, small compared to that observed at solid waste sites where waste streams from different processes are collected and mixed and where a large number of samples is required to properly characterize the waste.

Similarly, the low-grade ore used to cover a portion of the tailings area is also relatively uniform in composition, having originated from a blended-ore stockpile and having been further mixed during loading and subsequent placement on top of the tailings area.

1992 Sampling and Testing Program

The exploration and testing program for determining representative parameters for the tailings and ore material consisted of excavating six test pits to a depth of 7 to 10 feet in the tailings area and collecting a composite sample over the entire depth of the pit for each type of material represented. Composite samples of fine tailings were collected from Test Pits TTP-3, TTP-5 and TTP-6, located in the center of the tailings area. Composite samples of coarse tailings and ore were collected from Test Pits TTP-1, TTP-2 and TTP-4, located along the west, southeast and north perimeters, respectively, of the tailings area. The locations of the six test pits completed in 1992 are shown on Sheet 2 of 10 of the 1992 Reclamation Plan.

Table 2 presents the laboratory results for each of the three composite samples of fine tailings and the mean averages for these data which were used for radon attenuation modeling. Although the three test pits are located 600 to 1,000 feet apart, the collected samples from each pit exhibited similar results for each parameter tested. The uniformity of the results is evident by the low standard deviation for each parameter compared to its mean value.

The only result not exhibiting uniformity was the radon diffusion value of 2.0×10^{-6} square centimeters per second reported for the sample from Test Pit TTP-5. This value was much smaller than values reported for the other two samples and is probably related to laboratory error in the degree of moisture saturation. As discussed on page 3-5 of "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design" (NUREG/CR-3533), small errors in moisture saturation will result in large apparent errors in the measured diffusion coefficient for samples close to saturation. The radon diffusion coefficient from this sample was not used in calculating the mean average for this parameter Excluding this value is consistent with conservative engineering design because a low diffusion coefficient in the source material requires less soil cover than a material with a high diffusion coefficient.

Table 3 presents the laboratory results from each of the three composite samples of coarse tailings and ore cover material and the mean averages for theses data which were used for radon attenuation modeling. These data represent locations which are up to 2,000 feet apart, yet the results are also very uniform with low standard deviations for all parameters including the radium activity level for coarse tailings.

As shown in Table 2, the radium activity level for the coarse tailings ranged between 193.8 picoCuries per gram (pCi/g) and 278.6 with a standard deviation of only

43.2 pCi/g. The mean activity level of 241 pCi/g is also consistent with coarse tailings activity levels reported at other tailings facilities (e.g., 303 pCi/g at Western Nuclear's Split Rock facility and 154 pCi/g at United Nuclear's Church Rock facility).

The only other radioactive material included in the reclamation design is the affected soil in the vicinity of the mill. This soil will be used as the initial cover over the tailings material because it has radium activity levels an order of magnitude less than those observed in the ore and coarse tailings. Because the affected soil's principal purpose is as a cover material, the sampling and testing program was based on the collection and analyses of composite samples from the affected material exhibiting the coarsest grain size. Using this coarse fraction to represent all of the affected material is consistent with conservative engineering design because the coarse material has the highest diffusion coefficient, which will result in an underestimation of the radon that will be attenuated by the affected soil cover. Additional details of the sample selection for affected soils are provided in Attachment C of Appendix B of the 1992 Reclamation Plan on pages B-99 through B-111.

Ore Grade Calculations

Several guidance documents were consulted to determine if statistical methods existed to determine the number of composite samples needed to adequately characterize a relatively homogenous waste such as the Atlas tailings. These manuals included the draft "Manual for Conducting Radiological Surveys in Support of License Termination (NUREG/CR-5849)" provided by the NRC and the U.S Environmental Protection Agency document "Test Methods for Evaluating Solid Waste." Both of these manuals provide statistical methods for characterization and cleanup of hot-spot type contamination requiring comparison of sample results to a "guideline value" or "regulatory threshold." While these methods can be applied to the remediation control survey conducted during cleanup of contaminated areas or the final status survey conducted after cleanup is complete, they are not appropriate for characterizing a homogenous waste for soil cover design purposes.

The document, "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design" (NUREG/CR-3533) does, however, provide a second methodology for determining the radium concentration of the tailings based on the ore grade processed by the mill. Comparison of the tailings radium concentration calculated by this method with the sampling results allows for verification of the sampling results. The ore grade methodology is conservative because it assumes that all of the radium-226 originally present in the ore was deposited in the tailings. Given this assumption, the radium concentration of the tailings is calculated using equation 18 of the handbook as shown below.

Radium Concentration (based on ore grade) =

[Ore Grade (wt% U-308)] x [2,812 (Ra-226) per gram soil/(wt% U-308)] =

0.228 x 2,812 pCi/g = 641 pCi/g

The analytical results obtained from the sampling of coarse and fine tailings can also be used to calculate an average radium concentration for the tailings as shown below.

Radium Concentration (based on sampling results) =

[Mean Fine Tailings Radium Conc. (pCi/g) x Proportion of Fine Tailings] +

[Mean Coarse Tailings Radium Conc. (pCi/g) x Proportion of Coarse Tailings] =

[1,275 pCi/g x .32] + [241 pCi/g x .68] = 572 pCi/g

The calculated upper bound value for the average radium concentration of the tailings area of 641 pCi/g is only 12 percent higher than the 572 pCi/g concentration calculated from the analytical results. This close correlation between processed ore grades and sample results indicates that the sample results accurately represent the radium concentrations for the tailings.

Additional sampling of the tailings may change the average concentration slightly. Such a change would, however, have a negligible effect on the design of the tailings cover. For example, if the radium concentrations for the fine and coarse tailings are increased by 12 percent to correspond with the ore grade calculation, the average thickness of the sandy soil cover over the six-inch Mancos layer will increase by only 2.5 inches, from 6.0 inches to 8.5 inches. Because the soil cover design is not very sensitive to small changes in radium concentrations, no additional sampling of tailings material is recommended.

Comment

2. Your reclamation plan does not establish a background concentration value of Ra-226 in soil. This value is necessary to estimate the amount of material that will be placed in the disposal area and the associated activity of that material. The background activity of 5.5 pCi/g referenced in License Condition No. 39 (B) was authorized in conjunction with cleanup activities of a small, isolated area. This value may not be appropriate for cleanup throughout the site area.

   Accordingly, provide the background Ra-226 concentration for soil at your site that was used for design purposes and your basis for that value for our review and approval. If the background concentration cannot be substantiated, revise your reclamation plan as necessary and submit it for review and approval.

Response

General Response

The methods used in the reclamation plan to estimate the amount of affected material do not rely on the existing background concentration value for Ra-226, but rather are based on a qualitative comparison between background and contaminated levels. These methods provide an approximate volume of affected materials which is adequate for engineering design and cost estimating purposes. Conducting additional radiological surveys at this time will not provide any more definitive results regarding the volume of affected material, because most of the affected material is believed to be directly below the mill where sampling and analysis is precluded by the existing structures and foundations.

The validity of the existing background standard will become much more important during actual reclamation when delineation and excavation of the affected soils will be based on threshold gamma radiation levels. These threshold values will be established in accordance with NRC regulations at 5.0 pCi/g above the background radium concentration in the first 15 centimeters (cm) of soil and 15 pCi/g above background for any 15 cm layer of soil below the first 15 cm. To address NRC's concerns regarding the currently established background level, Atlas proposes to conduct a second background radiological survey prior to the implementation of the reclamation plan. The results of this survey will be used to establish threshold gamma radiation levels for excavation of affected soils and will be submitted to the NRC for review and approval.

Additional details regarding the estimate of affected soils and the use of this estimate in the engineering design are provided below.

Affected Soil Estimate

The estimate of affected material to be excavated and placed in the disposal area included 200,000 cy of contaminated soil in the mill area and 25,000 cy of contaminated soil located southeast of the tailings impoundment. Additional amounts of windblown tailings are also expected to be excavated on the north and west sides of the tailings impoundment. Because most of this windblown material was removed in earlier cleanup efforts, the estimated quantity of this material was not included in the reclamation design calculations.

The 200,000 cy mill area estimate is based on 45 borings completed in the mill area in 1987 by Dames and Moore. These borings extended to depths of approximately 10 feet and were completed with 1.5-inch PVC pipe. Gamma log surveys conducted in the bore holes typically showed elevated gamma levels near the surface with levels dropping and stabilizing at depth. The depth at which gamma levels first stabilized in a boring was considered the depth of contamination. Copies of the gamma log surveys are provided in Appendix C and the inferred depths of contamination are summarized in Table 4.

Dames and Moore grouped these borings into areas based on the depth of contamination and assigned representative contamination depths to each area. Appendix A provides the Dames and Moore figure showing the location of the borings and the delineated areas. An estimate of the volume of affected material was then calculated by multiplying each area by its depth of contamination. No borings were completed in the area adjacent to the Colorado River because only minimal contamination was anticipated in this area. A six-inch depth of contamination was assumed for this area when calculating the volume of affected material to be excavated.

The Dames and Moore estimate relied on a qualitative comparison of contaminated soil gamma levels to background levels. The estimate of affected material in the mill area is considered conservative because NRC does not require excavation of soil to background levels, but rather to threshold levels set at a prescribed level above background. However, the Dames and Moore estimate may have underestimated the volume of affected material in the immediate vicinity of the mill because cement pads and foundations precluded drilling in many of these areas.

The 25,000 cy estimate for contaminated soils southeast of the tailings impoundment was developed by EnecoTech, Inc. with the results presented in their report "Evaluation of Southeast Area, Atlas - Moab Mill Facility" dated June 30, 1987. The volume of contamination was based on soil sampling for uranium and radium-226 on a grid system. Review of the maps generated from this sampling effort reveal that the contamination is limited to a small area, approximately 1500 feet long by 400 feet wide and that activity levels for radium-226 decrease rapidly to less than the site's background standard in the surrounding areas. Because the contamination is very localized, it appears unlikely that an adjustment in the background standard will result in a significant change in the volume of affected material to be excavated.

The third area containing affected soils is the area west and north of the tailings impoundment where windblown tailings accumulated. The majority of this area was cleaned up by Atlas in 1987 with the excavated soils being placed within the tailings impoundment. Some additional cleanup is anticipated during final reclamation, but the volumes of remaining affected soil to be excavated are believed to be small compared to those present in the mill area.

Affected Soil Cover Design

As discussed in the reclamation plan, the affected soils have radium concentrations that are an order of magnitude lower than the coarse tailings and ore and almost two orders of magnitude less than the fine tailings. Therefore, the affected soil can be used effectively as the initial cover over the tailings area. The reclamation design stipulates that a minimum of 16 inches of affected material be placed over the tailings area. This 16-inch depth is equivalent to approximately 200,000 cy of soil.

The use of a minimum of 16 inches of affected soil in the design and in the design model is conservative because the current estimate of 225,000 cy of affected soil in the mill area and in the southeast area would produce a cover thickness in excess of 18 inches. Affected soil is also expected to be generated from the cleanup of windblown tailings north and west of the tailings impoundment which would further increase the thickness of the affected soil cover.

In summary, if the volume of affected soil excavated during reclamation exceeds 200,000 cy, the affected soil cover will be greater than 16 inches thick resulting in additional radon attenuation. In the unlikely event that the affected soil excavated is less than 200,000 cy, the affected soil will be augmented with clean soil to achieve the minimum 16-inch thick soil cover stipulated in the design.

Comment

3. The estimated long-term moisture contents of the proposed clay material and of the fine tailings are not considered acceptable. The estimated values for these materials were based on the results from capillary moisture testing in accordance with recommendations in NRC Regulatory Guide 3.64 (RG 3.64), "Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers." It appears that the test procedure does not accommodate soils with large fractions of fines and may overestimate a long-term moisture. The

purpose of the capillary moisture test procedure is to establish a moisture content - moisture tension relationship for soils or, metric potential to water content. It was developed by the agricultural engineering disciplines to define soil/plant interactions, not to estimate a long-term moisture content in modeling the radon flux from a contaminated source. Accordingly, the results from this test should not automatically be applied in the modeling process and should only be used after evaluating the results with other available means of estimating the long-term moisture content.

The proposed long-term moisture content for the fine tailings was 30.9 percent. The in place moisture content you reported for the fine tailings was 27.7 percent. The average initial moisture content reported for the three capillary moisture relationship specimens was 27.5 percent; and the average calculated 100 percent saturation value was 35.0 percent the resulting moisture of 30.9 percent under -15 bar pressure indicates that the test procedure and/or test results may not be appropriate for consideration for fine grained materials.

For the clay material, the proposed long-term moisture content resulting from the capillary moisture test was 16.2 percent (average of three); but the average optimum moisture for this material was 15.1 percent. As indicated above, there is some question as to the validity of applying results from this test procedure.

For the clay material, you have supported the use of the capillary moisture test results because the specifications require that the radon barrier material be placed 2 to 5 percent greater than optimum moisture, making the projected minimum placement moisture approximately 17.1 percent. This argument is not considered valid. There is no basis to expect a soil to retain a moisture content above optimum over the 1000-year design life in a semi-arid climate. Evapotranspiration greatly exceeds precipitation at the Moab site. Even though the material will be insulated to some extent by the erosion protection layers and the sandy soil portion of the radon barrier, the assumption that the long-term moisture content will be above optimum over the design life is not realistic nor conservative.

It is our position, based on the information that you have currently submitted, that acceptable estimates of the long-term moisture content for the fine tailings and the clay material are 20 percent and 10 percent by weight, respectively. Therefore, modify the long-term moisture contents and associated parameters in the model for the clay and fine tailings, or substantiate that your proposed values will provide reasonable assurance that the radon flux criteria will not be exceeded during the project design life.

<u>Response</u>

General Response

The comment regarding long-term moisture contents is similar to NRC's comment in the previous review of the 1992 Reclamation Plan which was addressed by Atlas under Response No. 14 of the April 1993 Response to NRC Comments. A compromise was reached on this issue with Atlas agreeing to increase the sandy soil layer of the radon barrier to one foot over the coarse tailings and two feet over the fine tailings. This modification to the plan provides an ample safety factor in the cover design because the added soil cover will further insulate the clay cover from the effects of evapotranspiration as well as providing additional attenuation capacity.

The moisture contents proposed by NRC appear to be set arbitrarily low and are not technically justified for either the encapsulated tailings material found at the site or for the compacted clay cover. The use of these moisture contents for attenuation modeling would result in a substantial change in the calculated diffusion coefficient for both the fine tailings and clay material. This in turn would result in an unnecessarily high soil thickness for the engineered cover. According to information provided by NRC during the June 21, 1993, meeting with Atlas, the proposed NRC clay moisture content of 10 percent was developed from an empirical equation for in-situ soils present in uranium mining regions of the western United States. The use of such an equation to characterize an engineered soil cover ignores the following mechanisms which result in increased moisture contents for an engineered soil cover compared to natural undisturbed soils:

1. Water is added to the clay during placement and compaction to increase the moisture content to slightly above optimum, thereby providing the best degree of compaction. The compaction process also causes a higher degree of saturation due to reduced porosity.

2. The water is held in the clay after placement and compaction by capillary tension, which is much higher in fine-grained soils such as the Mancos Shale clay.

3. The clay cover is protected from the effects of evapotranspiration by the overlying sandy soil cover and the erosion protection layer. The sandy soil cover and erosion protection layer have relatively large pore diameters indicating that they have low potential for capillary action (i.e., low potential to draw water away from the clay layer).

4. The erosion protection layer consists of a soil-rock matrix which, because of its coarse nature, will intercept runoff and channel it downward to the clay cover. This mechanism will help to maintain the long-term moisture content in the clay cover.

The use of the 15-bar permanent wilting point test to approximate long-term moisture content in the tailings and soil cover is one of the methods that NRC has accepted as providing conservative results. In fact, the NRC Regulatory Guide 3.64 (RG 3.64) states unequivocally that "The NRC staff will accept the moisture content at which permanent wilting occurs as a reasonable value of the long-term moisture content." The Mancos Shale clay is ideally suited for use in an engineered clay cover because it has a relatively high 15-bar moisture content. To arbitrarily assume an extremely low moisture content for this material to compensate for what appears to be too high a 15-bar moisture content is overly conservative and not representative of an engineering designed cover.

Atlas recommends that the previously agreed-upon solution of increasing the design thickness of the sandy soil cover to minimize moisture loss in the clay layer be implemented. This type of design provides an additional safety factor for radon attenuation without unfairly penalizing a cover material for having excellent moisture retention characteristics. Alternately, Atlas is agreeable to reducing the moisture contents for the fine tailings and clay in the radon attenuation model by approximately 10 percent to provide additional confidence in the design.

Comment

4. Because of the previous requests for information, it will be necessary to revise the design of radon barrier thickness and submit it for review and approval. The expected performance of the revised barrier over the design life should be included in the evaluation. For example, this should include such things as the potential for cracking and freeze-thaw effects.

Response

Responses to Comments 1 and 2 above do not propose any change in the design of radon barrier thickness. Regarding Comment 3, Atlas is agreeable to modifying the reclamation plan to increase the sandy soil cover to one foot over the coarse tailings and two feet over the fine tailings consistent with Condition 41.A of the 1993 draft license. This modification will provide for additional moisture retention in the underlying compacted clay cover and is shown on the attached revised Sheet 5 of 10 of the reclamation plan, "Reclaimed Impoundment Cross Sections and Soil Cover Details."

As discussed in the 1992 reclamation plan, the potential for frost heaving is low because the material below the cover material is relatively free draining and will not support the capillary action required for frost heaving to occur. The additional 6 to 18 inches of sandy soil cover will not change this characteristic of the reclamation design. The additional cover will enhance the stability of long-term moisture content in the underlying clay cover layer by isolating the clay further from the ambient climate and attendant drying. This will reduce the possibility for shrinkage in the soil cover.

At the present time, Atlas is in the process of placing an interim cover over the tailings area as required by the NRC. It is anticipated that all but approximately 10 to 15 acres of the tailings area will be covered this spring with the remainder to be completed after the central area of the tailings dries up and consolidates sufficiently to allow placement of the interim cover. The interim cover consists of low-grade ore and affected soils and has averaged approximately 18 inches in thickness over the coarse tailings and 36 inches over the fine tailings. The affected soils used for the interim cover were excavated from the southwest portion of the mill area based on visual evidence of contamination. The excavated depths have, to date, either equaled or exceeded the projected depths of affected soils used for reclamation planning purposes.

Use of affected soils as the interim cover over the fine tailings is not included in the reclamation plan or in the evaluation of the attenuation capacity of the reclamation cover. The placement of this layer of affected soil directly over the fine tailings adds additional conservatism to the cover design because this material has low radioactivity compared to the fine tailings and provides increased radon attenuation capacity.

Atlas will prepare as-built drawings of the tailings area after the interim cover is completed. At that time, Atlas may elect to amend the reclamation plan to minimize re-excavation of the interim cover during reclamation. This modification of the reclamation plan would minimize exposure of the tailings material during final reclamation plus provide cost savings by eliminating some rehandling of the interim cover. Any amendment to the reclamation plan would be developed using the same engineering parameters and methods used in the current reclamation plan as approved by the NRC.

REFERENCES

REFERENCES

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., Bender, B.L., 1990, "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico", Miscellaneous Field Studies Map MF-2120, Department of the Interior, U.S. Geological Survey.

Canonie Environmental Services Corp., 1992, "Atlas Corporation Reclamation Plan Uranium Mill and Tailings Disposal Area, Moab, Utah", prepared for Atlas Corporation, June.

Carpenter, J.R., 1986, "STABL5/PCSTABL5 User's Manual, Indiana Department of Highways Joint Highway Research Project, JHRP-86/14.

Dames and Moore, 1987, "Revised Cost Estimate of Reclamation Plan, Mill Decommissioning, and Tailings Pile Reclamation, Atlas Minerals, Moab Uranium Mill".

Department of Energy, 1989, "Remedial Action Plan and Final Design for Stabilization of the Inactive Uranium Mill Tailings at Green River, Utah, Final", Vol. I, II and III, January, UMTRA-DOE/AL 050510.GRNO.

EnecoTech, Inc., 1987, "Evaluation of Southeast Area - Moab Mill Facility".

Hunt, G., 1994, Utah Oil and Gas Division, Personal Communication, January 4.

Low, M., 1993, Utah Geological Survey, Personal Communication, November 5.

Mathews, F., 1994, Utah Oil and Gas Division, Personal Communication, January 18.

Morgan, C.D., 1992a, "Cane Creek Exploration Play Area, Emery, Grand, and San Juan Counties", Utah Geological Survey, Open-File Report 232, March.

Morgan, C.D., 1992b, "Horizontal Drilling Potential of the Cane Creek Shale, Paradox Formation, Utah", Geological Studies Relevant to Horizontal Drilling in Western North America, Rocky Mountain Association of Geologists.

REFERENCES
(Continued)

Morgan, C.D., 1993, "Horizontal Drilling Technology Re-opens Old Play", Survey Notes, Utah Geological Survey.

U.S. Environmental Protection Agency, 1986, "Test Methods for Evaluating Solid Waste", Washington, D.C.

U.S. Nuclear Regulatory Commission, NUREG/CR-3533, 1984, "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design", Washington, D.C., NRC FIN No. B2269.

U.S. Nuclear Regulatory Commission, 1988, "Calculation of Radon Flux Attenuation by Earthen Mill Tailings Covers", Regulatory Guide 3.64.

U.S. Nuclear Regulatory Commission, NUREG/CR-5849, 1992, "Manual for Conducting Radiological Surveys in Support of License Termination", Draft Report for Comment, Washington, D.C., NRC FIN L1569.

TABLES

TABLE 1

SUMMARY OF ORE PROCESSED
ATLAS MILL
1978 THROUGH 1984

Year	Acid Plant		Alkaline Plant		Combined	
	Tons	Grade	Tons	Grade	Tons	Grade
1978	229,079	.181	152,432	.131	381,511	.161
1979	250,753	.169	181,859	.139	432,612	.157
1980	275,918	.256	172,993	.139	448,911	.211
1981	267,835	.326	139,232	.170	407,067	.273
1982	164,337	.396	2,021	.212	166,358	.394
1983	171,936	.313	----	---	171,936	.313
1984	39,899	.298	----	---	39,899	.298
TOTAL	1,399,757	.266	648,537	.144	2,048,294	.228

Notes:

1. Data obtained from the daily plant summaries.
2. The alkaline circuit did not operate after January 1982.
3. Grade is shown as weight-percent U-308.

TABLE 2

DATA USED TO DETERMINE FINE TAILINGS PARAMETERS FOR RADON ATTENUATION MODELING (a)

Material	Sample I.D.	Radium Concentration (pCi/g)	Radon Emanation Coefficient	Radon Diffusion Coefficient (cm^2/s)	Specific Gravity	Dry Density (g/cm^3)
Fine Tailings	TTP-3/Comfine-192	1,094 ± 3	0.36 ± 0.1	1.3E-4	2.97	1.32
	TTP-5/Comfine-292	1,270 ± 3	0.32 ± .01	2.0E-6(c)	2.84	1.28
	TTP-6/Comfine-392	1,461 ±4	0.36 ± .01	4.0E-4	2.92	1.13
	Mean	1,275.0	0.35	2.65E-04	2.91	1.24(b)
	Standard Deviation	184	0.02	NA	0.07	0.10

Notes:

(a) The data listed are from Rogers & Associates Engineering Corp. lab reports for composite samples dated 3/5/92 and 3/31/92 except for dry density which are from Lincoln DeVore, Inc.'s lab report for split-spoon samples dated 1/20/92.

(b) The dry density for fine tailings was adjusted to 89.8 lb/ft^3 (1.44 g/cm^3) to account for overburden stress during placement of the cover. Refer to Appendix B of the June 1992 reclamation plan.

(c) This value was not used in calculating the mean value because it was not consistent with the data reported for the other two samples.

TABLE 3

DATA USED TO DETERMINE COARSE TAILINGS AND ORE PARAMETERS FOR RADON ATTENUATION MODELING (a)

Material	Sample I.D.	Radium Activity Level (pCi/g)	Radon Emanation Coefficient	Radon Diffusion Coefficient (cm^2/s)	Specific Gravity	Dry Density (g/cm^3)
Coarse Tailings	TTP-1/Comcoarse-192	250.6 ± 1.3	0.28 ± .01	2.3E-02	2.72	1.54
	TTP-2/Comcoarse-292	278.6 ± 1.4	0.20 ± .01	2.8E-02	2.72	1.48
	TTP-4/Comcoarse-392	193.8 ± 1.2	0.22 ± .01	2.3E-02	2.69	1.58
	Mean	241.0	0.23	2.47E-02	2.71	1.53
	Standard Deviation	43.2	0.04	0.29E-02	0.02	0.05
Ore	TTP-1/Comore-192	180.4 ± 1.1	0.25 ± .01	8.8E-03	2.70	1.59
	TTP-2,4/Comore-292	250.1 ± 1.3	0.32 ± .01	8.8E-03	2.70	1.73
	TTP-2,4/Comore-392	207.7 ± 1.1	0.28 ± .01	7.3E-03	2.71	1.83
	Mean	212.7	0.28	8.3E-03	2.70	1.72
	Standard Deviation	35.1	0.04	0.9E-03	0.01	0.12

Note:
(a) The data listed are from Rogers & Associates Engineering Corp. lab reports for composite samples dated 3/5/92 and 3/31/92 except for dry density which are from Lincoln DeVore, Inc.'s lab report for split-spoon samples dated 1/20/92.

TABLE 4

SUMMARY OF JULY 1987
GAMMA SURVEY RESULTS
ATLAS MILL SITE
MOAB, UTAH

Borehole No.	Estimated Depth of Contamination (Feet)	Borehole No.	Estimated Depth of Contamination (Feet)
1	7.5	24	0.0
2	0.0	25	6.5
3	7.5	26	0.0
4	5.0	27	7.5 +
5	7.5	28	0.0
6	7.5	29	4.0
7	0.0	30	3.0
8	8.0	31	0.0
9	6.0 +	32	6.5
10	8.5 +	33	6.0
11	0.0	34	6.0
12	0.0	35	0.0
13	0.0	36	7.0
14	0.0	37	0.0
15	0.0	38	---
16	8.0	39	0.0
17	8.5	40	7.5
18	0.0	41	5.0
19	8.0	42	3.0
20	7.5	43	3.5
21	4.5	44	6.5
22	0.0	45	6.0
23	0.0		

FIGURES

APPENDIX A

STABILITY ANALYSIS
RECLAIMED TAILINGS EMBANKMENT
CALCULATION BRIEF

Slope Stability
Reclaimed Impoundment
ATLAS
88-067-11

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Canonie Environmental
By JWS Date 11/12/93 Subject Stability Analysis-Reclaimed Sheet 1 of 59
Chkd By PEC Date 1-4-94 Tailings Impoundment ATLAS Proj No 88-067-11

Purpose. The purpose of this calculation brief is to verify the stability of the Atlas Minerals Reclaimed Tailings Impoundment design presented in the Reclamation Plan (Canonie, June 1992 and April 1993). Figure 1 (sheet 11) shows the location of the existing tailings pile near Moab, Utah. The stability of the reclaimed impoundment will be analyzed under seismic conditions with (short term) and without (long term) a phreatic surface in the Tailings Pile.

Methodology. The computer program PCSTABL5 (Carpenter, 1985) is used to determine the critical failure surfaces and corresponding factor of safety (FOS) against instability. The stability computation methods used in PCSTABL5 are the simplified Janbu, the Simplified Bishop, and the Spencer's method of slices. The Simplified Bishop method is used in this analysis.

Critical Cross Section

The most critical location for stability is on the southeast side of the impoundment as shown on the plan view of the impoundment in Figure 2 (sheet 12). The southeast as well as the northeast embankment slopes are the steepest slopes and longest slopes on the Reclaimed Impoundment. However, the southeast slope is selected as being more critical because the existing ground elevation is lower and slopes slightly downward toward the Colorado River and away from the 10:3 embankment.

Figure 3 presents a generalized cross section of the impoundment and existing ground corresponding to the location shown on Figure 2. For purposes of modelling the impoundment with PCSTABL5, the cross section has been divided into four soil types: the natural soil beneath the tailings pile, the coarse tailings, the sandy soil along the embankment and top of the impoundment, and the cover material (consisting of ore, affected soil, and clay) on top of the coarse tailings.

The erosion protection layer is not simulated as a separate soil type in the stability analysis. However, the weight of the erosion protection layer is accounted for by applying a surcharge load on the 10:3 embankment and on top of the impoundment. According to the Atlas Reclamation Plan (Canonie, 1992), an 8" riprap layer is along the 10:3 embankment and a 6" soil rock matrix layer is on top of the impoundment. Using a specific gravity of the riprap is 2.47 (specified in Atlas Reclamation Plan), and assuming a porosity of 40%, the bulk unit weight of the riprap is:

$$2.47 \times 62.4 \times (1-0.4) = 92.5 \text{ pcf}$$

For an 8", riprap layer, the surcharge load is:

$$92.5 \text{ pcf} \times 8" \times 1 \text{ ft}/12" = \underline{61.7 \text{ psf}}$$

Conservatively assuming the same bulk unit weight for the soil rock matrix, the corresponding surcharge load is:

$$92.5 \text{ pcf} \times 6" \times 1 \text{ ft}/12" = \underline{46.3 \text{ psf}}$$

The individual 6" layer of clay, 16" layer of affected soil, and 6" layer of ore placed on top of the coarse tailings are not modeled as separate layers but rather as a single layer. Soil properties required by PCSTABL5 for this layer are determined as an average weighted by thickness. Soil properties are discussed further below.

Stability Scenarios

The following stability scenarios are analyzed by the PCSTABL5 model:

1) Long term - Critical circular failure surface with a 250 year earthquake return period loading and without phreatic surface in the coarse tailings.

2) Short term - Critical circular failure surface with a 250 year earthquake return period loading and with phreatic surface in the coarse tailings.

3) Critical circular failure surface with earthquake loading corresponding to the Maximum Credible Earthquake (MCE) for Colorado Plateau without phreatic surface in coarse tailings.

4) Critical circular failure surface with earthquake loading corresponding to the MCE for Colorado Plateau with phreatic surface in coarse tailings.

5) Trial failure surface between sand and tailings on embankment with earthquake loading corresponding to the MCE for Colorado Plateau with phreatic surface in coarse tailings.

6) Same conditions as Scenario 1 but maximum earthquake loading under which the reclaimed impoundment is stable will be determined.

7) Same conditions as Scenario 2 but maximum earthquake loading under which the reclaimed impoundment is stable will be determined.

For the circular failure surfaces, PCSTABL5 randomly searches for the most critical failure surface. For the trial failure surface in scenario 5, PCSTABL5 calculates a FOS for a user defined surface.

Earthquake Loads

To simulate earthquake loads, the PCSTABL5 model requires horizontal and vertical earthquake accelerations. The largest return period for which horizontal earthquake acceleration maps are available is 250 years. Figure 4 (sheet 14) is the most current map showing the mean horizontal earthquake acceleration which has a 90% probability of nonexceedance. For Moab, Utah the 250 year horizontal acceleration is approximately 0.05g (g is acceleration due to gravity) (The 0.05g value was confirmed by Utah Geological Survey Personnel - see Phone memo in Attachment A). For vertical earthquake acceleration, a conservative estimate of 0.05g is assumed

The reclaimed impoundment design life is a minimum of 1000 years (i.e. greater than the 250 year return period) and potentially during this period an earthquake of larger magnitude could occur. In correspondence with Joel Grimm, Project Manager with the Nuclear Regulatory Commission on 12/28/93, the Maximum Credible Earthquake used for a nearby Green River Title 1 site was 6.2 on the Richter scale corresponding to a horizontal earthquake acceleration of 0.21g. This value is used for scenarios 3, 4, and 5 along with a vertical earthquake acceleration of 0.05g. The purpose of scenarios 6 and 7 is to account for an earthquake of greater magnitude than the 250 year earthquake during the design life of the reclaimed impoundment. Under these scenarios, the maximum horizontal earthquake acceleration under which the reclaimed impoundment is stable will be determined.

Phreatic Surface

Dewatering of the existing tailings pile is currently on going. In the event that water is present in the tailings, a phreatic surface is assumed for scenarios 2, 4, 5, and 7 as a short term condition. The phreatic surface is assumed based on current water level information readings in piezometers at the tailings pile. Attachment B contains piezometer coordinates and the most current water level information. From the information in Attachment B, water levels in the piezometers have been transferred to Figure 2 and using the piezometers nearest the critical cross section, the phreatic surface is extrapolated on to Figure 3.

Soil Properties

Table 1 provides the soil properties used in the stability analysis. The derivation and reference for the soil properties are included with Table 1. Attachment C contains excerpts from the references listed in Table 1 from which soil properties were determined.

PCSTABL5 Input and Output.

The PCSTABL5 input files are included in Attachment D. Output files are provided in Attachment E. Boundary numbers and soil type numbers assigned are shown on Figure 3. Initiation and termination points of circular failure surfaces were adjusted until the minimum FOS was determined.

RESULTS. The factor of safety for the critical cross section for each of the scenarios discussed above are provided on Table 1 (sheet 8 of 59). The circular failure surfaces have been sketched on Figure 1. The factor of safety are greater than 1 for scenarios 1 through 5. For the worst case scenarios 6 and 7, the impoundment could withstand an earthquake with a horizontal earthquake acceleration of 0.25g (400 % larger than the 250 year earthquake loading predicted for Moab, Utah and 19% larger than the MCE loading)

References

Algermissen S.T., Perkins D.M., Thenhaus P.C., Hanson S.L., Bender, B.L., 1990, "Probabilistic Earthquake Acceleration And Velocity Maps for the United States and Puerto Rico", Miscellaneous Field Studies Map MF-2120, Department of the Interior, U.S. Geological Survey

Canonie, April 1993, Response to NRC comments Atlas Corporation Reclamation Plan Uranium Mill And Disposal Area

Canonie, June 1992, Atlas Corporation Reclamation Plan Uranium Mill And Disposal Area

Carpenter, J. R. "STABL5/PCSTABL5 User's Manual, 1986, Indiana Department of Highways Joint Highway Research Project JHRP-86/14

Dames and Moore, 1975 "Safety Analysis Report", Atlas Minerals Division, Atlas Corporation, Moab Uranium Mill

Das, Braja M. "Principles of Geotechnical Engineering", 1984

Grimm, Joel, Project Manager with the NRC, personal communication with Canonie Personnel on 12/28/93.

Tables

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Table 1

Factor of Safety Results · ATLAS Reclaimed Impoundment

Scenario	Failure Surface	Minimum FOS	Horizontal Earthquake Acceleration
1. Dewatered Tailings	Circular	1.6	0.05g
2. Partially Saturated Tailings.	Circular	1.6	0.05g
3. Dewatered Tailings	Circular	1.1	0.21g
4. Partially Saturated Tailings.	Circular	1.1	0.21g
5. Partially Saturated Tailings with Failure Surface Between sand and tailings on embankment.	Trial	1.4	0.21g
6. Dewatered Tailings	Circular	1.0	0.25g
7. Partially Saturated Tailings	Circular	1.0	0.25g

1-4-94

TABLE 2

SOIL PROPERTIES - ATLAS MILL SITE STABILITY ANALYSIS

Material	Porosity	Long Term Moisture (%)	Specific Gravity	Density (pcf)			Cohesion (psf)	Angle of Internal Friciton (deg)
				Dry	Moist	Saturated		
NATURAL SOILS					125	125	50	38
CLEAN SAND	0.3368	2.8	2.70	112	115	133	0	30
COVER MATERIAL	0.3302	7	2.73	114	122	135	0	30
COARSE TAILINGS	0.4350	4.4	2.71	96	100	123	0	37

Notes

1) NATURAL SOIL PROPERTIES

- Properties taken from Dames and Moore (1977) - see Attachment C for excerpt.
- Natural soils are granular (sand and gravels, silts) and are within range of properties presented below for granular soils.

2) CLEAN SAND PROPERTIES

Clean sand and Affected Sand angle of internal friction assumed as 30 deg. based on typical value for sands.
Values of angle of internal friction for sands from several sources are presented below:

Source	Angle of Internal Friction
Bowels (1988)	32 - 34 deg. (average value for sands)
Das (1985)	27 to 45 deg.(Drained angle for Sands)
Terzaghi, Peck, and Skempton	30 to 40 deg. (SC and SM soil types)
Pile Buck Inc. (1987)	28 to 41 deg. (loose to dense granular soils)

- Attachment C contains excerpts from these sources.

- Porosity, long term moisture, and specific gravity of Clean Sand based on geotechnical testing performed on three representative samples from Clean Moab Wash Soils. Results are reported in ATLAS Reclamation Plan (Canonie, 1992) - See Attachment C for excerpts.

- Zero cohesion in sand is assumed.

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TABLE 2

SOIL PROPERTIES - ATLAS MILL SITE STABILITY ANALYSIS

- Moist density = Dry Density (1 + moisture content)
  From Pile Buck Inc. (1987) moist density for granular soil ranges from 95 to 140 pcf.
- Saturated Density = [(1-n)Gs + n] x Density of Water (62.4 pcf)
  From Pile Buck Inc. (1987) moist density for granular soil ranges from 120 to 150 pcf.

4) COARSE TAILINGS PROPERTIES

- Properties based on geotechnical testing performed on three representative samples from Coarse Tailings. Results are reported in ATLAS Reclamation Plan (Canonie, 1992) - See Attachment C for excerpts.

5) COVER MATERIAL PROPERTIES

Cover material consist of a 6" clay layer, 16" affected sandy soil layer, and a 6" ore layer. Properties of each layer are averaged (thickness weighted) together to provided properties for on e composite layer. Properties for each are summarized below for each individual layer. Properties are from Canonie (1992) - See attachment C for excerpts.

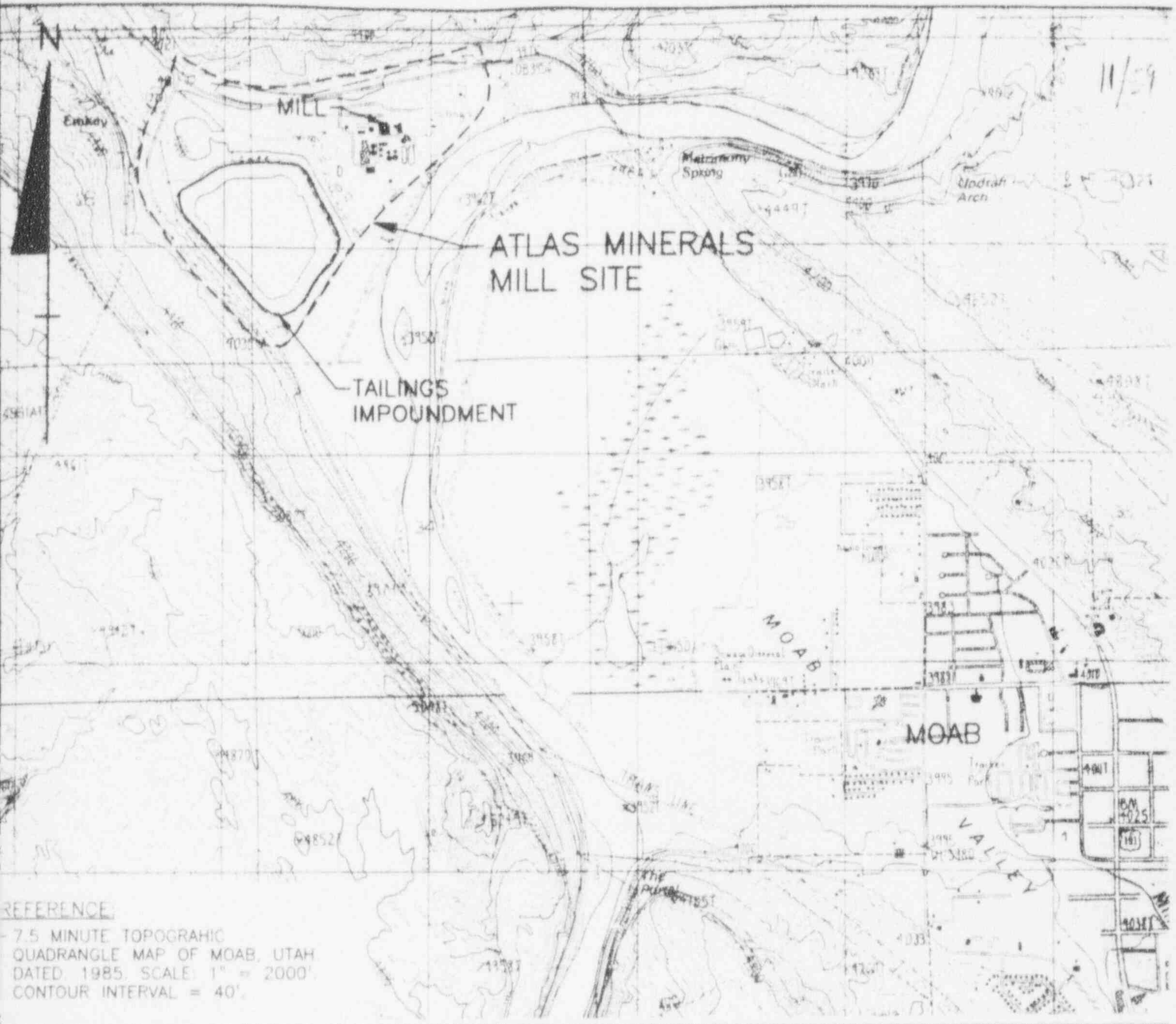
Material	Thickness (in)	Porosity	Long Term Moisture (%)	Specific Gravity	Dry Density (pcf)
Clay	6	0.3897	16.2	2.80	106.7
Affected Soil	16	0.2954	2.8	2.72	119.2
Ore	6	0.3637	9.0	2.70	107.3
-Weighted Avg. =		0.3302	7.0	2.73	114.0

- Zero Cohesion for the cover material is conservatively assumed. An angle of internal friction of 30 deg. is assumed for the cover material based on typical literature values for sands and clays (see Attachment C) .

Canonie Environmental
By JWS Date 11/12/93 Subject Stability Analysis-Reclaimed Sheet 11a of 59
Chkd By pcl Date 1-4-94 Tailings Impoundment ATLAS Proj No 88-067-11

Figures

11/59



REFERENCE:
- 7.5 MINUTE TOPOGRAHIC QUADRANGLE MAP OF MOAB, UTAH DATED 1985. SCALE: 1" = 2000' CONTOUR INTERVAL = 40'.

Chkd by PEC 1-4-94

FIGURE 1. VICINITY MAP

SCALE

2000 0 2000 4000 FEET

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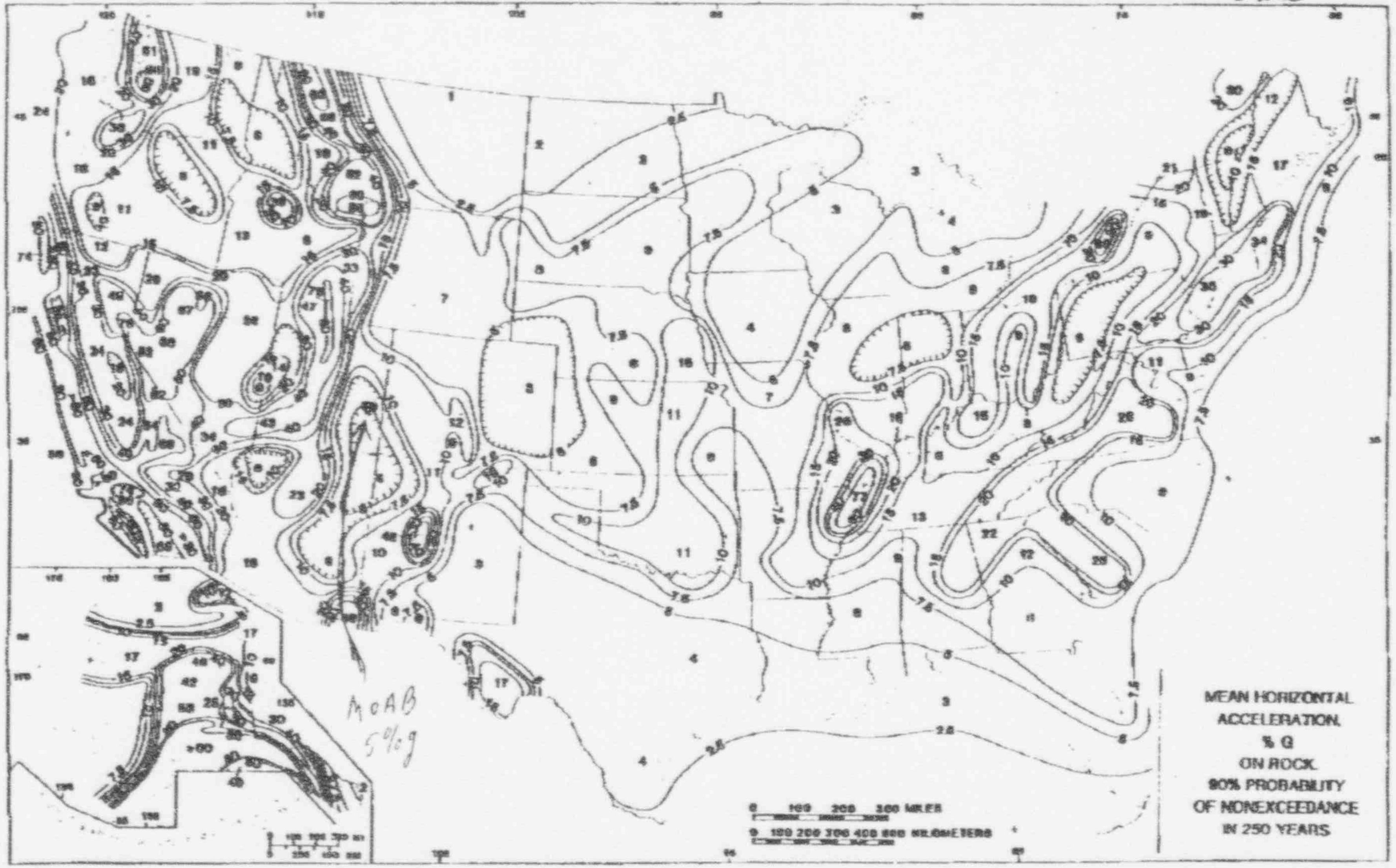
FIGURE 4. MEAN HORIZONTAL EARTHQUAKE ACCELERATION

FROM MF-2120



MOAB
5%g

From Algermissen et al, 1990

14/59

ATTACHMENT A

PHONE MEMO WITH UTAH GEOLOGICAL SURVEY

CanonieEnvironmental

TELEPHONE
CALL
RECORD

Date: 11/5/93 Time: 10:15 Phone No.: 1-801- 467-7970 16/

Project Name(s): ATLAS Project No.(s): 88-067-11

To: MIKE LOW of UTAH GEOLOGICAL SURVEY

From: JOHN SJOSTROM of CANONIE

Other Participants:

Subject(s): SEISMIC PROPERTIES OF MOAB, UT.

Notes:

MIKE PROVIDED ME THE FOLLOWING INFO:

① MOAB, UT IS IN SEISMIC ZONE 1

② HORIZONTAL EARTHQUAKE ACCELERATION FOR MOAB, UT IS ≤ 5% g FOR 250 yr EARTHQUAKE WITH 10% PROBABILITY OF EXCEEDANCE ACCORDING TO USGS REPORT, MF 2120 BY ALGERMISSEN ET. AL
↳ OBTAINED MAP FROM DENVER USGS FROM DAVE PERKINS.

③ THERE IS A MAP AND REPORT SHOWING FAULTS IN UTAH CALLED UGS Bulletin 127 - cost $17.00

{ I OBTAINED AN INTERIM GEOLOGICAL MAP OF MOAB FOR $3.50 EARLIER WHICH SHOWS FAULTS)

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Page 1 of 1

FM0006-1-93-M

Canonie Environmental
By JWS Date 11/12/93 Subject Stability Analysis-Reclaimed Tailings Impoundment ATLAS Sheet 17 of 39
Chkd By pe Date 1-4-94 Proj No 88-067-11

ATTACHMENT B

WATER LEVEL DATA IN TAILINGS PILE

CanonieEnvironmental

TELEPHONE CALL RECORD

18/59

Date: 11-5-93 Time: 1100 Phone No.: 801-259-5131

Project Name(s): ATLAS Project No.(s): 88-067-11

To: CARL DIXON of ATLAS

From: PHIL CROUSE of CES

PE ~~[illegible]~~ 1-4-94

Other Participants: JOHN SJOSTROM

Subject(s): WATER LEVEL DATA: 10-30-93

Notes: WATER POND IS DRY: EL 4027

RIVER
3951
1/4 MILE ABOVE POND

✓ A1	3987.9	B5(16) DRY
✓ A2	4002.27	B11
✓ A3	3995.19	B15
✓ - A5	3975.01	B16
✓ - B2(14)	4001.91	B4 ↓
✓ - B4(17)	4021.85	
Pond ✓ B10 ~~[illegible]~~ * BEST TO USE	3970.05	
✓ - B7 * BEST TO USE	3971.62	
✓ - HPP2	3972.45	
✓ - HPP3	3972.08	
✓ - BBA4 ↑	4008.07	
✓ BBA3 BEST TO USE	3995.63	
✓ BBA2	3994.74	
- EE4	4016.34	
- ✓ EE3	3996.13	
- ✓ EE2 ↓	3996.17	
- A9	DRY	
- B1(15	↓	

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PEC 1-4-94

	#	ELEV	N.	E.
	BAA 2	4058.7	4021.0	6206.2
	" 3	4055.8	4064.6	6111.2
	" 4	4055.1	4107.2	6110.6
	EE 2	4056.8	5535.1	5243.4
	EE 3	4056.3	5496.1	5241.6
	EE 4	4054.0	5429.2	5234.2
NOT USED	B-8	4039.4	3135.1	5453.5
	A-9	4008.0	3925.8	6321.9
NOT USED	A-10	3986.7	3884.8	6384.2
	B-4(17)	4039.8	5581.7	4682.3
	A-1	4039.9	5600.3	5219.5
	B-5(16)	4040.5	5557.0	5759.2
NOT USED	A-4	4040.6	5142.2	6026.6
NOT USED	B-17	3987.1	5708.8	5888.0
	B-16	4001.9	5641.2	5833.6
	A-2	4030.4	5629.7	5220.9
	A-3	4019.9	5669.9	5223.3
	A-5	4040.8	3988.0	6266.4 ✓
	B-1(15)	4040.8	4346.1	6395.6
	B-2(14)	4040.3	3572.0	5965.9
	B-10	4057.6	3633.2	5917.3
	B-11	4010.9	3541.7	6051.0 ✓
	B-15	4055.2	5488.5	5699.6
	B-16	4001.9	5641.2	5833.6
	B-7	4057.3	3211.2	5447.2
	C-4	4011.9	3943.9	6199.7
	HPP-2	4040.6	5112.7	6041.3
	HPP-3	4040.7	4000.5	6274.2

ATTACHMENT C

SOIL PROPERTIES

B-14

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FROM ATLAS REC. PLAN
(CANONIE, 1992 - JUNE)..

Table 1
RADON Input Parameters
Atlas Minerals - 1992

MATERIAL	RADIUM CONC. (pCi/g)(c)	EMANATION FRACTION (c)	LONG-TERM MOISTURE (% WEIGHT)	DIFFUSION COEF. (cm^2/s)(c)	POROSITY (d)	DRY DENSITY (g/cm^3)
FINE TAILINGS	1275.0	0.35	30.9 a	2.65E-04	0.5057	1.44 e
COARSE TAILINGS	241.0	0.23	4.4 a	2.47E-02	0.4350	1.53 e
ORE	212.7	0.28	9.0 a	3.30E-03	0.3637	1.72 e
AFFECTED MOAB WASH SOILS	19.5	0.28	2.8 b	1.97E-02	0.2954	1.91 f
CLEAN MOAB WASH SOILS	0.0	0.00	2.8 b	2.10E-02	0.3368	1.79 f
KLONDIKE FLATS CLAY	0.0	0.00	16.2 a	1.08E-03	0.3897	1.71 f
BENTONITE AMENDED SOIL	0.0	0.00	8.9 a	5.63E-03	0.3162	1.84 f

(a) Measured 15-bar Moisture Content
(b) Estimated 15-bar Moisture Content using Rawl's Equation (Eqn. 5/RG 3.64)
(c) Average measured lab values
(d) Calculate based on n = 1-(rho(s)/Gs*rho(w)) (Eqn. 4/RG 3.64)
(e) Average measured in-situ dry density
(f) Average dry density of based on 95% of Standard Proctor

From Canonie N

Atlas: Rec. Plan

Jl b PEC
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TABLE 2

MODIFIED 4/15/93

LAB TEST RESULTS
ATLAS CORPORATION
MOAB, UTAH

	Geotechnical									Radiological		
	Gradation and Hydrometer											
Material Description	Percent Passing 200 Sieve (%)	Percent Smaller than 0.005 mm (%)	Liquid Limit	Plastic Index	Ave. In-Place or Ave. Adjusted In-Place Dry Density (PCF)	Optimum Moisture Content (%)	Moisture Content at 15 Bar (%)	Porosity	Specific Gravity	Radium Content (pCi/Gram)	Diffusion Coefficient (cm^2/sec)	Emanation Coefficient
Fine Tailings												
ComFine - 192	74	20	42	15	89.8	NT	31.9	0.516	2.97	1094	1.3E-04	0.36
ComFine - 292	34	19	NP	NP	89.8	NT	27.5	0.493	2.84	1270	2.0E-06	0.32
ComFine - 392	70	21	44	21	89.8	NT	33.3	0.507	2.92	1461	4.0E-04	0.36
Coarse Tailings												
ComCoarse - 192	21	9	NP	NP	95.6	NT	5.4	0.437	2.72	250.6	2.3E-02	0.28
ComCoarse - 292	14	7	NP	NP	95.6	NT	4.7	0.437	2.72	278.6	2.8E-02	0.20
ComCoarse - 392	11	5	NP	NP	95.6	NT	3.2	0.431	2.69	193.8	2.3E-02	0.22
Ore Plating												
ComOre - 192	26	11	NP	NP	107.4	NT	9.6	0.363	2.70	180.4	8.8E-03	0.25
ComOre - 292	30	12	NP	NP	107.4	NT	8.8	0.363	2.70	250.1	8.8E-03	0.32
ComOre - 392	31	16	NP	NP	107.4	NT	9.6	0.365	2.71	207.7	7.3E-03	0.28
SN-Site Affected Soil												
1	17	6	NP	NP	125.8	8.1	2.8 *	0.259	2.72	18.2	2.3E-02	0.27
2	17	6	NP	NP	125.8	8.4	2.8 *	0.259	2.72	20.8	1.4E-02	0.29
3	17	7	NP	NP	125.8	8.1	2.8 *	0.256	2.71	19.5	2.2E-02	0.29
N-Site Moab Wash Soil												
1	11	5	NP	NP	118.0	9.9	2.8 *	0.294	2.68	NT	2.3E-02	NT
2	12	6	NP	NP	117.3	10.3	2.8 *	0.304	2.70	NT	2.6E-02	NT
3	11	6	NP	NP	117.3	10.5	2.8 *	0.306	2.71	NT	1.4E-02	NT
Mancus Shale (Klondike Flat)												
1	96	42	34	16	113.3	15.7	16.11	0.352	2.80	NT	7.4E-04	NT
2	82	42	37	20	112.4	14.8	16.32	0.358	2.80	NT	1.5E-03	NT
3	81	42	38	21	111.9	14.9	16.21	0.362	2.81	NT	1.0E-03	NT
Atlas Property												
1	11	6	NP	NP	129.0	9.3	7.19	0.248	2.75	NT	6.9E-03	NT
2	16	7	NP	NP	129.0	9.5	7.54	0.243	2.73	NT	1.3E-02	NT
3	18	9	NP	NP	128.8	9.8	7.61	0.244	2.73	NT	9.3E-03	NT
Bentonite Amended Moab Wash Soil												
1	16	8			120.3	10.9	9.07	0.286	2.70	NT	5.4E-03	NT
2	15	8			120.7	10.9	8.94	0.281	2.69	NT	7.9E-03	NT
3	16	8			121.2	10.7	8.57	0.273	2.67	NT	3.6E-03	NT

Note: NT = not tested.

15-15

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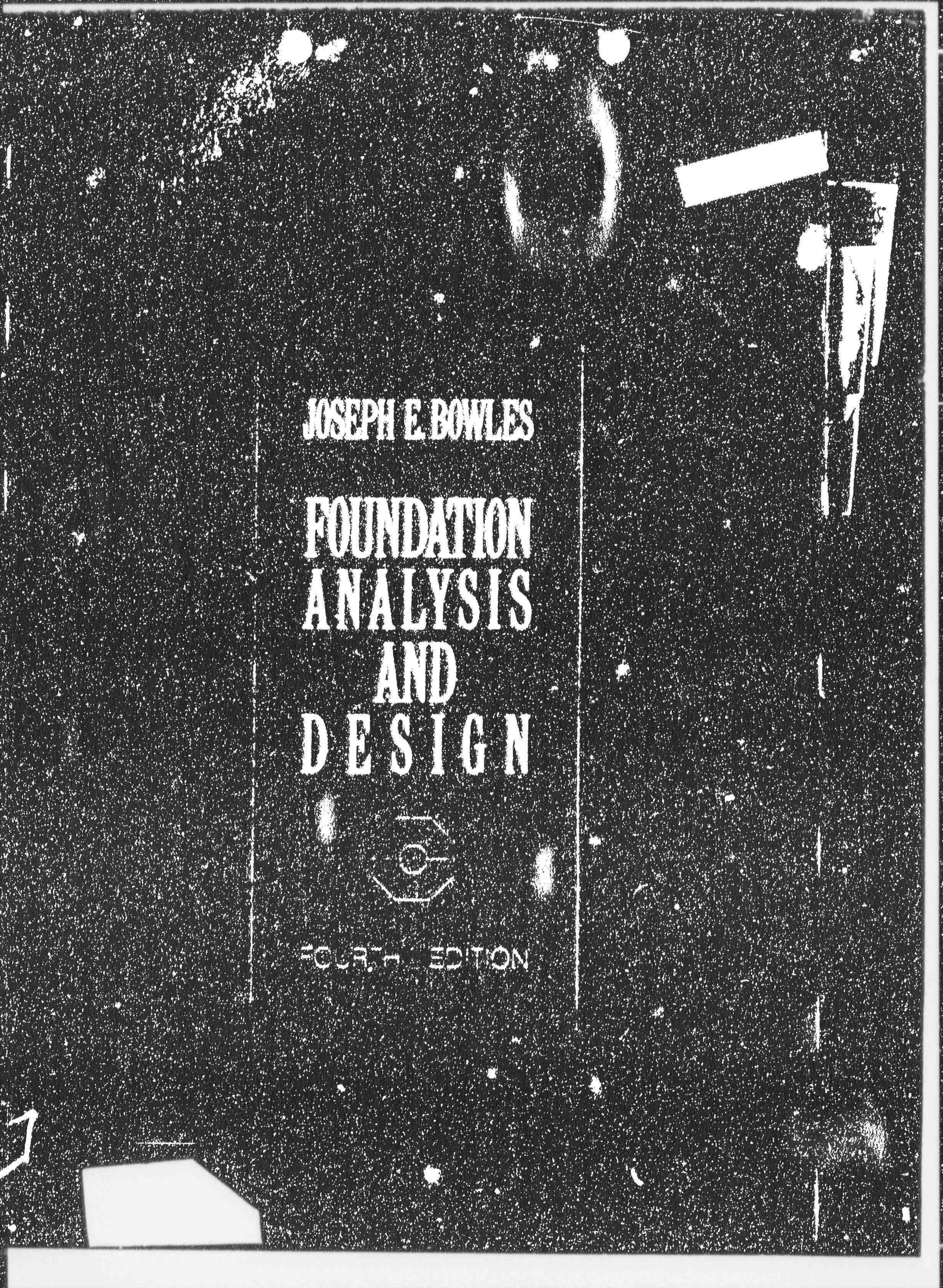

JOSEPH E. BOWLES

FOUNDATION ANALYSIS AND DESIGN

FOURTH EDITION

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UE triaxial tests and $s_{u,D}$ is from the direct simple shear test. According to Aas et al. (1986) (who also cite others) this may be the best value and is applicable for embankments, excavations, and shallow foundations. This strength parameter is also the most costly to obtain.

While the above comments may be used as a guide, each project must be evaluated separately for the strength recommendation. There are simply too many project dependent considerations to make a blanket recommendation to use either this or that particular strength value in any general use publication such as this.

2-11.9 Shear Strength Correlations and the s_u/p'_o Ratio

Shear strength correlations or parameters are widely used for both preliminary and final design studies. For example, shear tests on cohesionless soils are seldom made to obtain ϕ. Instead tabulated values as in Table 2-6 or values from in situ testing as in Table 3-4 are commonly used.

The drained angle of internal friction of cohesive soils can be estimated from

TABLE 2-6 **Representative values for angle of internal friction ϕ**

	Type of test*		
Soil	**Unconsolidated-undrained** U	**Consolidated-undrained** CU	**Consolidated-drained** CD
Gravel			
Medium size	40–55°		40–55°
Sandy	35–50°		35–50°
Sand			
Loose dry	28–34°		
Loose saturated	28–34°		
Dense dry	35–46°		43–50°
Dense saturated	1–2° less than dense dry		43–50°
Silt or silty sand			
Loose	20–22°		27–30°
Dense	25–30°		30–35°
Clay	0° if saturated	3–20°	20–42°

* See a laboratory manual on soil testing for a complete description of these tests, e.g., Bowles (1986*b*).

Notes:

1. Use larger values as γ increases
2. Use larger values for more angular particles
3. Use larger values for well-graded sand and gravel mixtures (EGW, SW)
4. Average values for
   Gravels: 35–38°
   Sands: 32–34°

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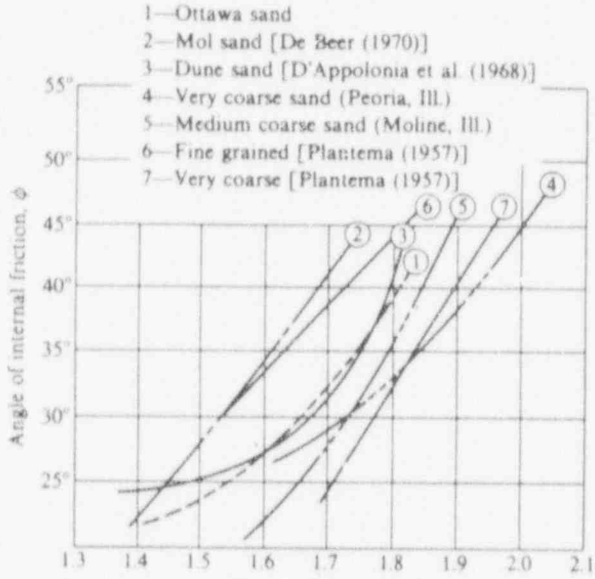
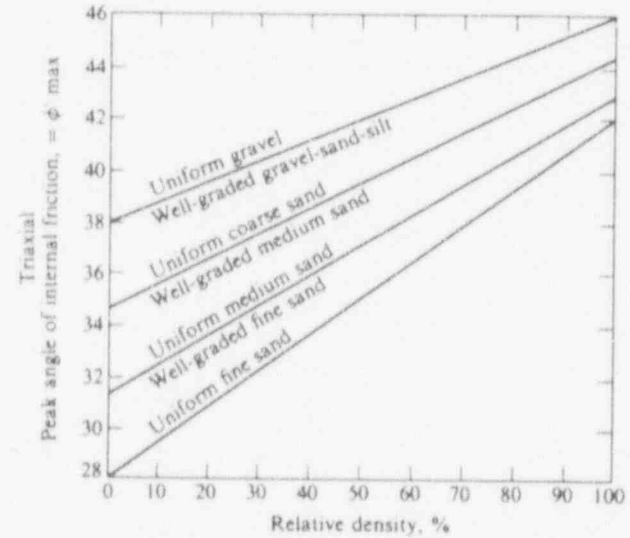


(a) ϕ vs. γ for several soils. [*From Bowles (1974a).*]



(b) ϕ vs. D_r. [*From Schmertmann (1978) who modified from D. M. Burmister (1948), "The Importance and Practical Use of Relative Density in Soil Mechanics", ASTM Proceedings, vol. 48.*]

FIGURE 2-24 Relationships between angle of internal friction ϕ and unit weight γ or relative density D_r.

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Oin

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To Janice and Val

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However, the preceding equation could also have been easily derived using Mohr's circle and simple geometry.

Shear Failure Law in Saturated Soil

In saturated soil, the total normal stress at a point is the sum of the effective stress and the pore water pressure, or,

$$\sigma = \sigma' + u$$

The effective stress, σ', is carried by the soil solids. So, to apply to soil mechanics, Eq. (8.2) needs to be rewritten as

$$\tau_f = c + (\sigma - u)\tan\phi = c + \sigma' \tan\phi \qquad (8.8)$$

The value of c for sand and inorganic silt is zero. For normally consolidated clays, c can be approximated at *zero*. Overconsolidated clays have values of c that are greater than zero. The angle of friction, ϕ, is sometimes referred to as the *drained angle of friction*. Typical values of ϕ for some granular soils are given in Table 8.1.

8.2

Determination of Shear Strength Parameters for Soils in the Laboratory

The shear strength parameters of a soil can be determined in the laboratory primarily by two types of tests: direct shear test and triaxial test. The procedures for conducting each of these tests are explained in detail in the following sections.

Direct Shear Test

This is the oldest and simplest form of shear test arrangement. A diagram of the direct shear test apparatus is shown in Figure 8.4. The test equipment

Table 8.1 Typical Values of Drained Angle of Friction for Sands and Silts

Soil type	ϕ(deg)
Sand: Rounded grains	
Loose	27–30
Medium	30–35
Dense	35–38
Sand: Angular grains	
Loose	30–35
Medium	35–40
Dense	40–45
Gravel with some sand	34–48
Silts	26–35

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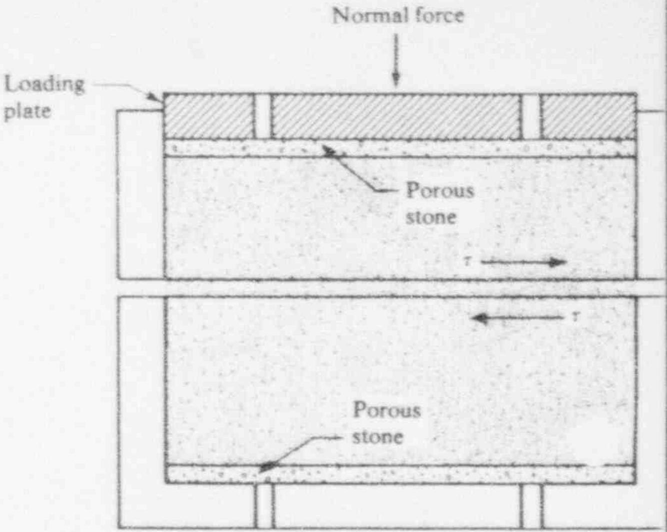

Figure 8.4 Diagram of direct shear test arrangement

consists of a metal shear box in which the soil sample is pla
may be square or circular in plan. The size of the sampl
about 3 or 4 in.^{2} (1935.48 or 2580.64 mm^2) across and al
high. The box is split horizontally into two halves. Normal
is applied from the top of the shear box by dead weights.
the samples obtained by the application of dead weight c
lb/in.^{2} (1034.2 kN/m^2). Shear force is applied to the side
box to cause failure in the soil sample.

Depending on the equipment, the shear test ca
controlled or strain-controlled.

In stress-controlled tests, the shear force is lied
equal increments until the sample fails. The failure takes
of split of the shear box. After the application of each i
shear displacement of the top half of the box is measure
gauge. The change in the height of the sample (thus the
sample) during the test can be obtained from the reading
measures the vertical movement of the upper loading pl

In strain-controlled tests, a constant rate of shear dis
to the top half of the box by a motor acting through gears
shear displacement is observed by a horizontal dial gaug
force of the soil corresponding to any shear displacement
horizontal proving ring. The volume change of the sam
obtained in a manner similar to the stress-controlled test
photograph of strain-controlled direct shear test equipm

The advantage of the strain-controlled tests is that,
sand, peak shear resistance (that is, at failure) as well as l
(that is, at a point after failure called *ultimate strength*)

= 50 kN/m^2

= $\sigma_3 + (\Delta\sigma_d)_f = 50 + 384.37$

37 kN/m^2

s are overconsolidated. Using the relationship given by Eq. (8.7)

$\tan^2\left(45 + \frac{\phi_1}{2}\right) + 2c \tan\left(45 + \frac{\phi_1}{2}\right)$

en 1

$$00 \tan^2\left(45 + \frac{\phi_1}{2}\right) + 2c \tan\left(45 + \frac{\phi_1}{2}\right) \tag{8.14a}$$

2

$$50 \left(45 + \frac{\phi_1}{2}\right) + 2c \tan\left(45 + \frac{\phi_1}{2}\right) \tag{8.14b}$$

8.14b) from Eq. (8.14a)

$= 50 \tan^2\left(45 + \frac{\phi_1}{2}\right)$

$= \tan^{-1}\left[\sqrt{\frac{76.23}{50}}\right] = 51°$

12° in Eq. (8.14a)

$100 \tan^2[45 + (12/2)] + 2c \tan[45 + (12/2)]$

$152.5 + 2.47c$

kN/m^2

of Friction for Normally Consolidated Clay

ed angle of friction, ϕ, generally decreases with the plasticity his is shown in Figure 8.18 for a number of clays as reported by Although there is a considerable scattering, the general pattern ue.

Undrained Test

lidated-undrained test is the most common type of triaxial test. e saturated soil sample is first consolidated by an all-around pressure, σ_3, resulting in drainage. After the pore water pres- by the application of confining pressure is completely dissipated

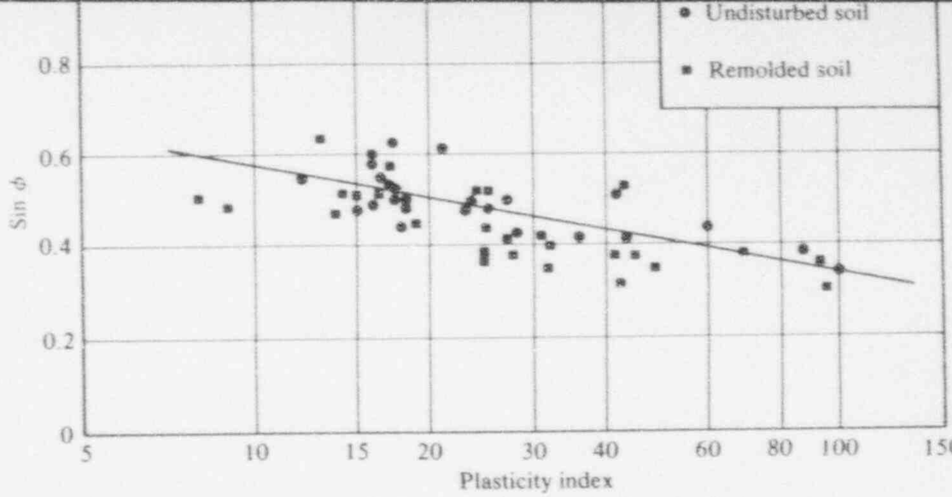

Figure 8.18 Variation of sin ϕ with plasticity index for a number of soils (after Kenney, 1959)

(that is, $u_c = B\sigma_3 = 0$), the deviator stress, $\Delta\sigma_d$, on the sample is increased to cause shear failure. During this phase of the test, the drainage line from the sample is kept closed. Since drainage is not permitted, the pore water pressure, Δu_d, will increase. During the test, simultaneous measurements of $\Delta\sigma_d$ and Δu_d are made. The increase of pore water pressure, Δu_d, can be expressed in a nondimensional form as

$$A = \frac{\Delta u_d}{\Delta\sigma_d} \tag{8.15}$$

where A = Skempton's pore pressure parameter (Skempton, 1954)

The general patterns of variation of $\Delta\sigma_d$ and Δu_d with axial strain for sand and clay soils are shown in Figure 8.19d, e, f, and g. In loose sand and normally consolidated clay, the pore water pressure increases with strain. In dense sand and overconsolidated clay, the pore water pressure increases with strain up to a certain limit, beyond which it decreases and becomes negative (with respect to the atmospheric pressure). This is due to a tendency of the soil to dilate.

Unlike the consolidated-drained test, the total and effective principal stresses are not the same in the consolidated-undrained test. Since the pore water pressure at failure is measured in this test, the principal stresses may be analyzed as follows:

Major principal stress at failure (total):

$$\sigma_3 + (\Delta\sigma_d)_f = \sigma_1$$

Major principal stress at failure (effective):

$$\sigma_1 - (\Delta u_d)_f = \sigma_1'$$

Minor principal stress at failure (total):

$$\sigma_3$$

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[illegible] PEC
1-4-94

Terzaghi & Peck
Skempton: $C_c = 0.009(LL - 10\%)$
for Normally Unconsolidated

AVERAGE PROPERTIES OF SOILS

Soil Classification Group	PROCTOR COMPACTION		Void Ratio	Permeability k, Ft. per Year	COMPRESSIBILITY		SHEARING STRENGTH		
	Maximum Dry Density	Optimum Water Content			2880 psf @ 20 p.s.i.	7200 psf @ 50 p.s.i.	C_o p.s.i.	C_{sat} p.s.i.	Tan ϕ
GW	> 119	< 13.3	(*)	27,000±13,000	< 1.4	(*)	(*)	(*)	> 0.79
GP	> 110	< 12.4	(*)	64,000±34,000	< 0.8	(*)	(*)	(*)	> 0.74
GM	> 114	< 14.5	(*)	> 0.3	< 1.2	< 3.0	(*)	(*)	> 0.67
GC	> 115	< 14.7	(*)	> 0.3	< 1.2	< 2.4	(*)	(*)	> 0.60
SW	119±5	13.3±2.5	0.37±*	(*)	1.4±*	(*)	5.7±0.6	(*)	0.79±0.02
SP	110±2	12.4±1.0	0.50±0.03	>15.0	0.8±0.3	(*)	3.3±0.9	(*)	0.74±0.02
SM	114±1	14.5±0.4	0.48±0.02	7.5±4.8	1.2±0.1	3.0±0.4	7.4±0.9	2.9±1.0	0.67±0.02
SM-SC	119±1	12.8±0.5	0.41±0.02	0.8±0.6	1.4±0.3	2.9±1.0	7.3±3.1	2.1±0.8	0.66±0.07
SC	115±1	14.7±0.4	0.48±0.01	0.3±0.2	1.2±0.2	2.4±0.5	10.9±2.2	1.6±0.9	0.60±0.07
ML	103±1	19.2±0.7	0.63±0.02	0.59±0.23	1.5±0.2	2.6±0.3	9.7±1.5	1.3±*	0.62±0.04
ML-CL	109±2	16.8±0.7	0.54±0.03	0.13±0.07	1.0±0.2	2.2±0.0	9.2±2.4	3.2±*	0.62±0.06
CL	108±1	17.3±0.3	0.56±0.01	0.08±0.03	1.4±0.2	2.6±0.4	12.6±1.5	1.9±0.3	0.54±0.04
OL	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
MH	82±4	36.3±3.2	1.15±0.12	0.16±0.10	2.0±1.2	3.8±0.8	10.5±4.3	2.9±1.3	0.47±0.05
CH	94±2	25.5±1.2	0.80±0.04	0.05±0.05	2.6±1.3	3.9±1.5	14.9±4.9	1.6±0.86	0.35±0.09
OH	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)

ϕ = 34°

ϕ = TAN⁻¹(.6) = 30°

ϕ 34°

ϕ 26°

The ± entry indicates 90% confidence limits of the average value.

* Denotes insufficient data. > is greater than. < is less than.

Source: Bur. Of Rec.

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Soil Propertie - Independent of the theory used t compute earth pressure on retaining structur, the results can be no more accurate t n the soil properties used in the calculations. Because of the wide variations of subsurface conditions at various sites, the soil constants should be determined on the basis of an exploratory boring program and laboratory tests of representative samples. Only then can a safe and economical design be assured. However, for the purpose of preliminary design it is often necessary to assume appropriate soil properties. The following tables and graphs are included for this purpose merely as a guide.

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Table 3 shows an approximate relationship between the relative density, standard penetration resistance, angle of internal friction, and unit weight of granular soils.

Rec
1-4-94
From Sheet Pile
Design Manual
Pile Buck, Inc.
1987

Compactness		*Very Loose*		*Loose*		*Medium*		*Dense*		*Very Dense*	
Relative density D_r	0		15%		35%		65%		85%		100%
Standard penetration resistance, N=no. of blows per foot	0		4		10		30		50		
ϕ (degrees)*			28		30		36		41		
Unit weight, pcf moist		<100		95-125		110-130		110-140		>130	
submerged		< 60		55-65		60-70		65-85		> 75	

*highly dependent on gradation

Table 3 — Relationship between relative density, standard penetration resistance, angle of internal friction and unit weight for granular soils (after Teng[45]).

Table 4 shows an approximate relationship between the unconfined compressive strength, standard penetration resistance and the unit weight of cohesive soils.

Consistency		*Very Soft*		*Soft*		*Medium*		*Stiff*		*Very Stiff*		*Hard*
q_u = unconfined compression strength, tons per square ft	0		0.25		0.50		1.00		2.00		4.00	
Standard penetration resistance, N=no. of blows per ft	0		2		4		8		16		32	
Unit weight, pcf (saturated)			100-120			110-130			120-140			130+
Identification characteristics		Exudes from between fingers when squeezed in hand		Molded by light finger pressure		Molded by strong finger pressure		Indented by thumb		Indented by thumb nail		Difficult to indent by thumb nail

Table 4 — Relationship between unconfined compressive strength, standard penetration resistance and unit weight for cohesive soils (after Teng[45]).

ATTACHMENT D

PCSTABL5 INPUT DATA FILES

- SCENARIO 1 DATA FILE -

by
EC
-4-94

```
PROFIL
10:3 EMBANKMENT SLOPE ATLAS MINERALS
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 0
115. 133. 0. 30. 0. 0. 0
122. 135. 0. 30. 0. 0. 0
100. 123. 0. 37. 0. 0. 0
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
EQUAKE
.05 .05 0.
CIRCL2
50 50
525. 625. 700. 950.
0. 10. 0. 0.
```

PEC
1-4-94

```
· SCENARIO 2 DATA FILE ·

PROFIL
10:3 EMBANKMENT SLOPE WITH WATER - ATLAS MINERALS
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 1
115. 133. 0. 30. 0. 0. 1
122. 135. 0. 30. 0. 0. 1
100. 123. 0. 37. 0. 0. 1
WATER
1 0.
4
795. 0.
850. 85.
950. 102.5
1000. 108.
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
EQUAKE
.05 .05 0.
CIRCL2
50 50
525. 650. 700. 950.
0. 10. 0. 0.
```

- SCENARIO ~~1~~ 3 INPUT DATA FILE -

[illegible] PEC 1-6-[illegible]

```
PROFIL
10:3 EMBANKMENT SLOPE ATLAS MINERALS - NO WATER 0.21g EQUAKE
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 0
115. 133. 0. 30. 0. 0. 0
122. 135. 0. 30. 0. 0. 0
100. 123. 0. 37. 0. 0. 0
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
EQUAKE
.21 .05 0.
CIRCL2
50 50
525. 625. 700. 950.
0. 10. 0. 0.
```

```
----- SCENARIO ϕ INPUT DATA FILE -------
                7
PROFIL
10:3 EMBANKMENT SLOPE WITH WATER - ATLAS MINERALS 0.21g EQUAKE
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 1
115. 133. 0. 30. 0. 0. 1
122. 135. 0. 30. 0. 0. 1
100. 123. 0. 37. 0. 0. 1
WATER
1 0.
4
795. 0.
850. 85.
950. 102.5
1000. 108.
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
EQUAKE
.21 .05 0.
CIRCL2
50 50
525. 650. 700. 950.
0. 10. 0. 0.
```

[illegible] pec 1-4 [illegible]

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d by
PEC
1-4-94

```
--- SCENARIO 5 INPUT DATA FILE -------

PROFIL
10:3 EMBANKMENT SLOPE ATLAS MINERALS TRIAL FAILURE SURFACE
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 1
115. 133. 0. 30. 0. 0. 1
122. 135. 0. 30. 0. 0. 1
100. 123. 0. 37. 0. 0. 1
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
WATER
1 0.
4
795. 0.
850. 85.
950. 102.5
1000. 108.
EQUAKE
.21 .05 0.
SURFAC
5
560. 69.
615. 78.
735. 114.
855. 150.
863. 160.
EXECUT
```

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6

```
- SCENARIO #2 DATA FILE -

PROF!L
10:3 EMBANKMENT SLOPE ATLAS MINERALS
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 0
115. 133. 0. 30. 0. 0. 0
122. 135. 0. 30. 0. 0. 0
100. 123. 0. 37. 0. 0. 0
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
EQUAKE
.25 .05 0.
CIRCL2
50 50
525. 625. 700. 950.
0. 10. 0. 0.
```

-4-94

MAX EQUAKE
NO WATER

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Rec 1-4-94

- SCENARIO ~~6~~ 7 DATA FILE -

MAX. EQUAKE

WATER

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```
PROFIL
10:3 EMBANKMENT SLOPE WITH WATER - ATLAS MINERALS
9 3
0. 60. 560. 69. 1
560. 69. 863. 160. 2
863. 160. 1000. 157.5 2
560. 69. 584. 69. 1
584. 69. 874. 155.7 4
874. 155.7 882. 158.2 3
882. 158.2 1000. 156.5 3
874. 155.7 1000. 154. 4
584. 69. 1000. 69. 1
SOIL
4
125. 125. 50. 38. 0. 0. 1
115. 133. 0. 30. 0. 0. 1
122. 135. 0. 30. 0. 0. 1
100. 123. 0. 37. 0. 0. 1
WATER
1 0.
4
795. 0.
850. 85.
950. 102.5
1000. 108.
LOADS
7
560. 610. 61.7 0.
610. 660. 61.7 0.
660. 710. 61.7 0.
710. 760. 61.7 0.
760. 810. 61.7 0.
810. 863. 61.7 0.
863. 1000. 46.3 0.
EQUAKE
.25 .05 0.
CIRCL2
50 50
525. 650. 700. 950.
0. 10. 0. 0.
```

ATTACHMENT E

PCSTABL5 OUTPUT DATA FILES

Chk by PEC 1-4-99

Scenario #1

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```
                              ** PCSTABL5M **

                                    by
                            Purdue University
 1

                       --Slope Stability Analysis--
                  Simplified Janbu, Simplified Bishop
                      or Spencer's Method of Slices


          Run Date:                  11-10-93
          Time of Run:               3:00
          Run By:                    JWS
          Input Data Filename:       H:atl1.IN
          Output Filename:           H:jnk



          PROBLEM DESCRIPTION   10:3 EMBANKMENT SLOPE ATLAS MINERALS




          BOUNDARY COORDINATES

              3 Top   Boundaries
              9 Total Boundaries

          Boundary     X-Left     Y-Left    X-Right    Y-Right    Soil Type
             No.        (ft)       (ft)       (ft)       (ft)     Below Bnd

              1           .00      60.00     560.00      69.00        1
              2        560.00      69.00     863.00     160.00        2
              3        863.00     160.00    1000.00     157.50        2
              4        560.00      69.00     584.00      69.00        1
              5        584.00      69.00     874.00     155.70        4
              6        874.00     155.70     882.00     158.20        3
              7        882.00     158.20    1000.00     156.50        3
              8        874.00     155.70    1000.00     154.00        4
              9        584.00      69.00    1000.00      69.00        1
 1


         ISOTROPIC SOIL PARAMETERS


           4 Type(s) of Soil

          Soil  Total  Saturated  Cohesion Friction   Pore    Pressure   Piez.
          Type Unit Wt. Unit Wt. Intercept   Angle  Pressure Constant Surface
           No.  (pcf)    (pcf)     (psf)     (deg)   Param.    (psf)     No.

            1   125.0    125.0      50.0     38.0     .00        .0       0
            2   115.0    133.0        .0     30.0     .00        .0       0
            3   122.0    135.0        .0     30.0     .00        .0       0
            4   100.0    123.0        .0     37.0     .00        .0       0
 1
```

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```
         BOUNDARY LOAD(S)

              7 Load(s) Specified

          Load        X-Left       X-Right      Intensity      Deflection
           No.         (ft)         (ft)        (lb/sqft)        (deg)


            1         560.00       610.00          61.7             .0
            2         610.00       660.00          61.7             .0
            3         660.00       710.00          61.7             .0
            4         710.00       760.00          61.7             .0
            5         760.00       810.00          61.7             .0
            6         810.00       863.00          61.7             .0
            7         863.00      1000.00          46.3             .0

          NOTE - Intensity Is Specified As A Uniformly Distributed
                 Force Acting On A Horizontally Projected Surface.


          A Horizontal Earthquake Loading Coefficient
          Of .050 Has Been Assigned

          A Vertical Earthquake Loading Coefficient
          Of .050 Has Been Assigned

          Cavitation Pressure =      .0 psf
1

          A Critical Failure Surface Searching Method, Using A Random
          Technique For Generating Circular Surfaces, Has Been Specified.


         2500 Trial Surfaces Have Been Generated.


           50 Surfaces Initiate From Each Of 50 Points Equally Spaced
          Along The Ground Surface Between  X = 525.00 ft.
                                       and  X = 625.00 ft.


          Each Surface Terminates Between   X = 700.00 ft.
                                      and   X = 950.00 ft.


          Unless Further Limitations Were Imposed, The Minimum Elevation
          At Which A Surface Extends Is  Y =    .00 ft.


          10.00 ft. Line Segments Define Each Trial Failure Surface.
1

          Following Are Displayed The Ten Most Critical Of The Trial
          Failure Surfaces Examined.  They Are Ordered - Most Critical
          First.


          * * Safety Factors Are Calculated By The Modified Bishop Method * *
```

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```
       Failure Surface Specified By 25 Coordinate Points

          Point       X-Surf       Y-Surf
           No.         (ft)         (ft)

            1         569.90        71.97
            2         579.73        73.78
            3         589.55        75.68
            4         599.35        77.67
            5         609.13        79.76
            6         618.89        81.95
            7         628.62        84.23
            8         638.34        86.61
            9         648.03        89.09
           10         657.69        91.65
           11         667.33        94.32
           12         676.94        97.08
           13         686.53        99.93
           14         696.08       102.87
           15         705.61       105.91
           16         715.11       109.04
           17         724.57       112.27
           18         734.01       115.59
           19         743.41       119.00
           20         752.77       122.50
           21         762.10       126.09
           22         771.40       129.78
           23         780.66       133.56
           24         789.88       137.42
           25         794.60       139.46

       Circle Center At X =  391.0 ; Y = 1075.8  and Radius, 1019.7

            ***      1.649    ***


            Individual data on the    28  slices

                             Water   Water     Tie      Tie     Earthquake
                             Force   Force    Force    Force       Force    Surcharge
  Slice  Width    Weight     Top     Bot      Norm     Tan      Hor      Ver     Load
   No.   Ft(m)   Lbs(kg)  Lbs(kg) Lbs(kg)  Lbs(kg)  Lbs(kg)  Lbs(kg)  Lbs(kg)  Lbs(kg)
    1     9.8     650.9      .0      .0       .0       .0      32.5     32.5    606.9
    2     9.8    1891.7      .0      .0       .0       .0      94.6     94.6    605.8
    3     9.8    3012.7      .0      .0       .0       .0     150.6    150.6    604.6
    4     9.8    4014.3      .0      .0       .0       .0     200.7    200.7    603.4
    5      .9     402.5      .0      .0       .0       .0      20.1     20.1     53.7
    6     8.9    4494.2      .0      .0       .0       .0     224.7    224.7    548.4
    7     9.7    5660.5      .0      .0       .0       .0     283.0    283.0    600.7
    8     9.7    6305.9      .0      .0       .0       .0     315.3    315.3    599.3
    9     9.7    6833.6      .0      .0       .0       .0     341.7    341.7    597.8
   10     9.7    7244.3      .0      .0       .0       .0     362.2    362.2    596.3
   11     2.3    1782.6      .0      .0       .0       .0      89.1     89.1    142.5
   12     7.3    5755.9      .0      .0       .0       .0     287.8    287.8    452.2
   13     9.6    7717.2      .0      .0       .0       .0     385.9    385.9    593.1
   14     9.6    7781.2      .0      .0       .0       .0     389.1    389.1    591.4
   15     9.6    7731.3      .0      .0       .0       .0     386.6    386.6    589.6
   16     9.5    7568.7      .0      .0       .0       .0     378.4    378.4    587.8
   17     4.4    3410.0      .0      .0       .0       .0     170.5    170.5    270.9
   18     5.1    3884.5      .0      .0       .0       .0     194.2    194.2    315.1
   19     9.5    6909.7      .0      .0       .0       .0     345.5    345.5    584.0
   20     9.4    6415.7      .0      .0       .0       .0     320.8    320.8    582.0
   21     9.4    5813.7      .0      .0       .0       .0     290.7    290.7    580.0
   22     9.4    5105.1      .0      .0       .0       .0     255.3    255.3    577.9
   23     7.2    3397.8      .0      .0       .0       .0     169.9    169.9    445.9
   24     2.1     893.7      .0      .0       .0       .0      44.7     44.7    129.9
   25     9.3    3374.3      .0      .0       .0       .0     168.7    168.7    573.6
   26     9.3    2355.1      .0      .0       .0       .0     117.8    117.8    571.3
   27     9.2    1235.7      .0      .0       .0       .0      61.8     61.8    569.0
   28     4.7     167.3      .0      .0       .0       .0       8.4      8.4    291.3
```

Chk by PEC 1-4-94

Scenario #2

```
                        ** PCSTABL5M **

                              by
                        Purdue University
1

                    --Slope Stability Analysis--
               Simplified Janbu, Simplified Bishop
                 or Spencer's Method of Slices


    Run Date:                   11-10-93
    Time of Run:                3:00
    Run By:                     JWS
    Input Data Filename:        H:atlw.IN
    Output Filename:            H:jnk


    PROBLEM DESCRIPTION    10:3 EMBANKMENT SLOPE WITH WATER - ATLAS
                            MINERALS


    BOUNDARY COORDINATES

         3 Top   Boundaries
         9 Total Boundaries

    Boundary      X-Left      Y-Left     X-Right     Y-Right     Soil Type
       No.         (ft)        (ft)        (ft)        (ft)      Below Bnd

        1           .00        60.00      560.00       69.00         1
        2        560.00        69.00      863.00      160.00         2
        3        863.00       160.00     1000.00      157.50         2
        4        560.00        69.00      584.00       69.00         1
        5        584.00        69.00      874.00      155.70         4
        6        874.00       155.70      882.00      158.20         3
        7        882.00       158.20     1000.00      156.50         3
        8        874.00       155.70     1000.0u      154.00         4
        9        584.00        69.00     1000.00       69.00         1
1

   ISOTROPIC SOIL PARAMETERS


     4 Type(s) of Soil


    Soil  Total  Saturated  Cohesion Friction    Pore   Pressure   Piez.
    Type Unit Wt. Unit Wt. Intercept   Angle  Pressure Constant Surface
     No.  (pcf)    (pcf)     (psf)     (deg)   Param.    (psf)     No.

      1   125.0    125.0      50.0      38.0     .00        .0       1
      2   115.0    133.0        .0      30.0     .00        .0       1
      3   122.0    135.0        .0      30.0     .00        .0       1
      4   100.0    123.0        .0      37.0     .00        .0       1
1


    1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED


    Unit Weight of Water =  62.40


    Piezometric Surface No.  1 Specified by  4 Coordinate Points


      Point       X-Water      Y-Water
       No.         (ft)         (ft)
```

```
          1        795.00          .00
          2        850.00        85.00
          3        950.00       102.50
          4       1000.00       108.00
1

     BOUNDARY LOAD(S)

          7 Load(s) Specified

      Load        X-Left        X-Right       Intensity       Deflection
       No.         (ft)           (ft)        (lb/sqft)          (deg)


        1         560.00        610.00           61.7              .0
        2         610.00        660.00           61.7              .0
        3         660.00        710.00           61.7              .0
        4         710.00        760.00           61.7              .0
        5         760.00        810.00           61.7              .0
        6         810.00        863.00           61.7              .0
        7         863.00       1000.00           46.3              .0

      NOTE - Intensity Is Specified As A Uniformly Distributed
             Force Acting On A Horizontally Projected Surface.


      A Horizontal Earthquake Loading Coefficient
      Of .050 Has Been Assigned

      A Vertical Earthquake Loading Coefficient
      Of .050 Has Been Assigned

      Cavitation Pressure =      .0 psf
1

      A Critical Failure Surface Searching Method, Using A Random
      Technique For Generating Circular Surfaces, Has Been Specified.


     2500 Trial Surfaces Have Been Generated.


       50 Surfaces Initiate From Each Of 50 Points Equally Spaced
      Along The Ground Surface Between  X = 525.00 ft.
                                   and  X = 650.00 ft.


      Each Surface Terminates Between    X = 700.00 ft.
                                  and    X = 950.00 ft.


      Unless Further Limitations Were Imposed, The Minimum Elevation
      At Which A Surface Extends Is  Y =    .00 ft.


      10.00 ft. Line Segments Define Each Trial Failure Surface.

1

      Following Are Displayed The Ten Most Critical Of The Trial
      Failure Surfaces Examined.  They Are Ordered - Most Critical
      First.


      * * Safety Factors Are Calculated By The Modified Bishop Method * *
```

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```
Failure Surface Specified By 24 Coordinate Points

  Point        X-Surf         Y-Surf
   No.          (ft)           (ft)

    1          560.71          69.21
    2          570.56          70.96
    3          580.39          72.80
    4          590.20          74.76
    5          599.98          76.82
    6          609.75          78.98
    7          619.48          81.25
    8          629.20          83.63
    9          638.89          86.10
   10          648.55          88.69
   11          658.18          91.37
   12          667.78          94.16
   13          677.35          97.06
   14          686.90         100.05
   15          696.40         103.15
   16          705.88         106.35
   17          715.32         109.66
   18          724.72         113.06
   19          734.08         116.57
   20          743.41         120.17
   21          752.70         123.88
   22          761.95         127.68
   23          771.15         131.59
   24          777.20         134.23

Circle Center At X =  404.0 ; Y =  983.9  and Radius,  928.0

         ***      1.650    ***



         Individual data on the    27  slices

                         Water   Water     Tie      Tie     Earthquake
                         Force   Force    Force    Force       Force    Surcharge
Slice  Width   Weight     Top     Bot     Norm      Tan      Hor      Ver     Load
 No.   Ft(m)  Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg)
  1      9.8    688.1      .0      .0      .0      .0    34.4     34.4    607.6
  2      9.8   1997.0      .0      .0      .0      .0    99.8     99.8    606.4
  3      9.8   3174.3      .0      .0      .0      .0   158.7    158.7    605.1
  4      9.8   4220.3      .0      .0      .0      .0   211.0    211.0    603.8
  5      9.8   5135.2      .0      .0      .0      .0   256.8    256.8    602.4
  6       .3    145.3      .0      .0      .0      .0     7.3      7.3     15.7
  7      9.5   5774.3      .0      .0      .0      .0   288.7    288.7    585.2
  8      9.7   6574.0      .0      .0      .0      .0   328.7    328.7    599.4
  9      9.7   7099.0      .0      .0      .0      .0   354.9    354.9    597.7
 10      9.7   7495.4      .0      .0      .0      .0   374.8    374.8    596.1
 11      9.6   7764.1      .0      .0      .0      .0   388.2    388.2    594.3
 12      1.8   1490.7      .0      .0      .0      .0    74.5     74.5    112.3
 13      7.8   6415.3      .0      .0      .0      .0   320.8    320.8    480.2
 14      9.6   7922.3      .0      .0      .0      .0   396.1    396.1    590.6
 15      9.5   7813.9      .0      .0      .0      .0   390.7    390.7    588.7
 16      9.5   7582.4      .0      .0      .0      .0   379.1    379.1    586.6
 17      9.5   7229.0      .0      .0      .0      .0   361.4    361.4    584.5
 18      4.1   3013.4      .0      .0      .0      .0   150.7    150.7    254.4
 19      5.3   3741.8      .0      .0      .0      .0   187.1    187.1    328.0
 20      9.4   6162.5      .0      .0      .0      .0   308.1    308.1    580.1
 21      9.4   5452.7      .0      .0      .0      .0   272.6    272.6    577.9
 22      9.3   4627.4      .0      .0      .0      .0   231.4    231.4    575.5
 23      9.3   3688.6      .0      .0      .0      .0   184.4    184.4    573.1
 24      7.3   2173.8      .0      .0      .0      .0   108.7    108.7    450.5
 25      1.9    464.4      .0      .0      .0      .0    23.2     23.2    120.1
 26      9.2   1478.2      .0      .0      .0      .0    73.9     73.9    568.0
 27      6.0    287.1      .0      .0      .0      .0    14.4     14.4    373.0
```

Ck'd PC 1-4-94

Scenario #3

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```
                         ** PCSTABL5M **

                               by
                        Purdue University
 1

                   --Slope Stability Analysis--
                Simplified Janbu, Simplified Bishop
                  or Spencer's Method of Slices


          Run Date:                  12-30-93
          Time of Run:               8:00
          Run By:                    JWS
          Input Data Filename:       h:atl3.in
          Output Filename:           H:jnk


          PROBLEM DESCRIPTION   10:3 EMBANKMENT SLOPE ATLAS MINERALS -
                                NO WATER 0.21g EQUAKE


          BOUNDARY COORDINATES

             3 Top   Boundaries
             9 Total Boundaries


          Boundary    X-Left     Y-Left    X-Right    Y-Right    Soil Type
             No.       (ft)       (ft)       (ft)       (ft)     Below Bnd

              1          .00      60.00     560.00      69.00        1
              2       560.00      69.00     863.00     160.00        2
              3       863.00     160.00    1000.00     157.50        2
              4       560.00      69.00     584.00      69.00        1
              5       584.00      69.00     874.00     155.70        4
              6       874.00     155.70     882.00     158.20        3
              7       882.00     158.20    1000.00     156.50        3
              8       874.00     155.70    1000.00     154.00        4
              9       584.00      69.00    1000.00      69.00        1
 1

         ISOTROPIC SOIL PARAMETERS


           4 Type(s) of Soil


          Soil  Total  Saturated  Cohesion Friction   Pore   Pressure   Piez.
          Type Unit Wt. Unit Wt.  Intercept  Angle  Pressure Constant Surface
           No.  (pcf)    (pcf)     (psf)     (deg)   Param.    (psf)     No.

            1   125.0    125.0      50.0      38.0     .00        .0      0
            2   115.0    133.0        .0      30.0     .00        .0      0
            3   122.0    135.0        .0      30.0     .00        .0      0
            4   100.0    123.0        .0      37.0     .00        .0      0
 1

         BOUNDARY LOAD(S)

             7 Load(s) Specified


          Load        X-Left       X-Right      Intensity      Deflection
          No.          (ft)          (ft)       (lb/sqft)        (deg)


            1         560.00       610.00          61.7             .0
            2         610.00       660.00          61.7             .0
            3         660.00       710.00          61.7             .0
            4         710.00       760.00          61.7             .0
            5         760.00       810.00          61.7             .0
            6         810.00       863.00          61.7             .0
            7         863.00      1000.00          46.3             .0
```

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```
     NOTE - Intensity Is Specified As A Uniformly Distributed
            Force Acting On A Horizontally Projected Surface.


    A Horizontal Earthquake Loading Coefficient
    Of .210 Has Been Assigned

    A Vertical Earthquake Loading Coefficient
    Of .050 Has Been Assigned

    Cavitation Pressure =      .0 psf
1

     A Critical Failure Surface Searching Method, Using A Random
    Technique For Generating Circular Surfaces, Has Been Specified.


  2500 Trial Surfaces Have Been Generated.


     50 Surfaces Initiate From Each Of 50 Points Equally Spaced
    Along The Ground Surface Between  X = 525.00 ft.
                                 and  X = 625.00 ft.


    Each Surface Terminates Between   X = 700.00 ft.
                                and   X = 950.00 ft.

     Unless Further Limitations Were Imposed, The Minimum Elevation
    At Which A Surface Extends Is  Y =    .00 ft.


    10.00 ft. Line Segments Define Each Trial Failure Surface.

1

     Following Are Displayed The Ten Most Critical Of The Trial
    Failure Surfaces Examined.  They Are Ordered - Most Critical
    First.

    * * Safety Factors Are Calculated By The Modified Bishop Method * *


    Failure Surface Specified By 25 Coordinate Points

      Point       X-Surf       Y-Surf
       No.         (ft)         (ft)

        1         569.90        71.97
        2         579.73        73.78
        3         589.55        75.68
        4         599.35        77.67
        5         609.13        79.76
        6         618.89        81.95
        7         628.62        84.23
        8         638.34        86.61
        9         648.03        89.09
       10         657.69        91.65
       11         667.33        94.32
       12         676.94        97.08
       13         686.53        99.93
       14         696.08       102.87
       15         705.61       105.91
       16         715.11       109.04
       17         724.57       112.27
       18         734.01       115.59
       19         743.41       119.00
       20         752.77       122.50
       21         762.10       126.09
       22         771.40       129.78
       23         780.66       133.56
       24         789.88       137.42
       25         794.60       139.46

   Circle Center At X =  391.0 ; Y = 1075.8  and Radius, 1019.7

        ***     1.099   ***
```

Chkd PEE 1-4-94

Scenario #4

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```
                           ** PCSTABL5M **

                                 by
                          Purdue University
 1

                      --Slope Stability Analysis--
                 Simplified Janbu, Simplified Bishop
                    or Spencer's Method of Slices


     Run Date:                   12-30-93
     Time of Run:                8:00
     Run By:                     JWS
     Input Data Filename:        h:atlW3.in
     Output Filename:            H:jnk



     PROBLEM DESCRIPTION    10:3 EMBANKMENT SLOPE WITH WATER - ATLAS
                             MINERALS  0.21g EQUAKE



     BOUNDARY COORDINATES

         3 Top   Boundaries
         9 Total Boundaries

     Boundary      X-Left      Y-Left     X-Right     Y-Right     Soil Type
        No.         (ft)        (ft)        (ft)        (ft)      Below Bnd

         1           .00        60.00      560.00       69.00         1
         2        560.00        69.00      863.00      160.00         2
         3        863.00       160.00     1000.00      157.50         2
         4        560.00        69.00      584.00       69.00         1
         5        584.00        69.00      874.00      155.70         4
         6        874.00       155.70      882.00      158.20         3
         7        882.00       158.20     1000.00      156.50         3
         8        874.00       155.70     1000.00      154.00         4
         9        584.00        69.00     1000.00       69.00         1
 1


    ISOTROPIC SOIL PARAMETERS


      4 Type(s) of Soil


     Soil  Total  Saturated  Cohesion Friction    Pore    Pressure   Piez.
     Type Unit Wt. Unit Wt. Intercept   Angle  Pressure Constant  Surface
      No.  (pcf)    (pcf)     (psf)     (deg)   Param.    (psf)     No.

       1   125.0    125.0      50.0      38.0     .00        .0       1
       2   115.0    133.0        .0      30.0     .00        .0       1
       3   122.0    135.0        .0      30.0     .00        .0       1
       4   100.0    123.0        .0      37.0     .00        .0       1
 1


    1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED


    Unit Weight of Water =  62.40


    Piezometric Surface No.  1 Specified by  4 Coordinate Points
```

```
       Point       X-Water      Y-Water
        No.          (ft)         (ft)

         1         795.00          .00
         2         850.00        85.00
         3         950.00       102.50
         4        1000.00       108.00
1

     BOUNDARY LOAD(S)

          7 Load(s) Specified

      Load          X-Left         X-Right        Intensity      Deflection
       No.           (ft)           (ft)         (lb/sqft)         (deg)


        1          560.00         610.00           61.7              .0
        2          610.00         660.00           61.7              .0
        3          660.00         710.00           61.7              .0
        4          710.00         760.00           61.7              .0
        5          760.00         810.00           61.7              .0
        6          810.00         863.00           61.7              .0
        7          863.00        1000.00           46.3              .0

      NOTE - Intensity Is Specified As A Uniformly Distributed
             Force Acting On A Horizontally Projected Surface.


      A Horizontal Earthquake Loading Coefficient
      Of .210 Has Been Assigned

      A Vertical Earthquake Loading Coefficient
      Of .050 Has Been Assigned

      Cavitation Pressure =      .0 psf
1


      A Critical Failure Surface Searching Method, Using A Random
      Technique For Generating Circular Surfaces, Has Been Specified.


     2500 Trial Surfaces Have Been Generated.


       50 Surfaces Initiate From Each Of 50 Points Equally Spaced
      Along The Ground Surface Between  X = 525.00 ft.
                                      and  X = 650.00 ft.


      Each Surface Terminates Between    X = 700.00 ft.
                                     and    X = 950.00 ft.


      Unless Further Limitations Were Imposed, The Minimum Elevation
      At Which A Surface Extends Is  Y =    .00 ft.


      10.00 ft. Line Segments Define Each Trial Failure Surface.


1


      Following Are Displayed The Ten Most Critical Of The Trial
      Failure Surfaces Examined.  They Are Ordered - Most Critical
      First.


      * * Safety Factors Are Calculated By The Modified Bishop Method * *
```

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```
Failure Surface Specified By 24 Coordinate Points

    Point       X-Surf       Y-Surf
     No.         (ft)         (ft)

      1         560.71        69.21
      2         570.56        70.96
      3         580.39        72.80
      4         590.20        74.76
      5         599.98        76.82
      6         609.75        78.98
      7         619.48        81.25
      8         629.20        83.63
      9         638.89        86.10
     10         648.55        88.69
     11         658.18        91.37
     12         667.78        94.16
     13         677.35        97.06
     14         686.90       100.05
     15         696.40       103.15
     16         705.88       106.35
     17         715.32       109.66
     18         724.72       113.06
     19         734.08       116.57
     20         743.41       120.17
     21         752.70       123.88
     22         761.95       127.68
     23         771.15       131.59
     24         777.20       134.23

Circle Center At X =  404.0 ; Y =  983.9  and Radius,  928.0

      ***      1.099   ***
```

Chk by PEC 1-4-94

Scenario #5

```
1                               ** PCSTABL5M **

                                      by
                               Purdue University

                          --Slope Stability Analysis--
                     Simplified Janbu, Simplified Bishop
                        or Spencer's Method of Slices

        Run Date:                12-30-93
        Time of Run:             8:00
        Run By:                  JWS
        Input Data Filename:     h:atlT1.in
        Output Filename:         H:jnk


        PROBLEM DESCRIPTION   10:3 EMBANKMENT SLOPE ATLAS MINERALS
                              TRIAL FAILURE SURFACE


        BOUNDARY COORDINATES

            3 Top   Boundaries
            9 Total Boundaries

        Boundary     X-Left     Y-Left    X-Right    Y-Right    Soil Type
           No.        (ft)       (ft)       (ft)       (ft)     Below Bnd

            1          .00      60.00     560.00      69.00         1
            2       560.00      69.00     863.00     160.00         2
            3       863.00     160.00    1000.00     157.50         2
            4       560.00      69.00     584.00      69.00         1
            5       584.00      69.00     874.00     155.70         4
            6       874.00     155.70     882.00     158.20         3
            7       882.00     158.20    1000.00     156.50         3
            8       874.00     155.70    1000.00     154.00         4
            9       584.00      69.00    1000.00      69.00         1
1
       ISOTROPIC SOIL PARAMETERS

         4 Type(s) of Soil

        Soil  Total  Saturated  Cohesion Friction   Pore   Pressure   Piez.
        Type Unit Wt. Unit Wt. Intercept   Angle  Pressure Constant Surface
         No.  (pcf)    (pcf)     (psf)     (deg)   Param.   (psf)     No.

          1   125.0    125.0      50.0      38.0     .00       .0       1
          2   115.0    133.0        .0      30.0     .00       .0       1
          3   122.0    135.0        .0      30.0     .00       .0       1
          4   100.0    123.0        .0      37.0     .00       .0       1
1

       BOUNDARY LOAD(S)

            7 Load(s) Specified

        Load        X-Left      X-Right      Intensity     Deflection
         No.         (ft)         (ft)      (lb/sqft)        (deg)


          1        560.00       610.00          61.7            .0
          2        610.00       660.00          61.7            .0
          3        660.00       710.00          61.7            .0
          4        710.00       760.00          61.7            .0
          5        760.00       810.00          61.7            .0
          6        810.00       863.00          61.7            .0
          7        863.00      1000.00          46.3            .0
```

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```
          NOTE - Intensity Is Specified As A Uniformly Distributed
                 Force Acting On A Horizontally Projected Surface.
1


          1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED


          Unit Weight of Water =  62.40


          Piezometric Surface No.  1 Specified by  4 Coordinate Points

            Point       X-Water      Y-Water
             No.          (ft)         (ft)

              1         795.00          .00
              2         850.00        85.00
              3         950.00       102.50
              4        1000.00       108.00


          A Horizontal Earthquake Loading Coefficient
          Of .210 Has Been Assigned

          A Vertical Earthquake Loading Coefficient
          Of .050 Has Been Assigned

          Cavitation Pressure =      .0 psf
1

          Trial Failure Surface Specified By  5 Coordinate Points

            Point       X-Surf       Y-Surf
             No.         (ft)         (ft)

              1         560.00        69.00
              2         615.00        78.00
              3         735.00       114.00
              4         855.00       150.00
              5         863.00       160.00


          Factor Of Safety For The Preceding Specified Surface =  1.378
1
```

chk by PCW
1-4-94

Scenario #6

MAX E QUAKE
NO WATER

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```
                     ** PCSTABL5M **

                           by
                    Purdue University

               --Slope Stability Analysis--
           Simplified Janbu, Simplified Bishop
             or Spencer's Method of Slices


 Run Date:                  11-10-93
 Time of Run:               3:00
 Run By:                    JWS
 Input Data Filename:       H:atl2.IN
 Output Filename:           H:jnk


 PROBLEM DESCRIPTION   10:3 EMBANKMENT SLOPE ATLAS MINERALS



 BOUNDARY COORDINATES

     3 Top   Boundaries
     9 Total Boundaries


 Boundary     X-Left      Y-Left      X-Right     Y-Right    Soil Type
   No.         (ft)        (ft)        (ft)        (ft)      Below Bnd

    1            .00       60.00      560.00       69.00         1
    2         560.00       69.00      863.00      160.00         2
    3         863.00      160.00     1000.00      157.50         2
    4         560.00       69.00      584.00       69.00         1
    5         584.00       69.00      874.00      155.70         4
    6         874.00      155.70      882.00      158.20         3
    7         882.00      158.20     1000.00      156.50         3
    8         874.00      155.70     1000.00      154.00         4
    9         584.00       69.00     1000.00       69.00         1
1
 ISOTROPIC SOIL PARAMETERS


  4 Type(s) of Soil


 Soil  Total  Saturated  Cohesion Friction   Pore   Pressure   Piez.
 Type Unit Wt. Unit Wt. Intercept  Angle  Pressure Constant  Surface
  No.  (pcf)    (pcf)     (psf)    (deg)   Param.    (psf)     No.

   1   125.0    125.0      50.0     38.0     .00        .0      0
   2   115.0    133.0        .0     30.0     .00        .0      0
   3   122.0    135.0        .0     30.0     .00        .0      0
   4   100.0    123.0        .0     37.0     .00        .0      0
1
 BOUNDARY LOAD(S)

     7 Load(s) Specified


 Load        X-Left      X-Right     Intensity     Deflection
  No.         (ft)         (ft)      (lb/sqft)       (deg)


   1         560.00       610.00         61.7            .0
   2         610.00       660.00         61.7            .0
   3         660.00       710.00         61.7            .0
   4         710.00       760.00         61.7            .0
   5         760.00       810.00         61.7            .0
   6         810.00       863.00         61.7            .0
   7         863.00      1000.00         46.3            .0
```

```
       NOTE - Intensity Is Specified As A Uniformly Distributed
              Force Acting On A Horizontally Projected Surface.

       A Horizontal Earthquake Loading Coefficient
       Of .250 Has Been Assigned

       A Vertical Earthquake Loading Coefficient
       Of .050 Has Been Assigned

       Cavitation Pressure =     .0 psf
1


       A Critical Failure Surface Searching Method, Using A Random
       Technique For Generating Circular Surfaces,  as Been Specified.


      2500 Trial Surfaces Have Been Generated.


        50 Surfaces Initiate From Each Of 50 Points Equally Spaced
       Along The Ground Surface Between  X = 525.00 ft.
                                    and  X = 625.00 ft.


       Each Surface Terminates Between    X = 700.00 ft.
                                   and    X = 950.00 ft.


       Unless Further Limitations Were Imposed, The Minimum Elevation
       At Which A Surface Extends Is  Y =   .00 ft.


       10.00 ft. Line Segments Define Each Trial Failure Surface.


       Following Are Displayed The Ten Most Critical Of The Trial
       Failure Surfaces Examined.  They Are Ordered - Most Critical
       First.


       * * Safety Factors Are Calculated By The Modified Bishop Method * *


       Failure Surface Specified By 25 Coordinate Points


         Point      X-Surf      Y-Surf
          No.        (ft)        (ft)

           1        569.90       71.97
           2        579.73       73.78
           3        589.55       75.68
           4        599.35       77.67
           5        609.13       79.76
           6        618.89       81.95
           7        628.62       84.23
           8        638.34       86.61
           9        648.03       89.09
          10        657.69       91.65
          11        667.33       94.32
          12        676.94       97.08
          13        686.53       99.93
          14        696.08      102.87
          15        705.61      105.91
          16        715.11      109.04
          17        724.57      112.27
          18        734.01      115.59
          19        743.41      119.00
          20        752.77      122.50
          21        762.10      126.09
          22        771.40      129.78
          23        780.66      133.56
          24        789.88      137.42
          25        794.60      139.46
```

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```
     Circle Center At X =  391.0 ; Y = 1075.8  and Radius, 1019.7

          ***     1.010   ***


          Individual data on the    28  slices

                           Water  Water     Tie      Tie      Earthquake
                           Force  Force    Force    Force        Force   Surcharge
Slice  Width     Weight     Top    Bot     Norm      Tan      Hor      Ver     Load
 No.   Ft(m)    Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg: Lbs(kg) Lbs(kg) Lbs(kg)
  1      9.8     650.9      .0      .0       .0       .0   162.7    32.5   606.9
  2      9.8    1891.7      .0      .0       .0       .0   472.9    94.6   605.8
  3      9.8    3012.7      .0      .0       .0       .0   753.2   150.6   604.6
  4      9.8    4014.3      .0      .0       .0       .0  1003.6   200.7   603.4
  5       .9     402.5      .0      .0       .0       .0   100.6    20.1    53.7
  6      8.9    4494.2      .0      .0       .0       .0  1123.6   224.7   548.4
  7      9.7    5660.5      .0      .0       .0       .0  1415.1   283.0   600.7
  8      9.7    6305.9      .0      .0       .0       .0  1576.5   315.3   599.3
  9      9.7    6833.6      .0      .0       .0       .0  1708.4   341.7   597.8
 10      9.7    7244.3      .0      .0       .0       .0  1811.1   362.2   596.3
 11      2.3    1782.6      .0      .0       .0       .0   445.6    89.1   142.5
 12      7.3    5755.9      .0      .0       .0       .0  1439.0   287.8   452.2
 13      9.6    7717.2      .0      .0       .0       .0  1929.3   385.9   593.1
 14      9.6    7781.2      .0      .0       .0       .0  1945.3   389.1   591.4
 15      9.6    7731.3      .0      .0       .0       .0  1932.8   386.6   589.6
 16      9.5    7568.7      .0      .0       .0       .0  1892.2   378.4   587.8
 17      4.4    3410.0      .0      .0       .0       .0   852.5   170.5   270.9
 18      5.1    3884.5      .0      .0       .0       .0   971.1   194.2   315.1
 19      9.5    6909.7      .0      .0       .0       .0  1727.4   345.5   584.0
 20      9.4    6415.7      .0      .0       .0       .0  1603.9   320.8   582.0
 21      9.4    5813.7      .0      .0       .0       .0  1453.4   290.7   580.0
 22      9.4    5105.1      .0      .0       .0       .0  1276.3   255.3   577.9
 23      7.2    3397.8      .0      .0       .0       .0   849.5   169.9   445.9
 24      2.1     893.7      .0      .0       .0       .0   223.4    44.7   129.9
 25      9.3    3374.3      .0      .0       .0       .0   843.6   168.7   573.6
 26      9.3    2355.1      .0      .0       .0       .0   588.8   117.8   571.3
 27      9.2    1235.7      .0      .0       .0       .0   308.9    61.8   569.0
 28      4.7     167.3      .0      .0       .0       .0    41.8     8.4   291.3
```

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Scenario #7
MAX EQUAKE
WATER

Chk by
PEC
1-4-94

```
                    ** PCSTABL5M **

                           by
                    Purdue University
 1

               --Slope Stability Analysis--
           Simplified Janbu, Simplified Bishop
             or Spencer's Method of Slices


     Run Date:                  11-10-93
     Time of Run:               3:00
     Run By:                    JWS
     Input Data Filename:       H:atlW2.IN
     Output Filename:           H:jnk


     PROBLEM DESCRIPTION    10:3 EMBANKMENT SLOPE WITH WATER - ATLAS
                             MINERALS


     BOUNDARY COORDINATES

         3 Top   Boundaries
         9 Total Boundaries


     Boundary     X-Left     Y-Left    X-Right    Y-Right    Soil Type
        No.        (ft)       (ft)       (ft)       (ft)     Below Bnd

         1          .00      60.00     560.00      69.00        1
         2       560.00      69.00     863.00     160.00        2
         3       863.00     160.00    1000.00     157.50        2
         4       560.00      69.00     584.00      69.00        1
         5       584.00      69.00     874.00     155.70        4
         6       874.00     155.70     882.00     158.20        3
         7       882.00     158.20    1000.00     156.50        3
         8       874.00     155.70    1000.00     154.00        4
         9       584.00      69.00    1000.00      69.00        1
 1

    ISOTROPIC SOIL PARAMETERS


     4 Type(s) of Soil


     Soil   Total  Saturated  Cohesion Friction   Pore   Pressure   Piez.
     Type Unit Wt. Unit Wt.  Intercept  Angle   Pressure Constant  Surface
      No.  (pcf)    (pcf)      (psf)    (deg)    Param.   (psf)     No.

       1   125.0    125.0      50.0     38.0      .00        .0       1
       2   115.0    133.0        .0     30.0      .00        .0       1
       3   122.0    135.0        .0     30.0      .00        .0       1
       4   100.0    123.0        .0     37.0      .00        .0       1
 1

     1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED


     Unit Weight of Water =  62.40



    Piezometric Surface No.  1 Specified by  4 Coordinate Points
```

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```
     Point       X-Water      Y-Water
      No.          (ft)         (ft)

       1         795.00          .00
       2         850.00        85.00
       3         950.00       102.50
       4        1000.00       108.00
1

BOUNDARY LOAD(S)

     7 Load(s) Specified

  Load         X-Left        X-Right       Intensity      Deflection
   No.          (ft)           (ft)        (lb/sqft)         (deg)

    1          560.00         610.00          61.7             .0
    2          610.00         660.00          61.7             .0
    3          660.00         710.00          61.7             .0
    4          710.00         760.00          61.7             .0
    5          760.00         810.00          61.7             .0
    6          810.00         863.00          61.7             .0
    7          863.00        1000.00          46.3             .0

  NOTE - Intensity Is Specified As A Uniformly Distributed
         Force Acting On A Horizontally Projected Surface.


  A Horizontal Earthquake Loading Coefficient
  Of .250 Has Been Assigned

  A Vertical Earthquake Loading Coefficient
  Of .050 Has Been Assigned

  Cavitation Pressure =      .0 psf
1


  A Critical Failure Surface Searching Method, Using A Random
  Technique For Generating Circular Surfaces, Has Been Specified.


 2500 Trial Surfaces Have Been Generated.


   50 Surfaces Initiate From Each Of 50 Points Equally Spaced
  Along The Ground Surface Between  X = 525.00 ft.
                               and  X = 650.00 ft.


  Each Surface Terminates Between   X = 700.00 ft.
                              and   X = 950.00 ft.


  Unless Further Limitations Were Imposed, The Minimum Elevation
  At Which A Surface Extends Is  Y =    .00 ft.


  10.00 ft. Line Segments Define Each Trial Failure Surface.

1

  Following Are Displayed The Ten Most Critical Of The Trial
  Failure Surfaces Examined.  They Are Ordered - Most Critical
  First.


  * * Safety Factors Are Calculated By The Modified Bishop Method * *
```

```
    Failure Surface Specified By 24 Coordinate Points

      Point      X-Surf       Y-Surf
       No.        (ft)         (ft)

        1        560.71        69.21
        2        570.56        70.96
        3        580.39        72.80
        4        590.20        74.76
        5        599.98        76.82
        6        609.75        78.98
        7        619.48        81.25
        8        629.20        83.63
        9        638.89        86.10
       10        648.55        88.69
       11        658.18        91.37
       12        667.78        94.16
       13        677.35        97.06
       14        686.90       100.05
       15        696.40       103.15
       16        705.88       106.35
       17        715.32       109.66
       18        724.72       113.06
       19        734.08       116.57
       20        743.41       120.17
       21        752.70       123.88
       22        761.95       127.68
       23        771.15       131.59
       24        777.20       134.23

    Circle Center At X =  404.0 ; Y =  983.9  and Radius,  928.0

           ***     1.009   ***



            Individual data on the    27  slices

                         Water   Water     Tie      Tie     Earthquake
                         Force   Force    Force    Force       Force   Surcharge
 Slice  Width   Weight    Top     Bot     Norm      Tan     Hor      Ver     Load
  No.   Ft(m)  Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg) Lbs(kg)
   1     9.8    688.1      .0      .0       .0       .0   172.0    34.4   607.6
   2     9.8   1997.0      .0      .0       .0       .0   499.2    99.8   606.4
   3     9.8   3174.3      .0      .0       .0       .0   793.6   158.7   605.1
   4     9.8   4220.3      .0      .0       .0       .0  1055.1   211.0   603.8
   5     9.8   5135.2      .0      .0       .0       .0  1283.8   256.8   602.4
   6      .3    145.3      .0      .0       .0       .0    36.3     7.3    15.7
   7     9.5   5774.3      .0      .0       .0       .0  1443.6   288.7   585.2
   8     9.7   6574.0      .0      .0       .0       .0  1643.5   328.7   599.4
   9     9.7   7099.0      .0      .0       .0       .0  1774.7   354.9   597.7
  10     9.7   7495.4      .0      .0       .0       .0  1873.8   374.8   596.1
  11     9.6   7764.1      .0      .0       .0       .0  1941.0   388.2   594.3
  12     1.8   1490.7      .0      .0       .0       .0   372.7    74.5   112.3
  13     7.8   6415.3      .0      .0       .0       .0  1603.8   320.8   480.2
  14     9.6   7922.3      .0      .0       .0       .0  1980.6   396.1   590.6
  15     9.5   7813.9      .0      .0       .0       .0  1953.5   390.7   588.7
  16     9.5   7582.4      .0      .0       .0       .0  1895.6   379.1   586.6
  17     9.5   7229.0      .0      .0       .0       .0  1807.2   361.4   584.5
  18     4.1   3013.4      .0      .0       .0       .0   753.3   150.7   254.4
  19     5.3   3741.8      .0      .0       .0       .0   935.5   187.1   328.0
  20     9.4   6162.5      .0      .0       .0       .0  1540.6   308.1   580.1
  21     9.4   5452.7      .0      .0       .0       .0  1363.2   272.6   577.9
  22     9.3   4627.4      .0      .0       .0       .0  1156.9   231.4   575.5
  23     9.3   3688.6      .0      .0       .0       .0   922.2   184.4   573.1
  24     7.3   2173.8      .0      .0       .0       .0   543.4   108.7   450.5
  25     1.9    464.4      .0      .0       .0       .0   116.1    23.2   120.1
  26     9.2   1478.2      .0      .0       .0       .0   369.5    73.9   568.0
  27     6.0    287.1      .0      .0       .0       .0    71.8    14.4   373.0
```

APPENDIX B

SOUTHWEST DRAINAGE AREA EROSION PROTECTION DESIGN CALCULATION BRIEF

EROSION PROTECTION ON BASE OF TAILINGS PILE SIDE SLOPES ADJACENT TO NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL

ATLAS CORPORATION

88-067-12

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EROSION PROTECTION ON BASE OF TAILINGS PILE SIDE SLOPES ADJACENT TO NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL

ATLAS CORPORATION

88-067-12

Background and Purpose. In this calculation brief, the previously designed trapezoidal Southwest Runoff Drainage Channel (SWRDC) at the Atlas Corp. Tailings Pile in Moab, Utah is replaced by a natural drainage way and, as a result, the riprap along the base of the tailings pile is redesigned to withstand flows down the natural drainage channel. Figure 1 shows the location of the SWRDC and the adjacent tailings pile.

The Nuclear Regulatory Commission considers that the potential exists for sediment and large rocks from nearby cliffs to enter the SWRDC and block or restrict flow. As a result of this concern, the analysis will evaluate the effects of rocks entering the natural drainage way. Also, the necessary riprap toe protection based on the maximum scour depth expected under Probable Maximum Flood (PMF) conditions will be designed. In addition, in this calculation brief the volume of the designed riprap erosion protection along the base of the tailings pile adjacent to the SWRDC will be determined and compared to the riprap volume of the previously designed trapezoidal channel.

A natural drainage way for the lower reach of the SWRDC will not be considered because existing contours adjacent to the Reclaimed Tailings Pile do not provide for adequate drainage nor does a natural channel provide adequate protection at the outlet of the SWRDC. Instead, the previously proposed man-made channel from the start of the width transition to the end of the channel and including the rock cutoff wall is considered for the lower reach.

Results. Figure 1 identifies the selected D_{50} riprap erosion protection and the location of the riprap erosion protection along the base of the tailings pile adjacent to the natural SWRDC. An actual (oversized for durability) D_{50} of 9 inches has been designed for the base of the tailings pile adjacent to the SWRDC from the beginning of the SWRDC to station 10+00 and from station 12+00 to station 18+15 (beginning of the width transition). From SWRDC station 10+00 to 12+00, an actual D_{50} of 17.4" has been designed. These D_{50} values are sized adequately to withstand a PMF flow in the natural drainage channel. Furthermore, the D_{50} values are adequately sized for flow conditions resulting from a reasonable volume of rocks, based on engineering judgement, falling into the channel.

Figure 2 shows a typical cross section through the channel illustrating the vertical extent of the riprap erosion protection. The riprap erosion protection extends sufficiently below existing grade to account for scour depth and sufficiently above existing grade to account for the maximum expected PMF depth in the channel under flow conditions resulting from falling rocks entering the channel. The maximum predicted depth under flow conditions resulting from rocks entering the channel was approximately 1.8 feet higher than PMF depth with no rocks entering the channel.

Table 1 summarizes the selected D_{50} sizes, the PMF depth, the average scour depth, and the width, area, and volume of riprap erosion protection throughout the natural reach of the channel. Table 2 presents the channel invert, riprap invert, and top of riprap elevations for the tailings embankment riprap erosion protection adjacent to the natural SWRDC.

Table 3 presents the required riprap volume of the previously designed man-made channel and compares the required riprap volume of the natural SWRDC to the riprap volume of the previously designed man-made channel. A total of approximately 6750 cubic yards (CY) of riprap and filter material is required for the tailings embankment erosion protection adjacent to the natural SWRDC. For the previously designed man-made channel, a total of approximately 6850 CY of riprap and filter material is required. The volume calculation for the man-made channel assumed that riprap also would be placed 1.8 feet above PMF depth along the tailings embankment to account for rocks entering the channel.

Method. The US Army Corps of Engineers (COE) riprap sizing method (Hydraulic Design of Flood Control Channels, EM 1110-2-1601, 1970) was selected to size the riprap erosion protection at the base of the tailings pile side slopes adjacent to the natural SWRDC. Depth of flow in the channel, required to apply the COE method, was determined through numerical modeling of the water surface profile using the US Army Corps of Engineers HEC-2 Water Surface Profile computer program (September 1990 version). The COE method and the HEC-2 model are described are described below.

Army Corps of Engineers Riprap Sizing Method

Excerpts from EM 1110-2-1601 describing the COE method have been included in Attachment A of this calculation brief. The main steps in the COE method and the major equations are summarized below.

The general procedure followed when applying the COE method to determine the riprap size at a channel cross section for a given channel discharge is, as follows:

1) Select a D_{50} (mean stone size of riprap in channel cross section).
2) Compute the local boundary shear at the channel cross section. (The local boundary shear is the shear at the location of interest in the channel. In this case, the local boundary shear will be computed for the tailings pile side of channel.)

3) Compute the riprap design shear (the local boundary shear that the in-place riprap can withstand).

4) Compare the local boundary shear to the design shear.

5) If the local boundary shear is more than the design shear, select a larger D50 and repeat the steps until the local boundary shear is less than the design shear. If the local boundary shear is less than the design shear on the first iteration, verify that the selected D_{50} is the minimum practical D_{50}.

Figure 1 shows the locations of the channel cross sections selected for application of the COE method. Attachment B of this calculation brief contains profiles of each of the cross sections. Steps 1,2 and 3 of the COE method are described in detail below. Steps 4 and 5 are performed in the calculations section.

1. *Selection of D_{50}.* D_{50} values were selected based on previously designed riprap gradations for the Reclaimed Atlas Tailings Pile. Table 4 presents the pre-designed riprap gradations. For development of these gradations, see the Revised Riprap Gradation Calc. brief [(Canonie, April 1993) and Moab Wash Channel Bank and Northeast Debris Pit Erosion protection Calc. brief (Canonie, 1994)]. The D_{50} values shown on the table have been oversized by 2% based on the durability of the rock source (see Rock Quality - Assessment of Oversizing Requirements (June 1992 Atlas Crop. Rec. Plan). For application in the COE method, the raw or non-oversized D_{50} values (i.e. oversized D_{50} divided by 1.02) were selected as a more conservative approach.

2. *Local Boundary Shear.* The local boundary shear is determined with the following equation:

where

$$\tau = \frac{\gamma V^2}{[32.6 LOG(\frac{12.2R}{k})]^2}$$

v = average local velocity, fps
R = local hydraulic radius, ft
k = roughness dimension taken as the spherical diameter of the average size bed material, ft (i.e. D_{50})
γ = unit weight of water = 62.4 lb/ft^3

The procedure outlined in Appendix IV of EM 1110-2-1601 (see Attachment A for excerpts) is followed to determine the average local velocity and the hydraulic radius. A channel cross section is divided in subsections as presented in Figure 3. The mean velocity, V_n, in subsection n is given by the following formula:

$$V_n = \frac{Q_T \, (CR^{1/2})_n}{\sum [(CR^{1/2})_i \, A_i]}$$

The term in the denominator of the equation is summed from i = 1 to the number of subsections of the channel cross section. Each variable in the equation is defined below:

Q_T = total discharge through entire channel cross section, cfs

A = channel subsection area, ft^2

R = Hydraulic radius of subsection calculated as:

$$R = A/P$$

where P = wetted perimeter of channel subsection.

C = Chezy's coefficient = 32.6 log (12.2 R/k) for channel subsections lined with riprap. For natural subsections, the Chezy's coefficient is estimated from Manning's n using the following formula from EM 1110-2-1601:

$$C = 1.486 \, R^{(1/6)} / n$$

3. *Riprap Design Shear*. The riprap design shear for riprap placed on channel side slopes is given by the following equation from EM 1110-2-1601:

$$\tau' = \tau\left(1 - \frac{\sin^2\phi}{\sin^2\theta}\right)^{0.5}$$

where

$$\tau = a\,(\gamma_s - \gamma)D_{50}$$

γ_s = unit weight of stone = 154.2 lb/ft^3 from Surface Water Calc. (June 1992 Atlas Rec. Plan)

γ = unit weight of water = 62.4 lb/ft^3

a = coefficient = 0.04

ϕ = Tailings embankment side slope angle of channel

θ = angle of repose of riprap = 42° from Surface Water Calc. (June 1992 Atlas Rec. Plan)

HEC-2 Computer Model and Required Input

To determine channel subsection area, wetted perimeter, and hydraulic radius for the channel cross section locations shown on Figure 1, the depth of flow at each of these cross sections must be determined. The HEC-2 model was selected to compute the depth of flow at the cross section locations in the channel. The HEC-2 model is applicable to steady gradually varied flow conditions and has the capability of computing both subcritical and supercritical flow profiles. Friction losses in channels are calculated with the Manning's equation and water surface profiles are computed iteratively using the standard step method. Input required by the HEC-2 model is discussed below.

To compute a basic water surface profile in a channel, the HEC-2 computer program requires the following input: channel discharge, Manning's n, channel cross section geometry, and the distance between each cross section. A beginning water surface elevation at the farthest upstream point in the channel reach for supercritical runs and at the farthest downstream point in the channel reach for subcritical runs is also required as part of the input. Separate supercritical and subcritical HEC-2 simulations must be performed, if both supercritical and subcritical flow conditions are present in different reaches of the channel, because HEC-2 does not allow water surface profile computations to cross critical depth. Each input parameter is discussed below:

Channel discharge. The discharge selected to compute the water surface profile in the natural SWRDC was the PMF of 1605 cfs computed for the upper reach of SWRDC in the Revised PMF Flow Calculation brief (Canonie, April, 1993). The discharge is still applicable to the natural SWRDC because the same amount of water is expected whether the channel is man-made or natural.

Manning's n. The Manning's n is a coefficient of roughness for the channel. For the natural SWRDC with erosion protection on one side of the channel and natural ground on the other side of the channel, Manning's n varies across the width of the channel. For the tailings pile side (i.e. side with erosion protection), Manning's n was computed with the following equation from NUREG/CR-4620 (see Attachment A for excerpt) relating Manning's n to the riprap D_{50}:

$$n = 0.0395\ (D_{50})^{(1/6)}$$

where D_{50} is the mean rock size in feet. As an example, for a D_{50} of 4.9 inches, the corresponding Manning's n is 0.034. For the natural side of the channel, a Manning's n of 0.035 was chosen based on typical values found in the literature (Linsley et. al, 1982, and Lindeburg, 1992 - see Attachment A for excerpts) for natural channels with stones and weeds.

Channel Cross Section Geometry. Locations of selected cross sections are shown on Figure 1 and profiles of the selected cross sections are presented in Attachment B. The cross sections were selected at representative locations throughout the channel reach and where water surface profile information was desired. Additional cross sections between sections 4 and 6 were chosen to allow for a more detailed analysis of the effects of rocks entering the channel. Looking downstream, the geometry of the right hand side of the channel was determined from existing ground contours. The geometry of the left hand side of the channel cross section (the tailings pile side slope) was determined by projecting upward from the channel invert to the top of the reclaimed tailings pile side slope. The channel invert is the lowest point in the channel. The only exception is cross section 10.0, the start of the width transition, where the channel geometry is trapezoidal (the previously designed man-made channel).

Channel inverts of the natural channel were aligned along the lowest point of the existing ground contours (see Figure 1). A minimum amount of cut was assumed to provide a uniform slope of 0.011 in the upper reach of the channel. Since the portion of the channel downstream from cross section 10.0 remains unchanged from the previously designed trapezoid, the invert elevation of 4010 feet at cross section 10.0 was held constant and the channel cross section invert elevations upstream of cross section 10.0 were extrapolated using a slope of 0.011.

For input into HEC-2, each point where the cross section side slope changes must be defined with a station number corresponding to the horizontal distance from a zero point on the left bank and an elevation. The HEC-2 runs contained in Attachments C and E present the station numbers and elevation for points in each of the selected channel cross sections. These values are contained on the HEC-2 "GR" cards.

Distance Between Each Cross Section. Distance between cross sections are defined as reach lengths. The left overbank, right overbank, and channel reach lengths are required for input to HEC-2. The left and right over bank reach lengths are measured along the anticipated path of the center of mass of the overbank flow. The channel reach length is measured along the deepest portion of the channel.

Beginning Water Surface Elevations. Beginning water surface elevations were specified as the elevations corresponding to critical depth at cross section 10.0 for subcritical runs and at cross section 1.0 for supercritical runs. Beginning the HEC-2 simulations at critical depth is reasonable. At cross section 10.0, a flow transition from subcritical to supercritical occurs because of the width transition in the channel at this location. This flow transition was previously demonstrated in the "HEC-2 Simulations on the Southwest Drainage Channel and the Impoundment Drainage Channel" Calc. brief (Canonie, April, 1993). Also, specifying critical depth at cross section 1.0 for the supercritical runs is reasonable because HEC-2 subcritical runs (see Attachment C) indicate that flow is subcritical at cross section 1.0. Since HEC-2 cannot pass a flow profile from subcritical to supercritical, the water surface elevation corresponding to critical depth is chosen as the starting water elevation at cross section 1.0.

Calculations. This section describes the HEC-2 simulations, D_{50} riprap sizing analysis, scour depth calculations, and riprap volume calculations.

HEC-2 Simulations

The following HEC-2 simulations are presented:

1) Subcritical Run not accounting for rocks entering the channel.
2) Supercritical Run not accounting for rocks entering the channel.

3) Subcritical Run accounting for rocks entering the channel at HEC-2 cross sections 4.0, 4.1, 4.2, and 5.0.

4) Supercritical Run accounting for rocks entering the channel at HEC-2 cross sections 4.0, 4.1, 4.2, and 5.0.

5) Subcritical Run accounting for rocks entering the channel at HEC-2 cross sections 5.0, 5.1, 5.2, and 6.0.

6) Supercritical Run accounting for rocks entering the channel at HEC-2 cross sections 5.0, 5.1, 5.2, and 6.0.

HEC-2 simulations 1 and 2; 3 and 4; and 5 and 6 are evaluated together when selecting the depth of flow at selected cross sections in the channel. For example for a given pair of simulations (i.e. 1 & 2; 3 & 4; or 5 & 6), when the flow condition is subcritical, depth of flow from the subcritical simulation is selected for sizing the D_{50} riprap protection. When the flow condition is supercritical, depth of flow from the supercritical simulation is selected for sizing the D_{50} riprap protection. Each simulation is discussed below.

Simulations 1 and 2. HEC-2 output from simulations 1 and 2 is presented in Attachment C. From the results of simulations 1 and 2, the flow condition is subcritical between cross sections 1.0 and 5.0, supercritical from cross sections 5.0 through 6.0, and subcritical between cross sections 6.0 through 10.0. Table 5 summarizes the depth of flow in the channel computed by HEC-2 at each of the selected cross sections. For cross sections 1.0 through 5.0 and 6.5 through 10.0 depth of flow is from simulation 1 (subcritical run) HEC-2 output. For cross sections 5.1 through 6.0, depth of flow is from simulation 2 (supercritical run) HEC-2 output.

Simulations 3, 4, 5, and 6. For simulations 3, 4, 5, and 6, approximately 500 CY of rocks were distributed in the natural reach of the channel. This rock volume was determined by measuring boulders which are presently located in the vicinity of the southwest side of the tailings pile and north of highway 279. The resulting volume was approximately 25 CY. It was assumed that the boulders and rocks had fallen in the past 50 years. To obtain a volume over the 1000 year design life of the Tailings Embankment, the 50 year volume of 25 CY was extrapolated to 1000 years. Attachment D provides a detailed calculation of the predicted rock volume which may enter the channel.

For HEC-2 simulations 3 and 4, the rocks were placed on the natural side of the channel in between cross sections 4.0, 4.1, 4.2, and 5.0 from the lowest point the channel cross section to an elevation of approximately 4030 ft. These cross sections were chosen because they represent both subcritical and supercritical flow conditions. Attachment D illustrates how the rocks were incorporated into channel cross sections 4.0, 4.1, 4.2, and 5.0. Placement of the rocks only on the natural side of the channel is consistent with currently observed conditions adjacent to the southwest portion of the tailings pile.

HEC-2 simulations 5 and 6 were performed to evaluate an additional possible scenario of rocks entering the channel. For these simulations, the 500 CY of rocks were distributed on the natural side of channel cross sections 5.0, 5.1, 5.2, and 6.0 from the lowest point the channel cross section to an elevation of approximately 4030 ft. Flow is supercritical in these sections. Attachment D illustrates how the rocks were incorporated into channel cross sections 5.0, 5.1, 5.2, and 6.0.

HEC-2 output from simulations 3, 4, 5, and 6 are contained in Attachment E. Depth of flows computed by HEC-2 for these simulations are presented in Table 5. Comparing the depths of flow from simulations 1 and 2 to those of simulations 3, 4, 5 and 6, it is seen that by accounting for the effects of rocks entering the channel, the depth of flow in the channel increases on the average approximately 1.2 feet. The maximum predicted increase in depth of flow was observed in cross section 4.1. The depth of flow at this section increased 1.8 ft from a depth of 6.6 ft with no rocks in the channel to a depth 8.4 ft when rocks were placed between sections 4.0 and 5.0. Accordingly, the tailings embankment riprap was extended by 1.8 ft above PMF depth calculated with no rocks in the channel as shown in Figure 2 and discussed in the riprap volume calculations.

D_{50} Riprap Sizing Analysis

After determining the depth of flow at selected channel cross sections from the HEC-2 simulations, the D_{50} riprap sizes to protect the southwest tailings embankment were determined by the COE riprap sizing method. Detailed calculations of the COE method are contained in Attachment F using depths of flow computed from each of the HEC-2 simulations. Table 6 summarizes the results of the calculations in Attachment F. The minimum raw D_{50} values which were adequate to withstand a PMF flow down the natural SWRDC are presented in Table 6 for each of the HEC-2 simulations. Also presented on Table 6 are the recommended D_{50} sizes to protect the southwest tailings embankment based on comparing the results of the each of the HEC-2 simulations.

A 9" D_{50} riprap size (oversized) is recommended from HEC-2 cross sections 1.0 through 5.0 (start of the natural reach of the SWRDC to station 10+00) and from HEC-2 cross sections 6.5 through 10.0 (station 12+00 through 18+15). The 9" was selected for all sections except those between sections 5.0 and 6.0 as a conservative recommendation due to uncertainties in how and where rocks may enter the channel. When rocks were placed in HEC-2 sections 4.0, 4.1, 4.2, and 5.0 (Simulations 3 and 4) the necessary raw D_{50} size increased from 4.9 and 8.8 in section 4.1 and 4.2. It is conceivable that a similar increase in D_{50} size could occur had rocks been placed in sections 1.0, 2.0 and 3.0.

A 17.4" D_{50} riprap size (oversized) is recommended from HEC-2 cross sections 5.0 and 6.0 (station 10+00 to station 12+00). The 17.4" D_{50} was selected for the channel reach between sections 5.0 and 6.0 because flow in these sections is supercritical and velocities are higher than those encountered under subcritical flow. Also, the raw D_{50} riprap sizes in sections 5.0 and 5.1 increased from 8.8" to 17.04" when rocks were placed in these sections. Therefore, 17.4" D_{50} is recommended between sections 5.0 and 6.0.

Scour Calculations

Depth of scour must be estimated to determine the depth the riprap toe protection should extend below the existing grade. To estimate the scour depth resulting from the PMF flow of 1605 cfs in the SWRDC, the applicable methods listed in Pemberton (1984) (see Attachment A for excerpts) will be used. Specifically, equations for riprap bank slope protection will be applied. Velocities from the HEC-2 simulations 1 and 2 (before the introduction of rocks into the channel) will be used to compute the depth of scour. The selected depth of scour methods are summarized below:

Method 1. Field Measurement of Scour.

$d_s = K (q)^{0.24}$ (eq. 24 in Attachment A)

where

$K = 2.45$ (constant)

q = discharge (ft^3/s) / topwidth of channel flow (ft). Total PMF discharge in SWRDC is 1605 cfs. Topwidth of channel flow for the channel cross sections are given as part of the HEC-2 output in Attachment C.

Method 2. Regime Equation by field measurement

a. Lacey Empirical Equation:

$d_m = 0.47 (Q/f)^{1/3}$ (eq. 26 in Attachment A)

where

Q = design discharge, cfs

f = Lacey silt factor = $1.76\ D_m^{\ 1/2}$ where D_m = mean grain size of bed material. A D_m of 2 mm is assumed based on grain size of soil material which will be scoured.

$d_s = Z\ d_m$ where $Z = .25$ straight bends.

b. Blench Equation for zero bed factor.

$d_{fo} = (q_f)^{2/3}/F_{bo}^{\ 1/3}$ (eq. 27 in Attachment A)

where

d_{fo} = depth for zero bed sediment transport, ft

q_f = design flood discharge per unit width (same as q in method 1)

F_{bo} = Blench's zero bed factor in ft/s^2. From Figure 9 in Attachment A using $D_m = 2.0$ mm, $F_{bo} = 2.2$ ft/s^2

$d_s = z\ d_{fo}$ where $z = 0.6$ for straight bends.

Method 3. Mean Velocity Method from field measurements:

$d_s = d_m Z$

where

d_m = mean channel depth, ft = area of flow (ft^2)/topwidth of flow (ft)

z = defined above as for method 2a.

Method 4. Competent or limiting control to scour method:

$d_s = d_m\ (V_m/V_c - 1)$ (eq. 32 Attachment A)

where

d_s = scour depth, ft

d_m = mean depth as defined above in Method 3.

V_m = mean velocity, ft/s = Q/A

V_c = competent velocity, ft/s ≈ 3 ft/s (Fig. 12 in Attachment A using bed material size of 2 mm on the figure and depth of flow of 5 ft.)

Scour depth calculations for each of the channel cross sections are summarized in Table 7. The final scour depth is computed by averaging scour depths from each of the methods. From the literature supplied in Attachment A, methods 1 and 4 presented above may not be entirely applicable because these methods are more applicable for channels with coarser bed size material. However, by using all four methods, the final averaged scour depth result is slightly more conservative.

Using the final averaged scour depths at each channel cross (Page 3 of Table 7), the depth of riprap toe protection below grade was computed. The riprap toe protection was designed to extend 1.5 times the estimated depth of scour below the existing grade as recommended in NUREG/CR-4480 (see Attachment A for excerpts). Table 2 summarizes the riprap invert elevation computed by subtracting 1.5 times the scour depth from the channel invert elevation and Figure 2 illustrates the placement of the riprap toe protection.

Volume of Riprap Calculations

Vertically, the riprap erosion protection was placed 1.5 times the scour depth below the existing grade and 1.8 feet plus the PMF depth (with no rocks in the channel) above the existing grade as shown in Figure 2. The 1.8 feet above PMF depth was the maximum predicted increase in depth of flow in the channel when rocks were placed in the channel and is shown on Table 5. Volume of the riprap designed to withstand flows in the upper reach of SWRDC along the base of the tailings pile side of the channel was determined by multiplying the width of the riprap by the length of the riprap by the thickness of the riprap layer. Table 1 summarizes the riprap volume calculations. Two riprap filters are required for the 9" and 17.4" D_{50} riprap gradations. Volume of filter material for the filters are also shown on the table.

A corresponding volume of riprap and filter material for the previously designed trapezoidal channel is shown on Table 3. The trapezoidal channel requires slightly more overall material to construct. Also, it is anticipated that construction costs would be higher to build the trapezoidal channel than the natural channel.

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By JWS Date 5/10/94 Subject Riprap Size Design Natural Sheet 17 of 31
Chkd By UAP Date 5/20/94 Southwest Channel - Atlas Proj No 88-067-12

REFERENCES

Response to NRC Comments Atlas Corporation Reclamation Plan, Uranium Mill and Tailings Disposal Area, April 1993 Canonie Environmental Report.

Atlas Corporation Reclamation Plan, Uranium Mill and Tailings Disposal Area, June 1992 Canonie Environmental Report.

Lindeburg, M.R, 1992, "Civil Engineering Reference Manual", Professional Publications Inc.

Linsley R.K, Kohler M., and Pahulhus J., Hydrology for Engineers, 1982, Third Edition, McGraw Hill

NUREG/CR-4480, 1986, " Erosion Protection of Uranium Tailings Impoundments", U.S. Nuclear Regulatory Commission

NUREG/CR-4620, June 1986, "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments", U.S. Nuclear Regulatory Commission

Pemberton, E.L., and Lara, J.M., 1984 "Computing degradation and local scour", Bureau of Reclamation, Denver, CO., January, 1984

U.S. Army Corps of Engineers, "Hydraulic Design of Flood Control Channels", EM 1110-2-1601, July 1970

U.S. Army Corps of Engineers, September 1990 (Revised February 1991), "HEC-2 Water Surface Profiles" Hydrological Engineering Center, Davis, CA.

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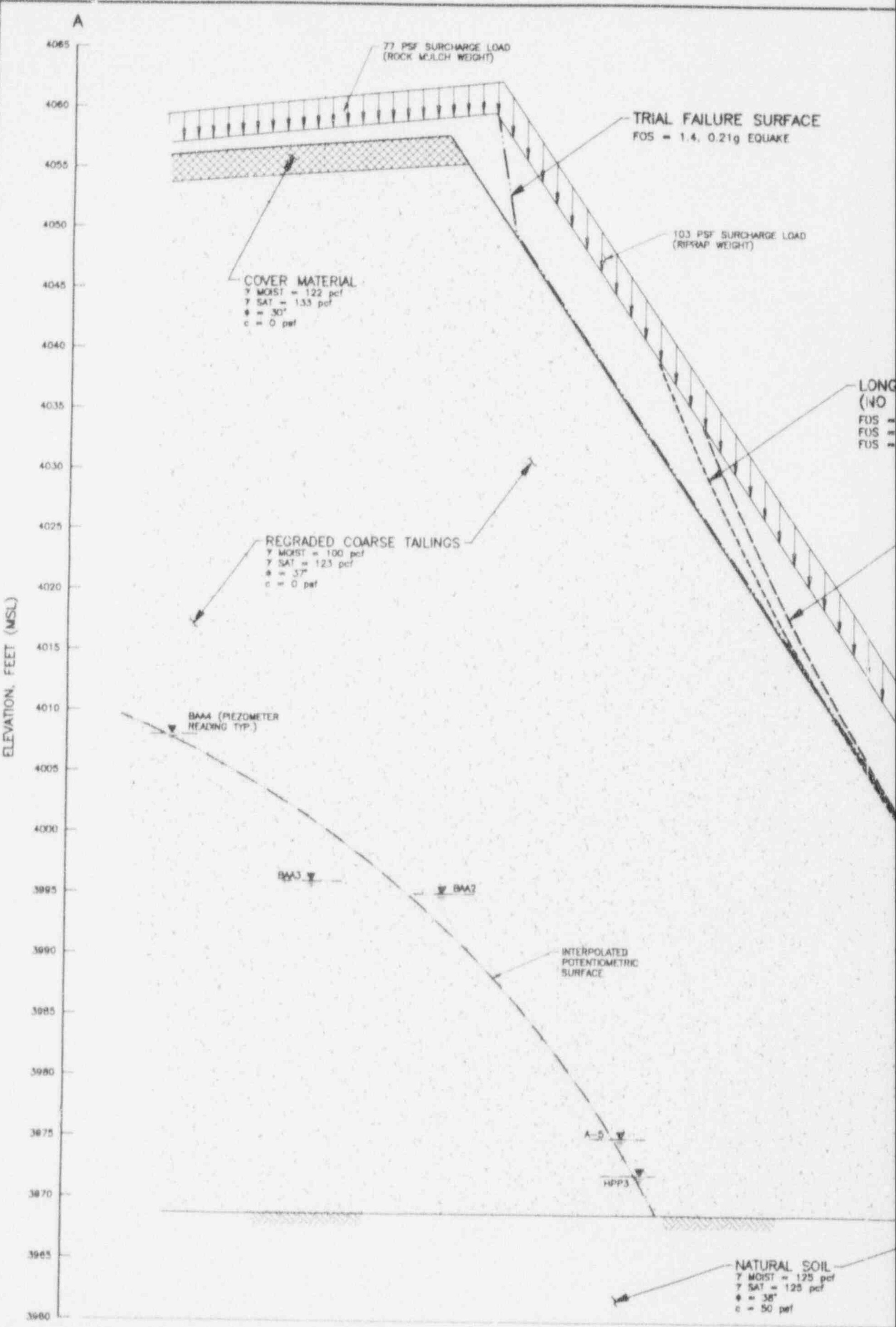
By JWS Date 5/10/94 Subject Riprap Size Design Natural Sheet 18 of 31
Chkd By WAP Date 5/20/94 Southwest Channel - Atlas Proj No 88-067-12

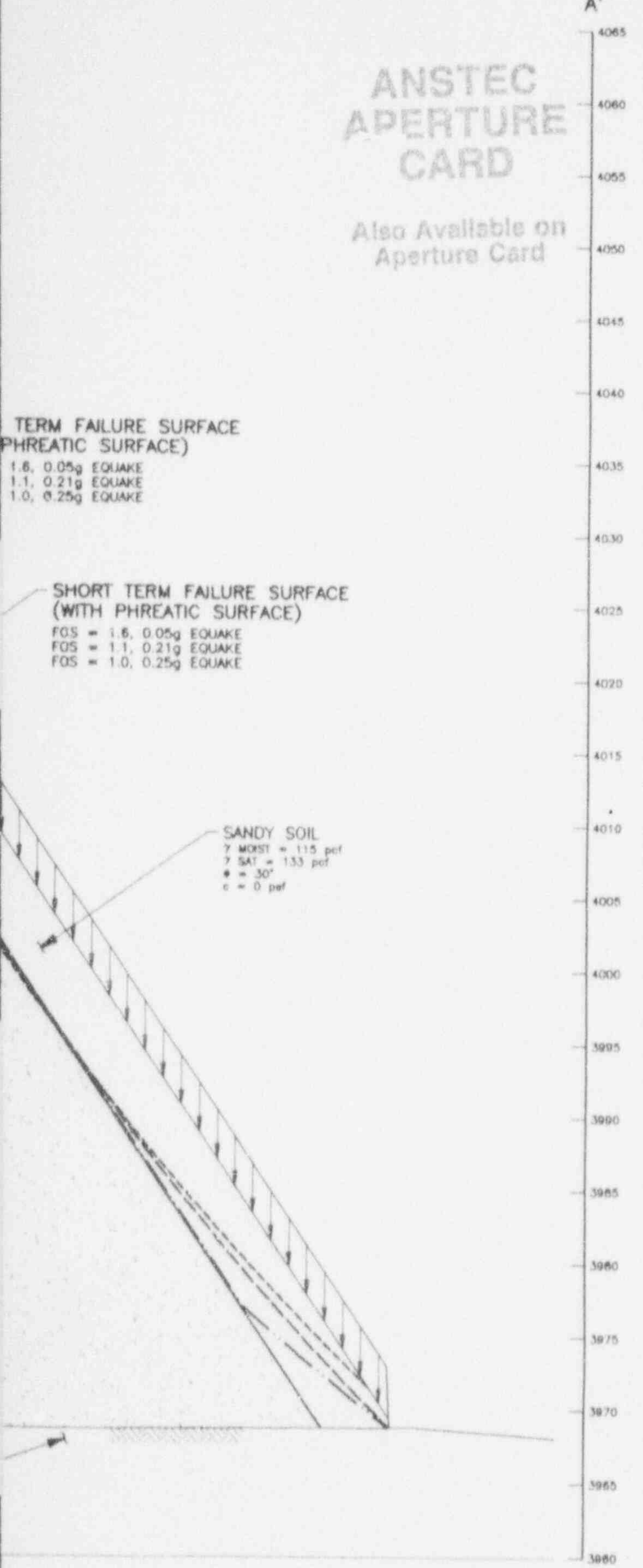
FIGURES

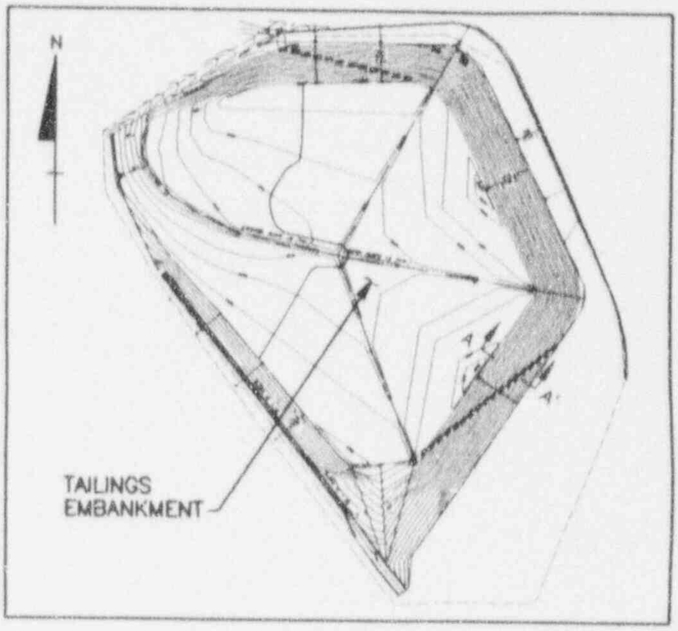
DRAWING NUMBER 88-067-E88



No.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY
△	5/21/94	ISSUED FOR RESPONSE TO NRC COMMENTS	M.T.H.	JWS	

SECTION A-A'





KEY MAP
NOT TO SCALE

LEGEND:

FOS	FACTOR OF SAFETY AGAINST INSTABILITY
0.05g EQUAKE	HORIZONTAL EARTHQUAKE ACCELERATION
γ MOIST	MOIST UNIT WEIGHT OF SOIL MATERIAL
γ SAT	SATURATED UNIT WEIGHT OF SOIL MATERIAL
c	COHESION OF SOIL MATERIAL
φ	ANGLE OF INTERNAL FRICTION OF SOIL MATERIAL
↓↓↓↓	SURCHARGE LOAD

NOTES:

1. LOCATION OF GENERALIZED CROSS SECTION A-A' IS SHOWN ON KEY MAP, THIS DRAWING.
2. POTENTIOMETRIC SURFACE BASED ON WATER ELEVATIONS IN PIEZOMETERS ON OCTOBER 30, 1993 PROVIDED BY ATLAS CORPORATION.

VERTICAL SCALE
5 0 5 10 FEET

HORIZONTAL SCALE
25 0 25 50 FEET

VERTICAL EXAGGERATION = 5X

CRITICAL FAILURE SURFACES
ATLAS RECLAIMED TAILINGS EMBANKMENT
STABILITY ANALYSIS
PREPARED FOR

ATLAS CORPORATION

CanonieEnvironmental

DATE: 12-7-93	FIGURE 1	DRAWING NUMBER 88-067-E88	△
SCALE: AS SHOWN			

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DRAWING NUMBER 88-067-E95

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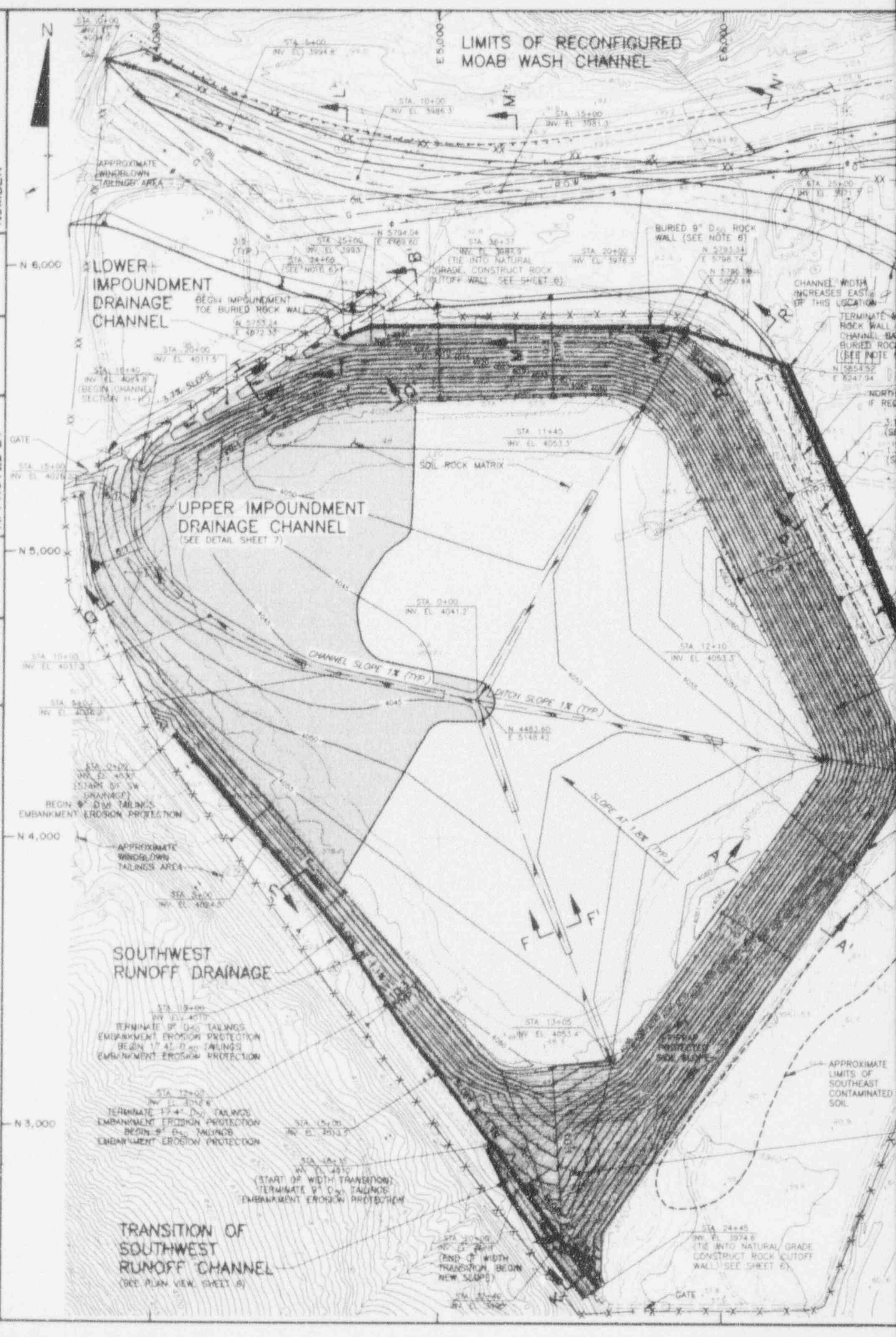
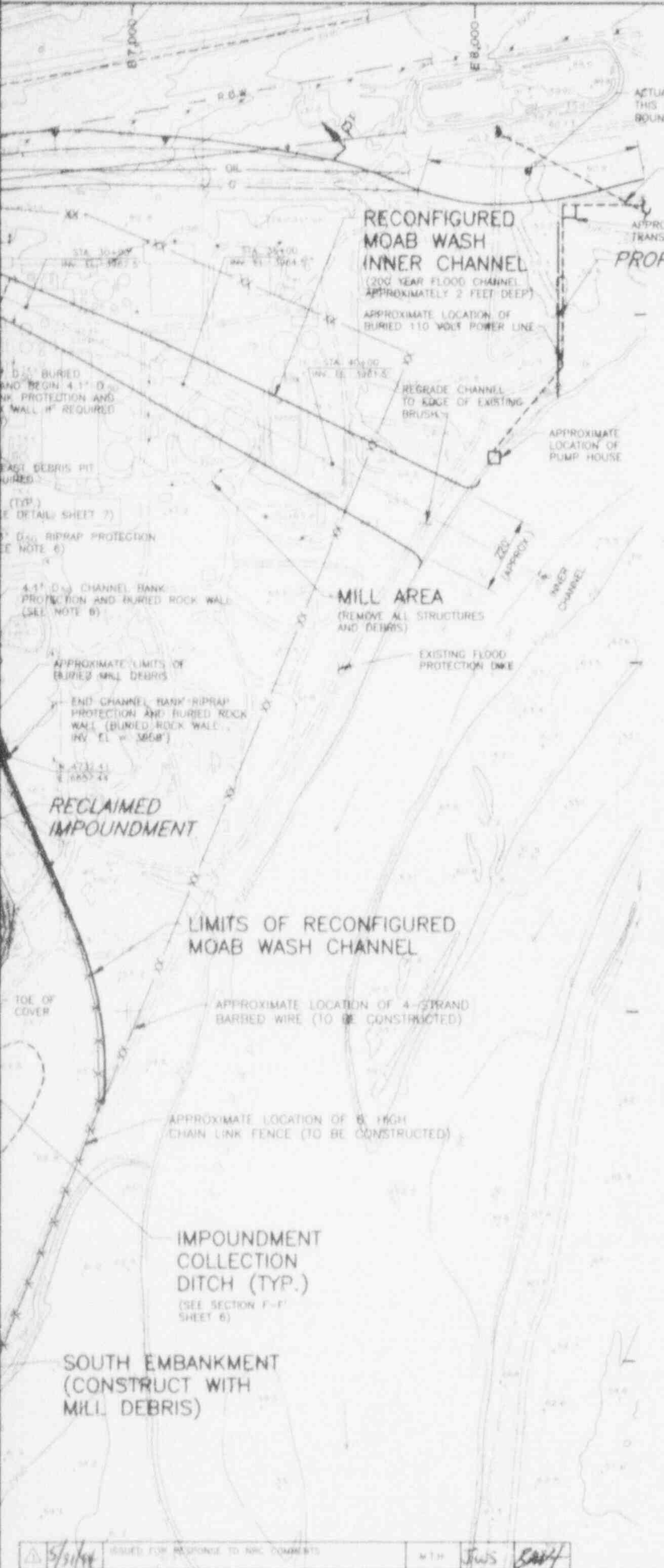
APPROVED BY

DRAWN BY





LEGEND:

——4000——	RECLAIMED IMPOUNDMENT DESIGN CONTOURS, FEET
——4050——	EXISTING TOPOGRAPHIC CONTOURS, FEET
→ — →	DRAINAGE DITCH LOCATION AND DIRECTION OF FLOW
— — — —	APPROXIMATE CONTEL AERIAL AND BURIED TELEPHONE CABLES
——ø——	APPROXIMATE UTAH POWER AND LIGHT 69 kv AERIAL POWER LINE
········	APPROXIMATE UTAH POWER AND LIGHT 12 kv UNDERGROUND CABLE
——R.O.W.——	APPROXIMATE HIGHWAY RIGHT OF WAY
——OIL——	APPROXIMATE 10" ø MIDAMERICAN PIPE COMPANY LIQUID LINE
——G——	APPROXIMATE 26" ø NORTHWESTERN NATURAL GAS LINE
▨	LIMITS OF 1.3" D_{50} SOIL/ROCK MATRIX
▨	RIPRAP
▨	LIMITS OF 3.0" D_{50} SOIL/ROCK MATRIX
▨	LIMITS OF 1.3" D_{50} RIPRAP PROTECTION OVER NORTHEAST DEBRIS PIT (SEE NOTE 6)

NOTES:

1. FOR CROSS SECTIONS SEE SHEETS 5, 6 AND 7.
2. FLOOD PROTECTION DIKE, WINDBLOWN TAILINGS, AND ORE STOCKPILES SHALL BE REMOVED AND USED AS REGRADING FILL FOR THE TAILINGS IMPOUNDMENT, PRIOR TO SOIL COVER PLACEMENT.
3. AFFECTED SOILS SHALL BE EXCAVATED AND PLACED OVER REGRADED TAILINGS ON IMPOUNDMENT TOP PRIOR TO SOIL COVER PLACEMENT.
4. REVEGETATE ALL EXPOSED DISTURBED SOIL.
5. DISPOSE OF MILL DEBRIS IN SOUTH EMBANKMENT AND NORTHEAST DISPOSAL PIT. DEBRIS SHALL BE DISPOSED OF IN SOUTH EMBANKMENT AREA INITIALLY.
6. BEGIN BURIED 9" D_{50} ROCK WALL AT STA. 24+60 OF THE LOWER IMPOUNDMENT DRAINAGE CHANNEL (EAST BANK). TERMINATE BURIED 9" D_{50} ROCK WALL AT LOCATION SHOWN ON THIS SHEET. CONSTRUCT 4.1" D_{50} CHANNEL BANK PROTECTION AND BURIED ROCK WALL AND PLACE 1.3" D_{50} RIPRAP OVER NORTHEAST DEBRIS PIT AT THE LOCATIONS SHOWN ON THIS SHEET <u>ONLY</u> IF NORTHEAST DEBRIS PIT IS USED FOR DISPOSAL OF DEBRIS. SEE SHEET 7 FOR DETAILS AND CROSS SECTIONS. IF NORTHEAST DEBRIS PIT IS NOT CONSTRUCTED, EXTEND ROCK ARMOR AS SHOWN ON SECTION A-A' TO MEET 9" D_{50} BURIED WALL.

SCALE
200 0 200 400 FEET

PLAN VIEW OF RECLAIMED IMPOUNDMENT

PREPARED FOR

ATLAS CORPORATION
DENVER, COLORADO

Canonie Environmental

△	5/31/94	ISSUED FOR RESPONSE TO NRC COMMENTS	MTH	JWS	SAW
No.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

88-067-E14

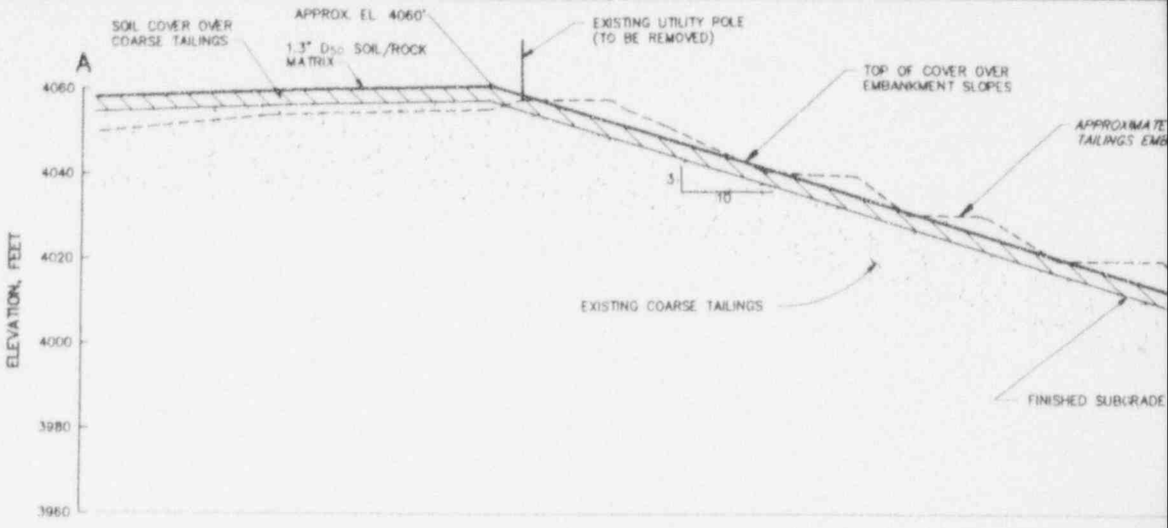
DATE: 5-19-94 SCALE: AS SHOWN	SHEET 4 of 10	DRAWING NUMBER 88-067-E95 △

88-067-E14

9406060234-02

DRAWN BY	R.H.	CHECKED BY	P.E.C.	8-4-88
	7-23-88	APPROVED BY	O.P.W.	8-4-88

DRAWING NUMBER 88-067-E19



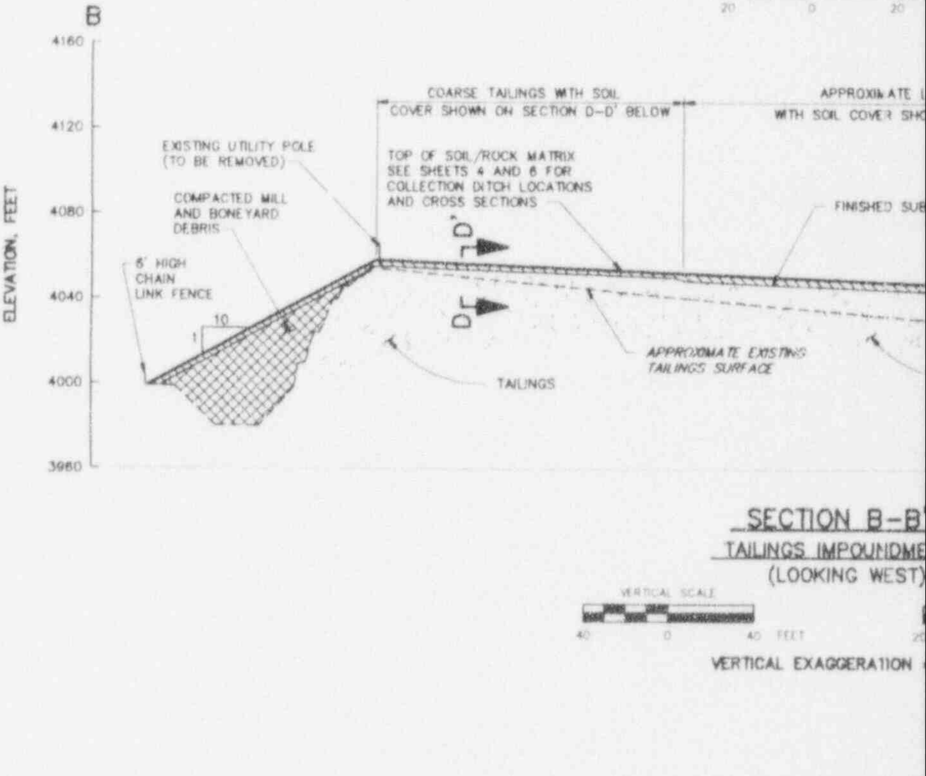
CROSS SECTION

TYPICAL EMBANKMENT

(LOOKING NORTHEA

SCALE

20 0 20



SECTION B-B'

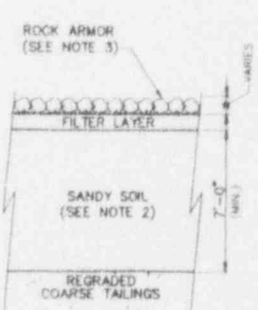
TAILINGS IMPOUNDME

(LOOKING WEST)

VERTICAL SCALE

40 0 40 FEET

VERTICAL EXAGGERATION

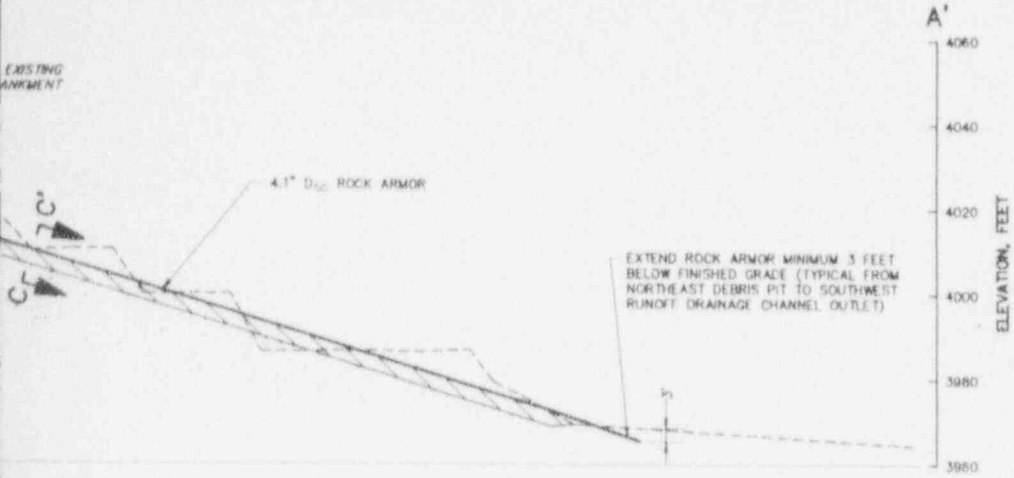


SECTION C-C'

COVER PROFILE ON EMBANKMENT

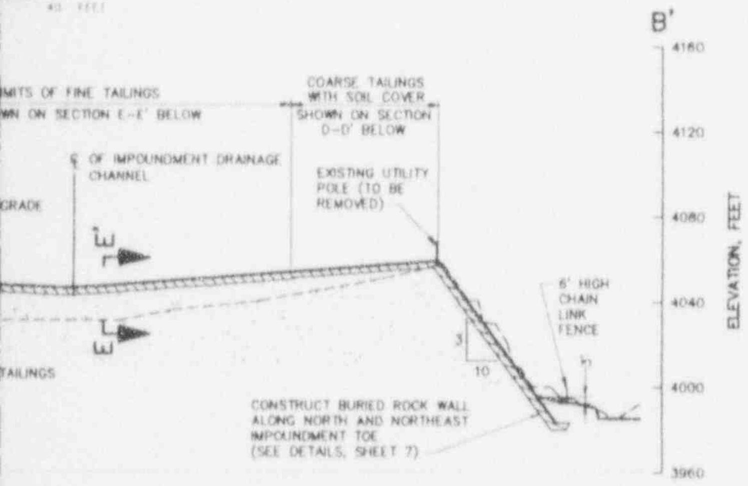
NOT TO SCALE

No.	DATE	ISSUE NUMBER / REVISIONS	DWN. BY DATE	CK'D BY DATE	AP'D BY DATE
6	5/31/94	ISSUED FOR RESPONSE TO NRC COMMENTS	D.J.R. 5-31-94	JWS 5/31/94	BEW 5/31/94
5	10-5-93	ISSUED TO COMPLY WITH NRC LICENSE No. 41 NOT FOR CONSTRUCTION	P.M.W. 8-31-93	J.W.S. 10-5-93	D.P.W. 10-5-93
4	4-15-93	ISSUED FOR RESPONSE TO NRC COMMENTS	S.C.G. 5-26-92	J.W.S. 4-15-93	D.W.K. 4-15-93
3	6-1-92	ISSUED FOR REVISED RECLAMATION PLAN	K.M.S. 5-26-92	J.W.S. 6-3-92	D.W.K. 6-3-92
2	1-18-89	REVISED FOR RECLAMATION PLAN	R.H. 1-11-89	D.H.G. 1-16-89	D.P.W. 1-16-89
1	8-4-88	ISSUED AS ENGINEER'S REPORT RECLAMATION PLAN URANIUM MILL AND TAILINGS DISPOSAL AREA	R.H. 7-30-88	P.E.C. 8-4-88	D.P.W. 8-4-88



A–A'
SLOPE
ST)

40 FEET

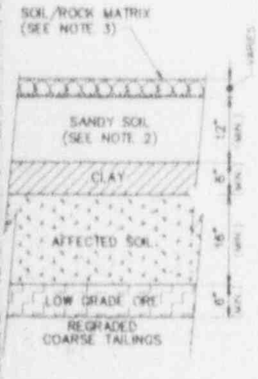


NT

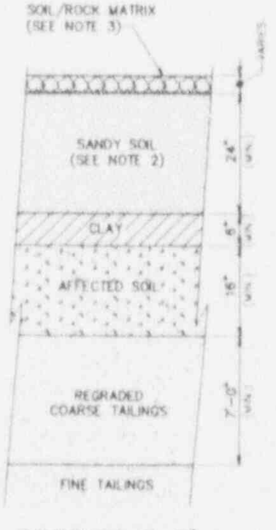
HORIZONTAL SCALE
0 0 200 FEET
= 5X

NOTES:

1. IF THE QUALITY OF THE ACTUAL ROCK BORROW SOURCE USED IS LESS THAN ASSUMED IN THE DESIGN, RIPRAP SIZE MUST BE CHANGED AND APPROVED BY THE NRC.
2. SANDY SOIL COVER THICKNESS WILL VARY BASED ON ACTUAL QUANITITY OF MATERIAL REMOVED FROM MOAB WASH DURING RECLAMATION.
3. SEE SPECIFICATIONS FOR ROCK ARMOR AND SOIL / ROCK MATRIX GRADATION AND THICKNESS.



SECTION D–D'
COVER PROFILE OVER
COARSE TAILINGS
NOT TO SCALE



SECTION E–E'
COVER PROFILE OVER
FINE TAILINGS
NOT TO SCALE

RECLAIMED IMPOUNDMENT
CROSS SECTIONS AND
SOIL COVER DETAILS
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DATE:	7-23-88	SHEET 5 of 10	DRAWING NUMBER 88-067-E19	REV. [illegible]
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DRAWING NUMBER 88-067-E96

DRAWN BY M.T.H. 5-18-94

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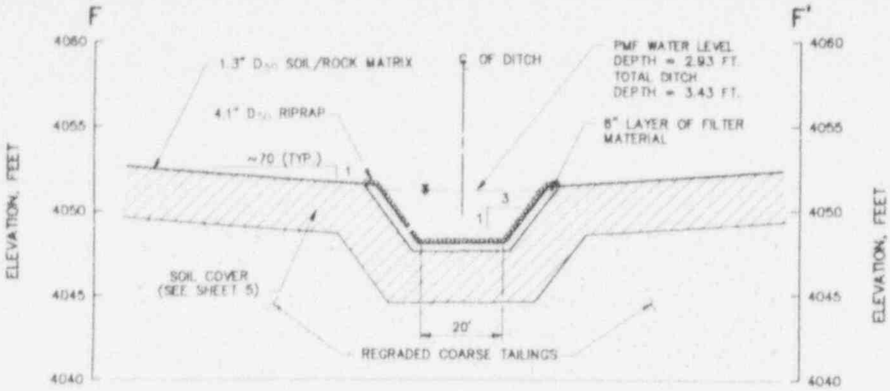


SECTION F-F'

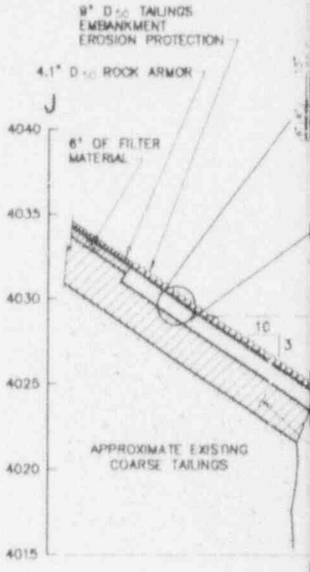
TYPICAL IMPOUNDMENT COLLECTION DITCH

(LOOKING NORTHWEST)

VERTICAL SCALE 5 0 5 FEET

HORIZONTAL SCALE 20 0 20 FEET

VERTICAL EXAGGERATION = 4X



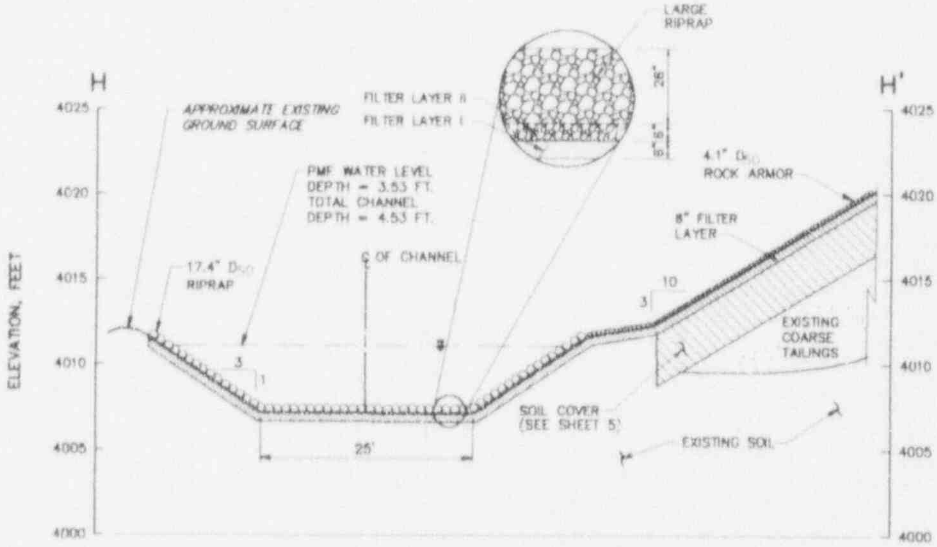
SE

SOUTHWEST RU

(LOO

VERTICAL SCALE 5 0

VERTICAL



SECTION H-H'

LOWER IMPOUNDMENT DRAINAGE CHANNEL

(LOOKING WEST)

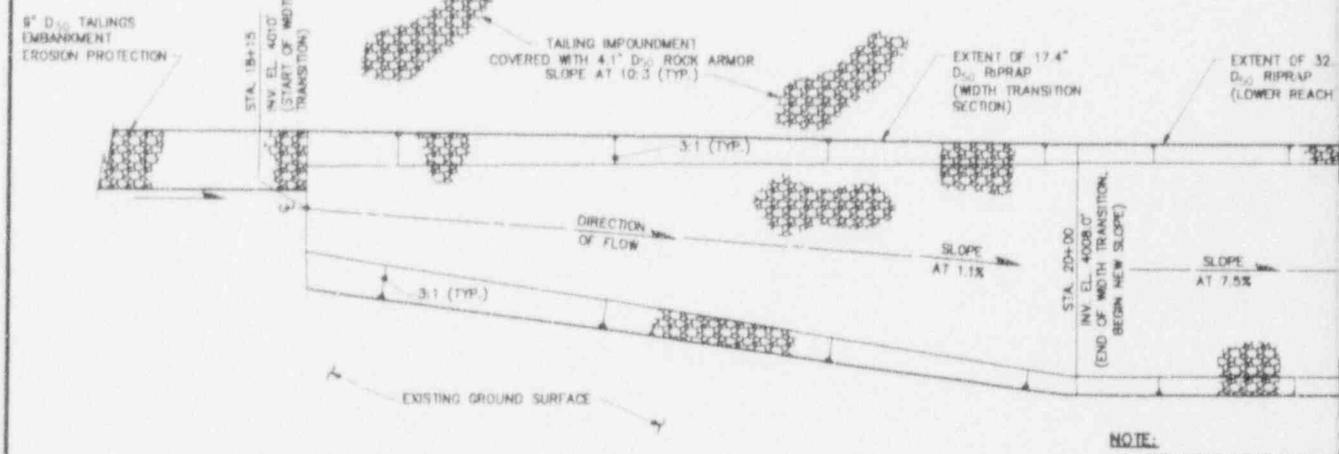
VERTICAL SCALE 5 0 5 FEET

HORIZONTAL SCALE 10 0 10 FEET

VERTICAL EXAGGERATION = 2X

SUMMARY OF CHAN
ROCK CUTOFF WAL

CHANNEL REACH	CHANNEL OUTLET CHA		
	BOTTOM WIDTH (FT.)	CHANNEL DEPTH (FT.)	CHAN SL (FT
IMPOUNDMENT DRAINAGE CHANNEL (LOWER REACH)	25	4.53	0.
SOUTHWEST RUNOFF DRAINAGE CHANNEL (LOWER REACH)	50	3.25	0.

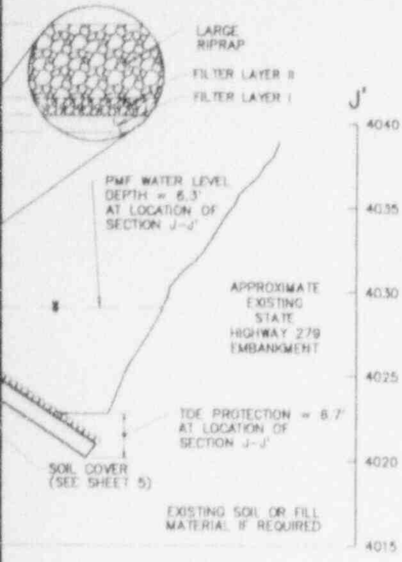


NOTE:

1. SEE SHEET 4 FOR PLAN LO

PLAN OF SOUTHWEST RUNOFF DRAINAGE CHANNEL TRANSITION

NOT TO SCALE

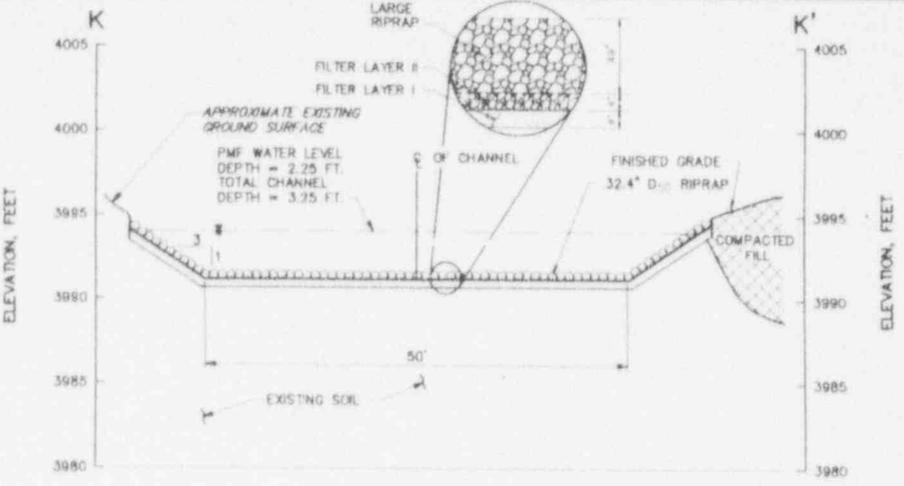


CTION J-J'

NOFF DRAINAGE CHANNEL

KING SOUTHEAST)

EXAGGERATION = 2X



SECTION K-K'

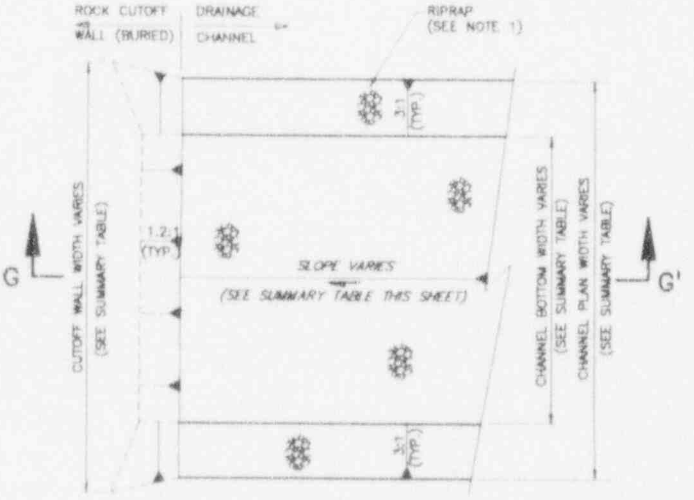
SOUTHWEST RUNOFF DRAINAGE CHANNEL

(LOOKING NORTHWEST)

VERTICAL EXAGGERATION = 2X

NNEL OUTLET AND
CHARACTERISTICS

RACTERISTICS		ROCK CUTOFF WALL CHARACTERISTICS		
NNEL PE FT.)	PLAN WIDTH OF CHANNEL (FT.)	RIPRAP ANGLE OF REPOSE (o)	DEPTH OF SCOUR (FT.)	WIDTH OF SCOUR (FT.)
37	49.2	42	5	48
15	63.5	42	8	64



PLAN

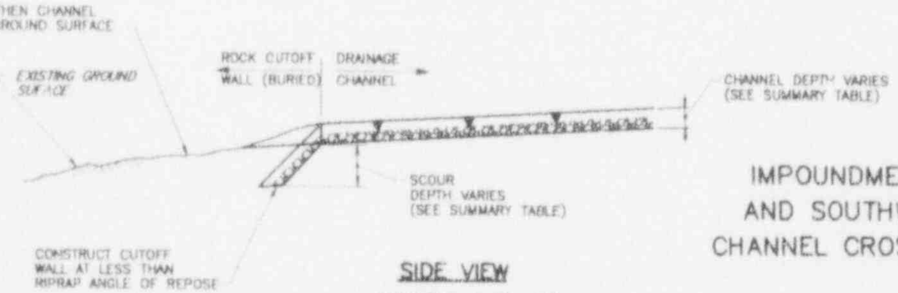
ROCK CUTOFF WALL (TYPICAL)

NOT TO SCALE
(SEE NOTE 5)

NOTES:

1. SEE SPECIFICATIONS FOR LARGE RIPRAP, INTERMEDIATE RIPRAP AND FILTER MATERIAL REQUIREMENTS. RIPRAP AND FILTERS ARE NOT SHOWN TO SCALE.
2. FOR PLAN LOCATION OF SECTIONS SEE SHEET 4.
3. DESIGN OF CHANNELS INCLUDES 12" FREEBOARD AND DESIGN OF COLLECTION DITCHES INCLUDES 6" FREEBOARD.
4. DITCH DIMENSION REPRESENTS WIDTH AND DEPTH OF CHANNEL AFTER PLACEMENT OF RIPRAP.
5. ROCK CUTOFF WALLS ARE TO BE CONSTRUCTED AT THE OUTLETS OF THE IMPOUNDMENT DRAINAGE CHANNEL AND SOUTHWEST RUNOFF CHANNEL. PLAN LOCATIONS ARE SHOWN ON SHEET 4.

CATION



SIDE VIEW

SECTION G-G'

NOT TO SCALE

IMPOUNDMENT DRAINAGE CHANNEL
AND SOUTHWEST RUNOFF DRAINAGE
CHANNEL CROSS SECTIONS AND DETAILS

PREPARED FOR

ATLAS CORPORATION
DENVER, COLORADO

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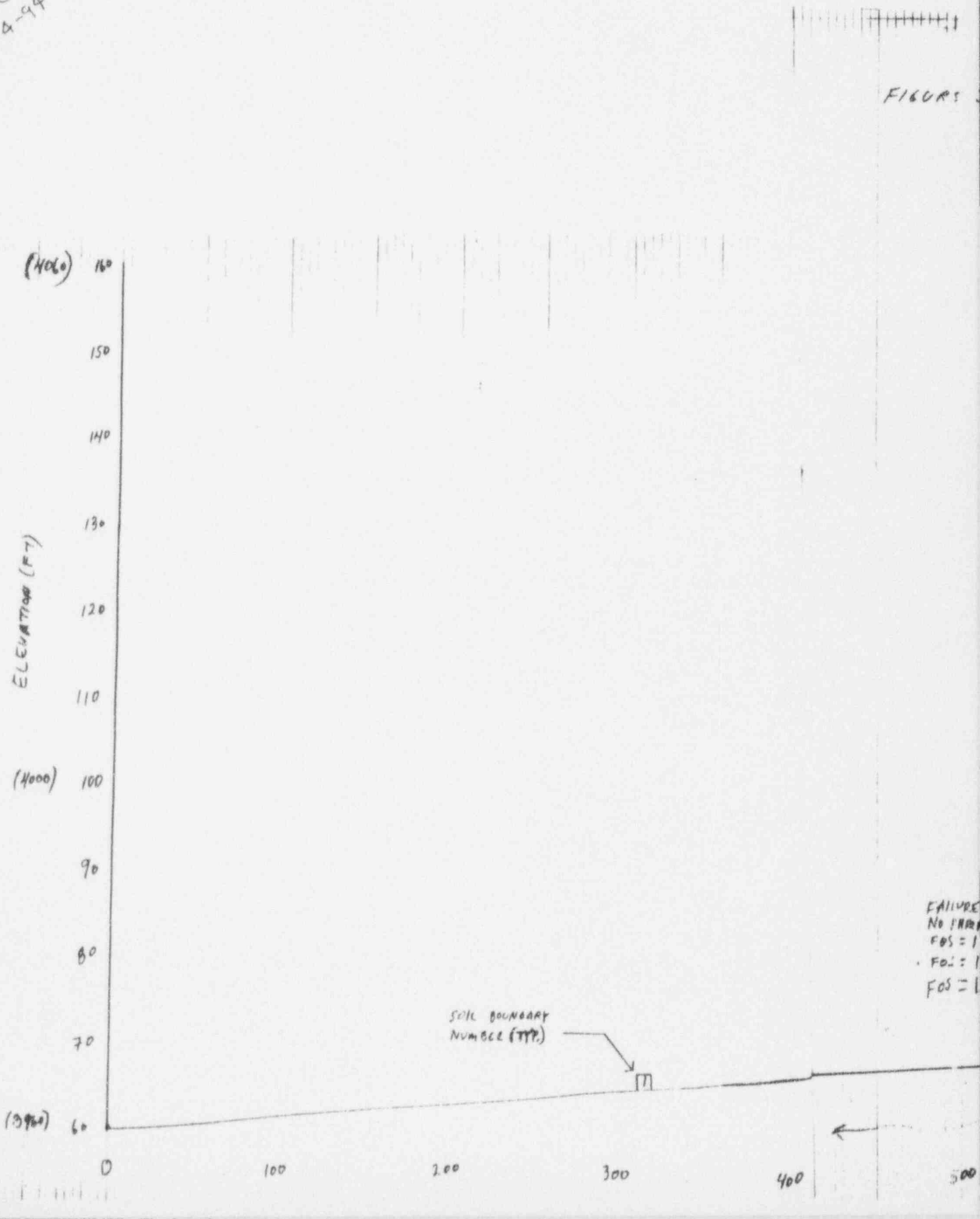
△	5/20/94	ISSUED FOR RESPONSE TO NRC COMMENTS	MTR	JWS	BWH
No.	DATE	ISSUE NUMBER / REVISIONS	DWN BY DATE	CK'D BY DATE	AP'D BY DATE

DATE: 5-18-94	SHEET 6 of 10	DRAWING NUMBER	REV.
SCALE: AS SHOWN		88-067-E96	△

9406060234-04

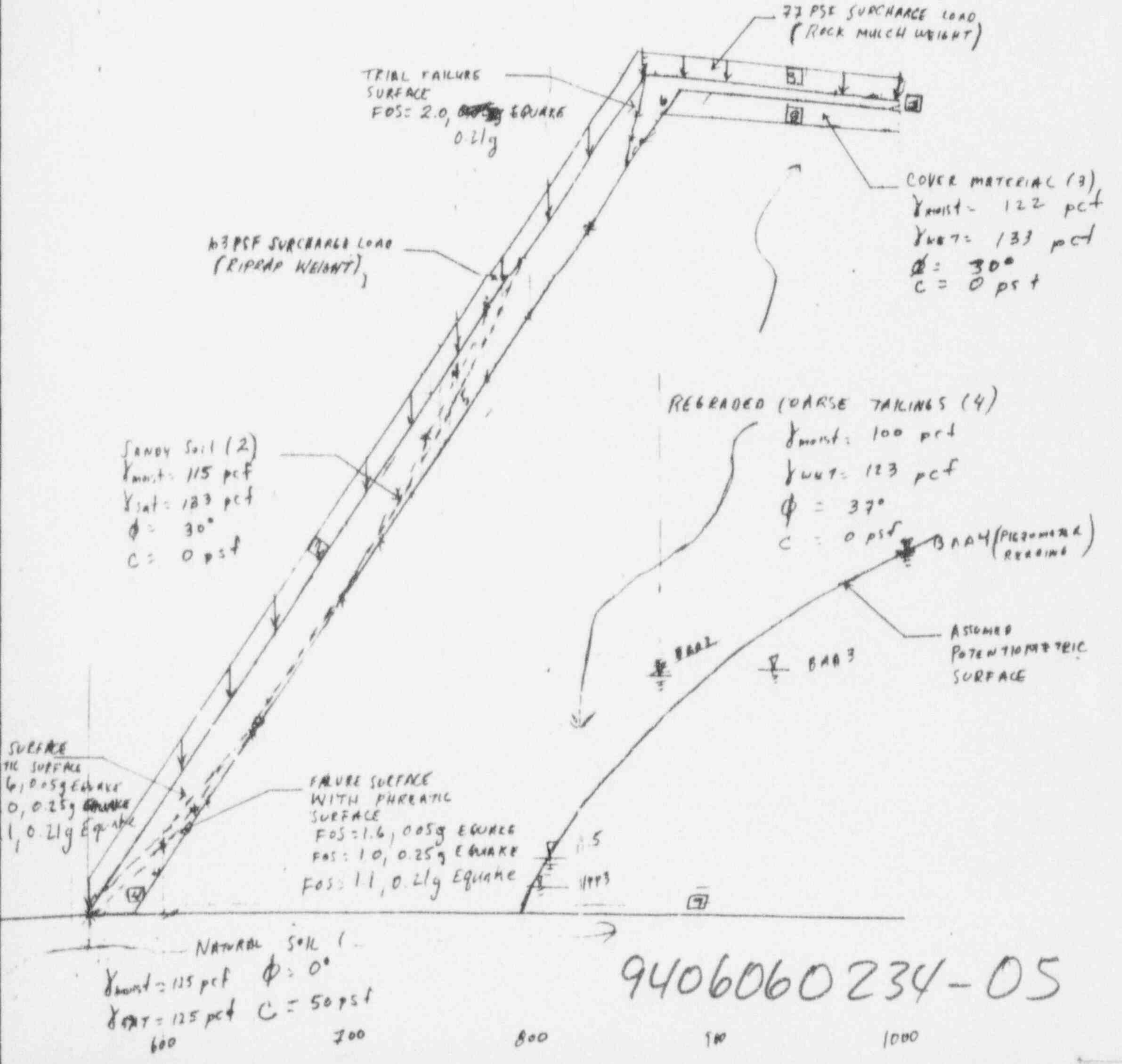
chkd by
PEC
1-4-94



FIGURE

13/59

3. GENERALIZED CROSS SECTION
ATLAS RECLAIMED TAILINGS IMPOUNDMENT
STABILITY ANALYSIS



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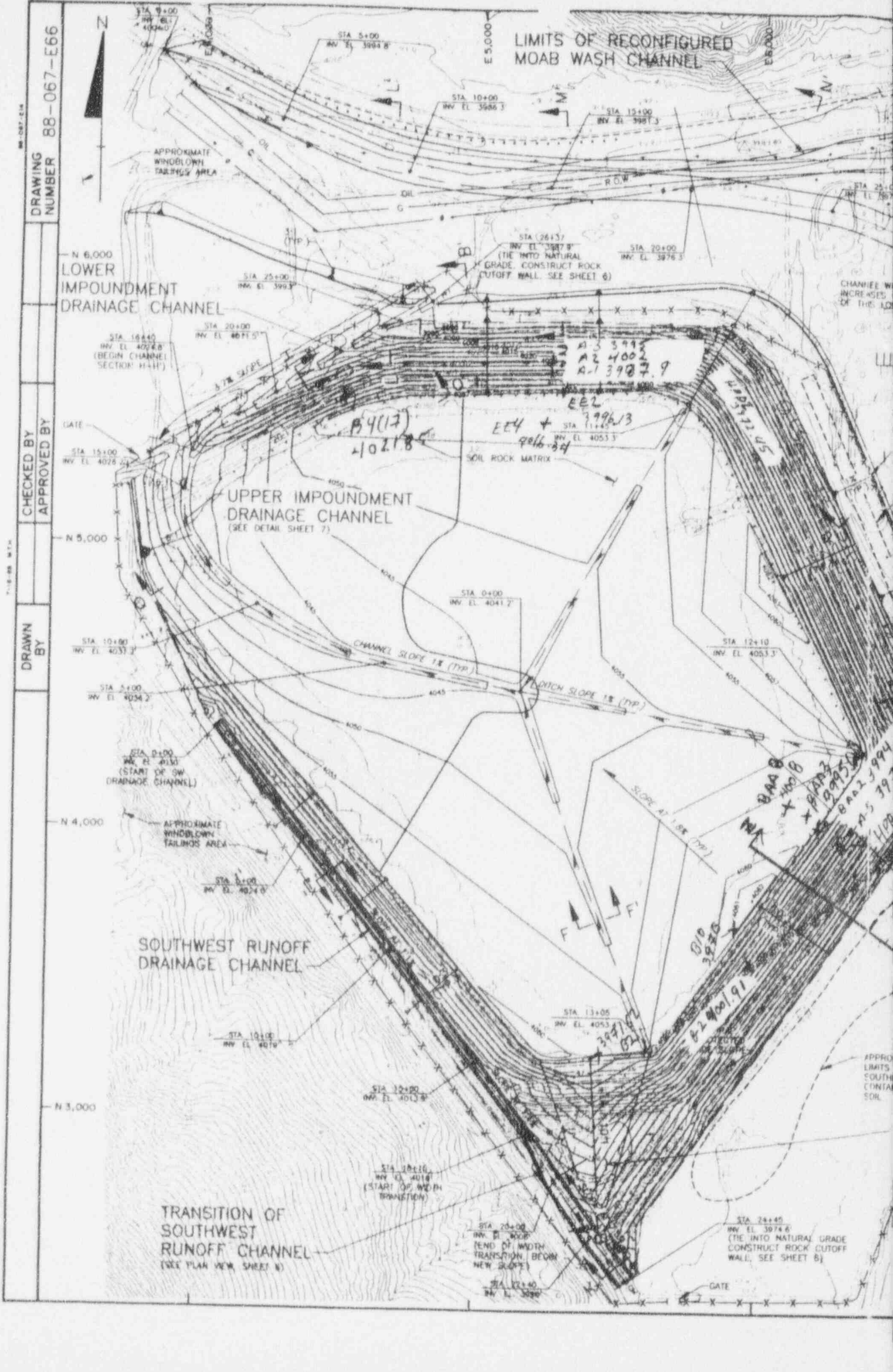
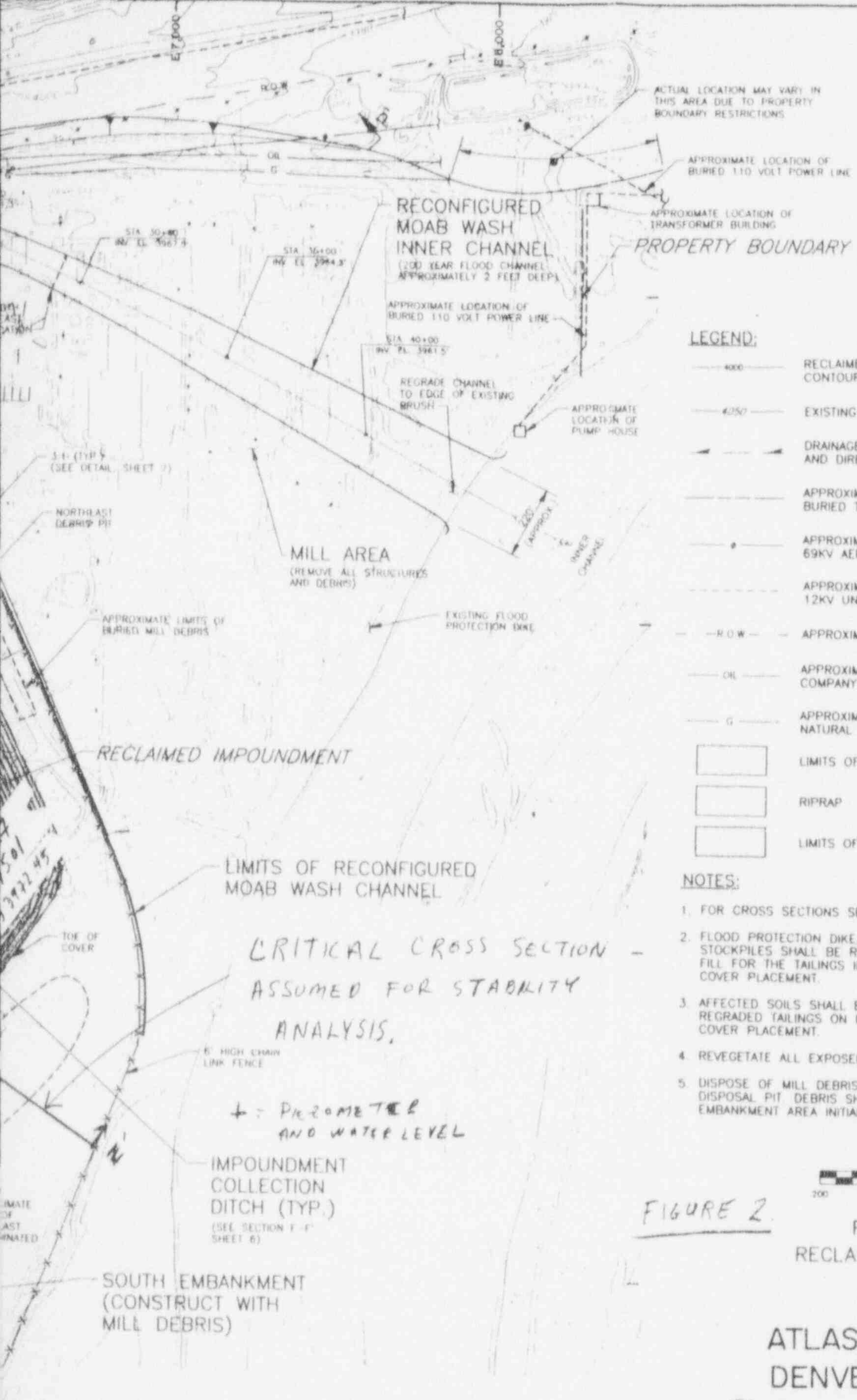
chd by
PEC
1-4-94



12/59



CRITICAL CROSS SECTION - ASSUMED FOR STABILITY ANALYSIS.

+ : PIEZOMETER AND WATER LEVEL

LEGEND:

——4000——	RECLAIMED IMPOUNDMENT DESIGN CONTOURS, FEET
——4250——	EXISTING TOPOGRAPHIC CONTOURS, FEET
◄— — ◄	DRAINAGE DITCH LOCATION AND DIRECTION OF FLOW
————	APPROXIMATE CONTEL AERIAL AND BURIED TELEPHONE CABLES
——•——	APPROXIMATE UTAH POWER AND LIGHT 69KV AERIAL POWER LINE
- - - -	APPROXIMATE UTAH POWER AND LIGHT 12KV UNDERGROUND CABLE
— —R.O.W.— —	APPROXIMATE HIGHWAY RIGHT OF WAY
——OIL——	APPROXIMATE 10" ø MIDAMERICAN PIPE COMPANY LIQUID LINE
——G——	APPROXIMATE 26" ø NORTHWESTERN NATURAL GAS LINE
☐	LIMITS OF 1.3" D_{50} SOIL/ROCK MATRIX
☐	RIPRAP
☐	LIMITS OF 3.0" D_{50} SOIL/ROCK MATRIX

NOTES:

1. FOR CROSS SECTIONS SEE SHEETS 5,6 AND 7.
2. FLOOD PROTECTION DIKE, WINDBLOWN TAILINGS, AND ORE STOCKPILES SHALL BE REMOVED AND USED AS REGRADING FILL FOR THE TAILINGS IMPOUNDMENT, PRIOR TO SOIL COVER PLACEMENT.
3. AFFECTED SOILS SHALL BE EXCAVATED AND PLACED OVER REGRADED TAILINGS ON IMPOUNDMENT TOP PRIOR TO SOIL COVER PLACEMENT.
4. REVEGETATE ALL EXPOSED DISTURBED SOIL.
5. DISPOSE OF MILL DEBRIS IN SOUTH EMBANKMENT AND NORTHEAST DISPOSAL PIT. DEBRIS SHALL BE DISPOSED OF IN SOUTH EMBANKMENT AREA INITIALLY.

SCALE
200 0 200 400 FEET

FIGURE 2

PLAN VIEW OF
RECLAIMED IMPOUNDMENT

PREPARED FOR

ATLAS CORPORATION
DENVER, COLORADO

Canonie Environmental

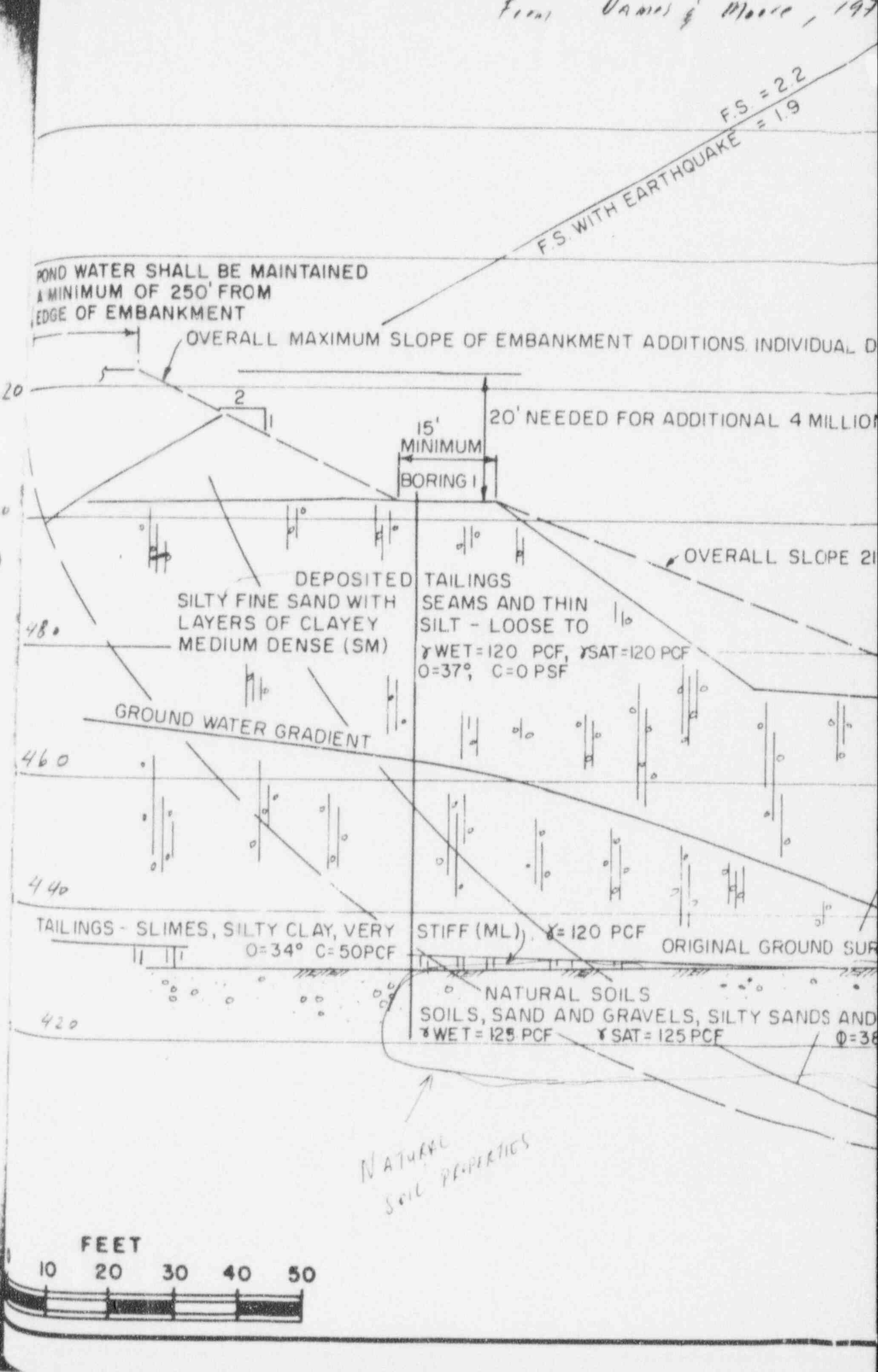
No	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY
△1	4-8-93	ISSUED FOR RESPONSE TO NRC COMMENTS	BKR		DLK

88-067-E14

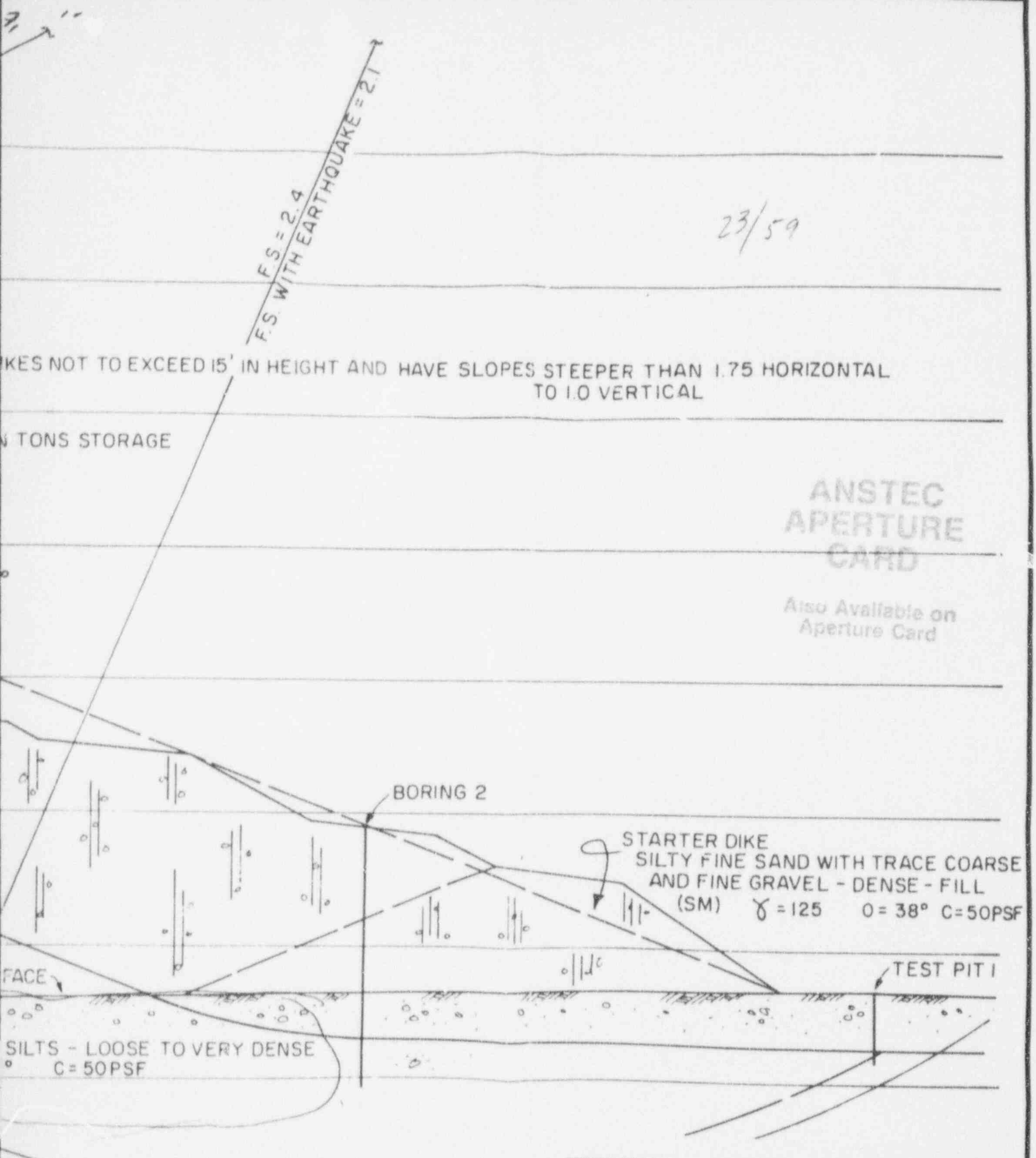
DATE: 4-7-93 SCALE: AS SHOWN	SHEET 4 of 10	DRAWING NUMBER 88-067-E66 △1 88-067-E14

From Dames & Moore, 197

per 1-4-94



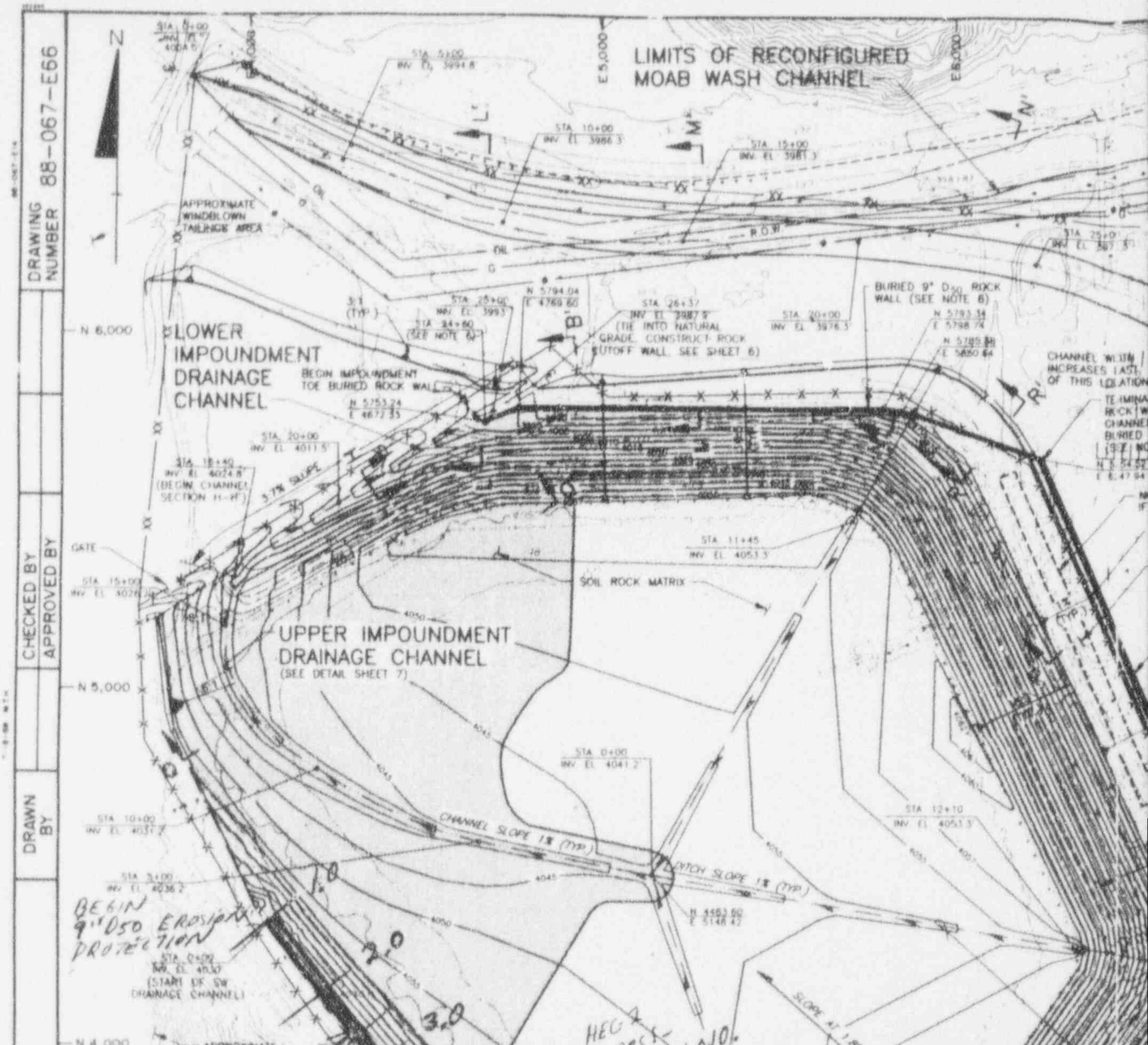
23/59



SAFETY ANALYSIS REPORT
ATLAS MINERALS DIVISION · ATLAS CORPORATION
MOAB URANIUM MILL

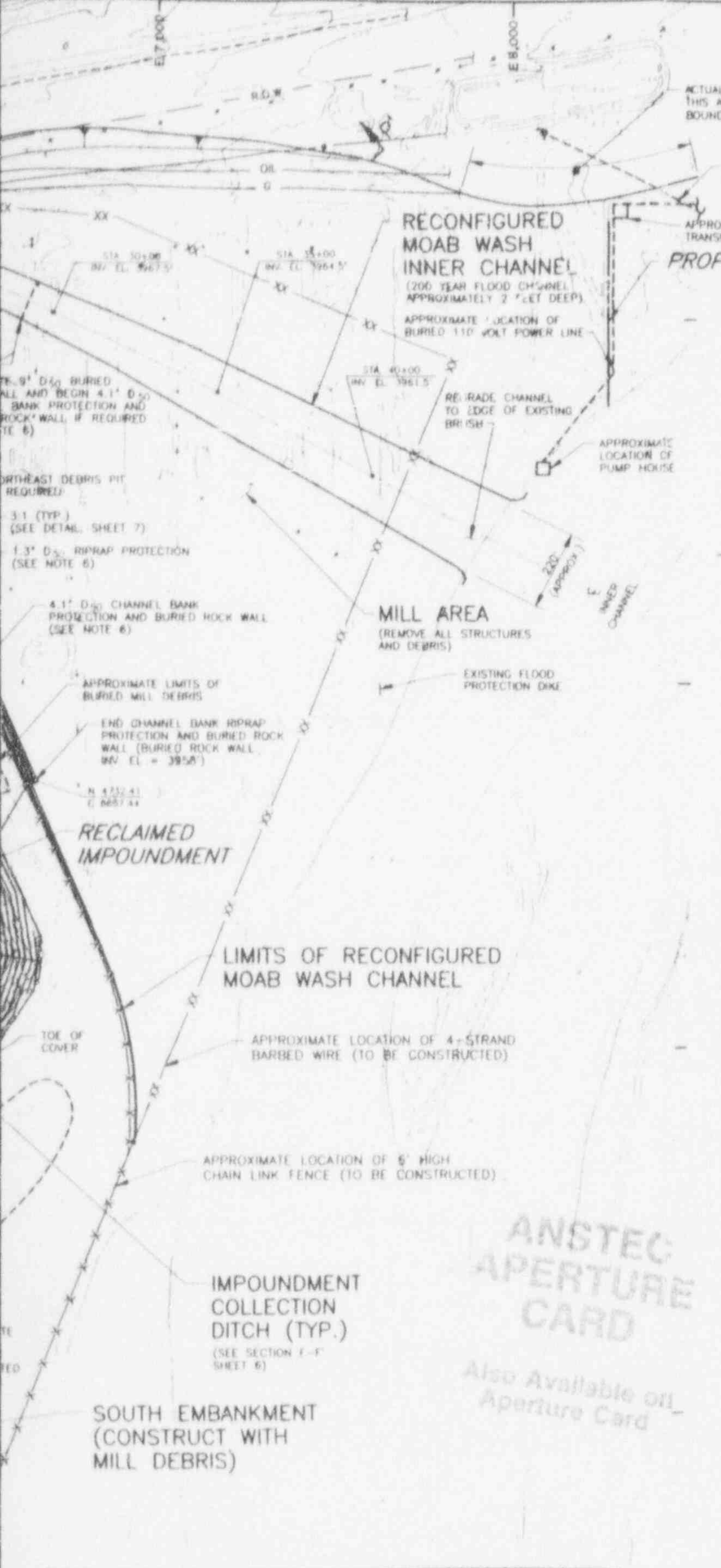
FIGURE 4.2-3
SUBSURFACE SECTION C-C'

9406060234-07



DRAWING NUMBER 88-067-E66
DRAWN BY
CHECKED BY
APPROVED BY
N
N 6,000
N 5,000
N 4,000
N 3,000
E 5,000
E 6,000
LIMITS OF RECONFIGURED MOAB WASH CHANNEL
LOWER IMPOUNDMENT DRAINAGE CHANNEL
UPPER IMPOUNDMENT DRAINAGE CHANNEL (SEE DETAIL SHEET 7)
SOUTHWEST RUNOFF DRAINAGE CHANNEL
TRANSITION OF SOUTHWEST RUNOFF CHANNEL (SEE PLAN VIEW, SHEET 6)
APPROXIMATE WINDBLOWN TAILINGS AREA
BEGIN IMPOUNDMENT TOE BURIED ROCK WALL
BURIED 9" D50 ROCK WALL (SEE NOTE 6)
STA 26+37 INV EL 3987.9 (TIE INTO NATURAL GRADE, CONSTRUCT ROCK CUTOFF WALL, SEE SHEET 6)
STA 24+45 INV EL 3974.6 (TIE INTO NATURAL GRADE CONSTRUCT ROCK CUTOFF WALL, SEE SHEET 6)
STA 0+00 INV EL 4041.2
STA 0+00 INV EL 4030 (START OF SW DRAINAGE CHANNEL)
STA 18+40 INV EL 4024.8 (BEGIN CHANNEL SECTION H-H')
STA 18+18 INV EL 4010 (START OF WIDTH TRANSITION)
STA 20+00 (END OF WIDTH TRANSITION, BEGIN NEW SLOPE)
STA 11+45 INV EL 4053.3
STA 12+10 INV EL 4053.3
STA 13+05 INV EL 4053.4
SOIL ROCK MATRIX
CHANNEL SLOPE 1% (TYP)
DITCH SLOPE 1% (TYP)
SLOPE AT 1.8% (TYP)
N 4463.60 E 5148.42
RIPRAP PROTECTED SIDE SLOPE
CHANNEL WIDTH INCREASES EAST OF THIS LOCATION
APPROXIMATE LIMITS OF SOUTHEAST CONTAMINATED SOIL
GATE
R.O.W.
F F'
A
BEGIN 9" D50 EROSION PROTECTION
9" D50 CHANNEL BANK EROSION PROTECTION
HEC-2 CROSS SECTION NO.
2.0
3.0
4.0
4.1
4.2
5.0
5.1
5.2
6.0
6.5
7.0
8.0
9.0
10.0
TERMINATE 9" D50 EROSION PROTECTION BEGIN 17.4" D50 EROSION PROTECTION
STA 12+00
TERMINATE 17.4" D50 EROSION PROTECTION BEGIN 9" D50 EROSION PROTECTION
TERMINATE 9" D50 EROSION PROTECTION

19/31



LEGEND:

4000	RECLAIMED IMPOUNDMENT DESIGN CONTOURS, FEET
4050	EXISTING TOPOGRAPHIC CONTOURS, FEET
	DRAINAGE DITCH LOCATION AND DIRECTION OF FLOW
	APPROXIMATE CONTEL AERIAL AND BURIED TELEPHONE CABLES
	APPROXIMATE UTAH POWER AND LIGHT 69 kv AERIAL POWER LINE
	APPROXIMATE UTAH POWER AND LIGHT 12 kv UNDERGROUND CABLE
R.O.W.	APPROXIMATE HIGHWAY RIGHT OF WAY
OIL	APPROXIMATE 10" ø MIDAMERICAN PIPE COMPANY LIQUID LINE
G	APPROXIMATE 26" ø NORTHWESTERN NATURAL GAS LINE
☐	LIMITS OF 1.3" D_{50} SOIL/ROCK MATRIX
☐	RIPRAP
☐	LIMITS OF 3.0" D_{50} SOIL/ROCK MATRIX
☐	LIMITS OF 1.3" D_{50} RIPRAP PROTECTION OVER NORTHEAST DEBRIS PIT (SEE NOTE 6)

NOTES:

1. FOR CROSS SECTIONS SEE SHEETS 5,6 AND 7.
2. FLOOD PROTECTION DIKE, WINDBLOWN TAILINGS, AND ORE STOCKPILES SHALL BE REMOVED AND USED AS REGRADING FILL FOR THE TAILINGS IMPOUNDMENT, PRIOR TO SOIL COVER PLACEMENT.
3. AFFECTED SOILS SHALL BE EXCAVATED AND PLACED OVER REGRADED TAILINGS ON IMPOUNDMENT TOP PRIOR TO SOIL COVER PLACEMENT.
4. REVEGETATE ALL EXPOSED DISTURBED SOIL.
5. DISPOSE OF MILL DEBRIS IN SOUTH EMBANKMENT AND NORTHEAST DISPOSAL PIT. DEBRIS SHALL BE DISPOSED OF IN SOUTH EMBANKMENT AREA INITIALLY.
6. BEGIN BURIED 9" D_{50} ROCK WALL AT STA. 24+60 OF THE LOWER IMPOUNDMENT DRAINAGE CHANNEL (EAST BANK). TERMINATE BURIED 9" D_{50} ROCK WALL AT LOCATION SHOWN ON THIS SHEET. CONSTRUCT 4.1" D_{50} CHANNEL BANK PROTECTION AND BURIED ROCK WALL AND PLACE 1.3" D_{50} RIPRAP OVER NORTHEAST DEBRIS PIT AT THE LOCATIONS SHOWN ON THIS SHEET ONLY IF NORTHEAST DEBRIS PIT IS USED FOR DISPOSAL OF DEBRIS. SEE SHEET 7 FOR DETAILS AND CROSS SECTIONS. IF NORTHEAST DEBRIS PIT IS NOT CONSTRUCTED, EXTEND ROCK ARMOR AS SHOWN ON SECTION A-A' TO MEET 9" D_{50} BURIED WALL.

SCALE
200 0 200 400 FEET

FIGURE 1

PLAN VIEW OF
RECLAIMED IMPOUNDMENT

PREPARED FOR

ATLAS MINERALS
GRAND JUNCTION, COLORADO

CanonieEnvironmental

No	DATE	ISSUE / REVISION	DWN BY	CK'D BY	AP'D BY
2	1-27-94	ISSUED TO COMPLY WITH NRC LICENSE CONDITION NO. 41 NOT FOR CONSTRUCTION	HMW	JAS	[illegible]
1	4-15-93	ISSUED FOR RESPONSE TO NRC COMMENTS	BKR	JMG	DWK

88-067-E14

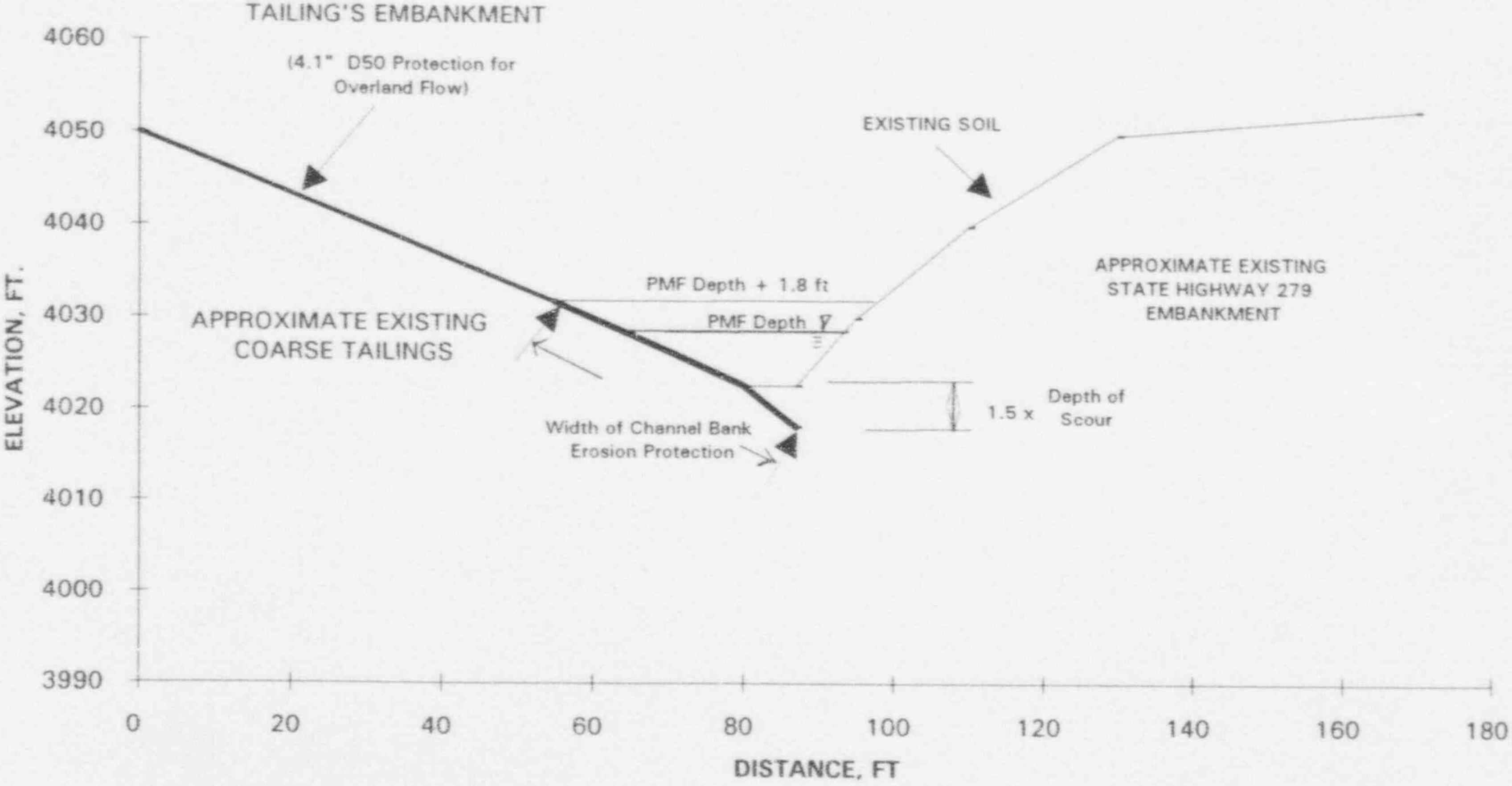
DATE: 4-7-93 SCALE: AS SHOWN	SHEET 4 of 10	DRAWING NUMBER 88-067-E66

88-067-E14

9406060234-08

Figure 2. SWRDC Riprap Detail

CROSS SECTION J-J



5/20/01

FIGURE 3. CHANNEL SUBSECTION DETAIL
(FROM EM 1110-2-1601)

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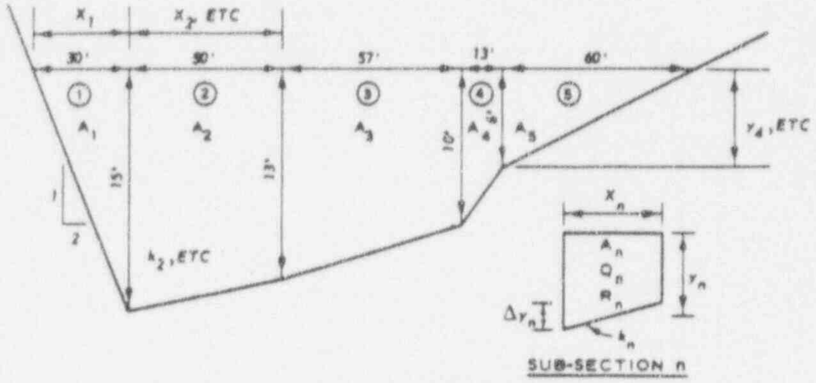

SUB-SECTION n

CHANNEL GEOMETRY

$Q_T = \Sigma Q_n = 20{,}000$ CFS

SUBSECTION	①	②	③	④	⑤
X_n, FT	30.0	50.0	57.0	13.0	60.0
Y_n, FT	7.5	14.0	11.5	8.0	3.0
AREA A_n, FT^2	225.0	700.0	655.0	104.0	180.0
k_n	1.33	2.0	2.5	3.0	4.0
P_n	33.5	50.0	57.0	13.6	60.3
HYDRAULIC RADIUS R_n	6.7	14.0	11.5	7.7	3.0
C (PLATE IV-2)	59	63	57	48	31
$(CR^{1/2})_n$	153	236	193	134	54
$(CR^{1/2})_n A_n \times 10^{-3}$	34.4	165.2	126.4	13.9	9.7
$(CR^{1/2})_n^3 A_n \times 10^{-9}$	0.81	9.20	4.71	0.25	0.03
$(CR^{3/2})_n A_n \times 10^{-6}$	0.23	2.31	1.45	0.11	0.03

$A_n = X_n Y_n$, WETTED PERIMETER $P_n = \left[X_n^2 + (\Delta Y_n)^2\right]^{1/2}$

$A_n = \frac{A_n}{P_n}$, k_n = EFFECTIVE ROUGHNESS HEIGHT

$Q_n = A_n V_n$, $A = \Sigma A_i$, $Q_T = \Sigma Q_i$

GEOMETRIC PROPERTIES

ALPHA METHOD
GEOMETRIC COMPUTATIONS

Plate IV-1

TABLES

23/31

Table 1

SUMMARY OF TAILINGS EMBANKMENT EROSION PROTECTION DESIGN ALONG NATURAL SWRDC

SWRDC Station, ft.	HEC-2 Sec. No.	Selected D50, in (oversized)	PMF Depth, ft.	Average Scour Depth, ft	Z	Width of RR, ft	Dist. btwn Sections, ft	Avg. Area, ft²	Layer Thick, in	Riprap Volume, ft³	Filter I Vol, ft³ (0.35" D50)	Filter II Vol, ft³ (1.90" D50)
0+00 - Start of Channel	1.0	9	5.37	3.17	3.00	37.73	250	9676.2	13.5	10885.8	4838.1	4838.1
	2.0	9	5.99	3.56	2.85	39.68	260	10622.5	13.5	11950.3	5311.2	5311.2
	3.0	9	6.15	4.32	2.73	42.03	250	10897.5	13.5	12259.7	5448.7	5448.7
	4.0	9	6.46	4.56	2.82	45.15	66	3037.3	13.5	3416.9	1518.6	1518.6
	4.1	9	6.65	4.49	2.92	46.89	66	3080.5	13.5	3465.6	1540.3	1540.3
	4.2	9	6.71	4.57	2.85	46.46	120	5469.8	13.5	6153.5	2734.9	2734.9
10+00	5.0	17.4	6.14	4.95	2.73	44.71	66	3023.9	26.1	6577.0	1511.9	1511.9
	5.1	17.4	5.88	4.84	2.98	46.93	66	3083.9	26.1	6707.4	1541.9	1541.9
	5.2	17.4	5.21	4.14	3.37	46.52	66	3072.2	26.1	6681.9	1536.1	1536.1
12+00	6.0	17.4	4.33	3.79	3.81	46.57	75	3222.1	26.1	7008.0	1611.0	1611.0
	6.5	9	4.28	2.60	3.81	39.35	72	2833.5	13.5	3187.7	1416.8	1416.8
	7.0	9	4.49	2.61	3.72	39.36	150	5997.2	13.5	6746.9	2998.6	2998.6
	8.0	9	4.4	2.95	3.69	40.60	160	8050.9	13.5	9057.3	4025.5	4025.5
	9.0	9	5.2	2.75	5.30	60.03	150	7465.8	13.5	8399.0	3732.9	3732.9
18+15- Start of Width Transition	10.0	9	4.6	4.06	3.00	39.51						
									17.4" Total, CY	999.0		
									9" Total, CY	2797.1		
									Total Vol., CY	3796.2	1472.8	1472.8

Grand Total Volume of Riprap and Filter Material, CY 6741.9

Note:

1) SWRDC denotes Southwest Runoff Drainage Channel.
2) Riprap to be placed along base of Tailings Pile adjacent to Southwest Runoff Drainage Channel.
3) Refer to Figure 1 for location and distance between HEC-2 sections and SWRDC Station No.
4) 1.8 feet is added to PMF Depth in computing width of riprap to allow for 1 ft. Free Board and potential depth increases due to rocks entering channel.
5) Z refers to side slope of Tailings Pile (Z - horizontal to 1 - vertical)
6) See Figure 2 for definition of Width of Riprap.
7) Average Area determined by multiplying average width of riprap by length between sections. (Avg. A = (Width1 + Width2)/2 x Dist. btwn Sec. 1 and 2)
8) For Layer Thickness see Table 4.
9) Riprap and Filter Volumes determined by multiplying area by layer thickness. Layer thickness is 6" for filter material.

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Table 2

Summary of Southwest Runoff Drainage Tailings Embankment Erosion Protection Riprap Invert and Top Elevations.

SWRDC(1) Station, ft.	SWRDC HEC-2 Cross Section(2)	Channel Invert Elevation (3), ft. msl.	Scour Depth(4) ft.	PMF Water Surface Elev.(3) ft	Riprap Invert Elevation(5) ft. msl.	Top of Riprap Elevation(6) ft. msl.
0+00 - Start of Channel	1.0	4030	3.17	4035.4	4025.2	4037.2
	2.0	4027.2	3.56	4033.2	4021.9	4035.0
	3.0	4024.4	4.32	4030.6	4017.9	4032.4
	4.0	4021.6	4.56	4028.1	4014.8	4029.9
	4.1	4020.9	4.49	4027.6	4014.2	4029.4
	4.2	4020.2	4.57	4026.9	4013.3	4028.7
10+00	5.0	4018.9	4.95	4025.0	4011.5	4026.8
	5.1	4018.1	4.84	4024.0	4010.8	4025.8
	5.2	4017.4	4.14	4022.6	4011.2	4024.4
12+00	6.0	4016.7	3.79	4021.0	4011.0	4022.8
	6.5	4015.9	2.60	4020.2	4012.0	4022.0
	7.0	4015.1	2.61	4019.6	4011.2	4021.4
	8.0	4013.4	2.95	4017.8	4009.0	4019.6
	9.0	4011.7	2.75	4016.9	4007.6	4018.7
18+15- Start of Width Transition	10.0	4010	4.06	4014.6	4003.9	4016.4

Notes:

1) SWRDC denotes Southwest Runoff Drainage Channel.
2) See Figure 1 for SWRDC Stations and HEC-2 Cross Sections.
3) See HEC-2 Simulations 1 and 2 for Channel Invert and PMF Surface Water Elevations.
4) Scour Depth from values computed on Table 7.
5) Channel Invert Elevation - scour depth * 1.5 (Per NUREG 4480)
6) PMF Water Elev. + 1.8' For Free Board and sediments/rocks
7) Riprap to be placed along base of Tailings Pile adjacent to Southwest Runoff Drainage Channel.

UAP
5/20/94

Table 3

RIPRAP VOLUME CALCULATION - MAN MADE UPPER REACH OF SOUTHWEST RUNOFF DRAINAGE CHANNEL

Location	PMF Depth ft	Bottom Width, ft	Side Slope	Ditch Perim. ,ft	Channel Length, ft	Riprap D50, in	Layer Thick, in	Riprap Vol, CY	Filter I Vol., CY
Main Channel	4.7	20	3	61.1	1815	5	10	3423.3	2054.0
4.1" to Reach Areal Extent of Riprap				17.5	1815	4.1	8	784.3	588.2

Note:

1.8 feet is added to PMF Depth to account for free board and for possible rocks entering channel.

Summary of Riprap Volume Requirements

Item	Natural Vol, CY	Man Made Vol, CY	Difference
17.4" Riprap	999.0		
9" Riprap	2797.1		
5" Riprap		3423.3	
4.1" Riprap		784.3	
Filter I	1472.8	2642.2	
Filter II	1472.8		
Totals	6741.9	6849.7	107.8

UPP 5/20/94

25/31

SWCH1.XLS 5/20/94

TABLE 4

SUMMARY OF RIPRAP PREVIOUSLY DESIGNED GRADATION REQUIREMENTS

(Allowable Percent Passing Given Dimension)

Location	Necessary D50 (a) (inches)	Actual D50 (inches)	Riprap Layer Thickness (inches)	54"	48"	36"	24"	20"	15"	12"	10"	6"	4"	3"	2"	1"	3/4"	1/2"	3/8"	Sieve No. 4	Rock Type (b)
Lower Southwest Drainage Channel	32.4	32.4	49		100	42-60	16-34	10-26	4-16	0-12											CD
Lower Impoundment Drainage Channel	17.4	17.4	26				100	54-70	30-40	16-31	8-25	0-12									CD
Moab Wash Channel Bank (sec. L-L' to N-N')	9.0	9.0	13.5							100	38-64	12-30	0-18	0-10							CD
Upper Southwest Drainage Channel	4.9	5.0	10								100	46-60	20-40	6-28	0-14						CD
Upper Impoundment Drainage Channel	4.3																				CD
Collection Ditches	3.3	4.1	8									100	34-48	18-32	2-19	0-3					CD
10:3 Embankment	4.1																				
10:1 Embankment	2.7																				
Moab Wash (Sec P-P')	3.3																				
Northeast Debris Pit	0.55	1.3	6										100	82-100	50-78	16-35	8-23	0-12			RA

Notes:

(a) Necessary riprap D50 based on design requirements and includes oversizing for rock durability and roundness (as necessary). See Appendix E.

(b) Gradation requirements are based on rock durability ratings for particular material: "CD" denotes crushed diorite rock type.

(c) Gradation requirements are based on rock durability ratings for particular material: "RA" denotes round alluvial cobbles.

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Table 5

Summary of Depth of Flow from HEC-2 Simulations

HEC -2	HEC-2 Simulations 1 & 2		HEC-2 Simulations 3 & 4		HEC-2 Simulations 5 & 6		Maximum Increase in Depth of Flow, ft
Cross Section	Flow Condition	PMF Depth, ft	Flow Condition	PMF Depth, ft	Flow Condition	PMF Depth, ft	
1.0	Subcritical	5.37	Subcritical	5.49	Subcritical	5.33	0.12
2.0	Subcritical	5.99	Subcritical	5.69	Subcritical	6.11	0.12
3.0	Subcritical	6.15	Subcritical	7.01	Subcritical	5.9	0.86
4.0	Subcritical	6.46	Subcritical	8.07	Subcritical	7.05	1.61
4.1	Subcritical	6.65	Subcritical	8.43	Subcritical	7.61	1.78
4.2	Subcritical	6.71	Subcritical	8.31	Subcritical	8.17	1.6
5.0	Critical	6.14	Critical	7.47	Subcritical	7.76	1.62
5.1	Supercritical	5.88	Supercritical	5.26	Subcritical	7.48	1.6
5.2	Supercritical	5.21	Supercritical	5.29	Critical	6.97	1.76
6.0	Supercritical	4.33	Supercritical	4.32	Supercritical	5.66	1.33
6.5	Subcritical	4.28	Subcritical	4.28	Subcritical	4.28	0
7.0	Subcritical	4.49	Subcritical	4.49	Subcritical	4.49	0
8.0	Subcritical	4.4	Subcritical	4.4	Subcritical	4.4	0
9.0	Subcritical	5.2	Subcritical	5.2	Subcritical	5.2	0
10.0	Subcritical	4.6	Subcritical	4.6	Subcritical	4.6	0

Average Maximum Increase in Depth of Flow in Sec. 1.0 to 6.0 =	1.24
Overall Maximum Increase in Depth of Flow =	1.78

Notes

1) HEC-2 Simulations 1 & 2 are initial conditions with no rocks or sediment in Channel.
(1 is based on subcritical flow calculations , 2 is based on supercritical calculations)

2) HEC-2 Simulations 3 & 4 have rocks /sediment in Channel Sections 4, 4.1, 4.2, and 5.0.
(3 is based on subcritical flow calculations , 4 is based on supercritical calculations)

3) HEC-2 Simulations 5 & 6 have rocks /sediment in Channel Sections 5.0, 5.1, 5.2, and 6.0.
(5 is based on subcritical flow calculations , 6 is based on supercritical calculations)

4) Increase in depth of flow refers to the maximum amount the depth of flow was increased from Simulations 1 & 2 to Simulations 3, 4, 5, and 6.

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Table 6

Summary of D50 Riprap Sizing Analysis for Tailings Embankment Erosion Protection

SWRDC HEC-2 Section	Minimum Required Raw D50, in HEC -2 Simulation 1 & 2	3 & 4	5 & 6	Recommended Raw D50, in	Recommended Oversized D50, in
1.0	4.02	4.02	4.02	8.8	9
2.0	4.9	8.8	4.9	8.8	9
3.0	8.8	4.02	8.8	8.8	9
4.0	8.8	4.9	4.02	8.8	9
4.1	4.9	4.02	4.02	8.8	9
4.2	4.9	8.8	4.02	8.8	9
5.0	8.8	17.04	8.8	17.04	17.4
5.1	8.8	17.04	8.8	17.04	17.4
5.2	17.04	17.04	8.8	17.04	17.4
6.0	17.04	17.04	17.04	17.04	17.4
6.5	4.02	4.02	4.02	8.8	9
7.0	4.02	4.02	4.02	8.8	9
8.0	4.9	4.9	4.9	8.8	9
9.0	4.02	4.02	4.02	8.8	9
10.0	8.8	8.8	8.8	8.8	9

Notes

1) See Attachment F for COE method calculations for each HEC-2 simulation.
2) Raw D50 is not oversized for durability
3) Oversized D50 is oversized by 2% based on durability of rock source.
4) D50 conservatively recommended due to uncertainties in how and where falling rocks may enter the channel.

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Table 7

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Scour Depth Calculations

Method 1

Section	Q, ft³/s (2)	Top Width. ft. (2)	q, ft	ds, ft
1.0	1605	66.4	24.17	5.26
2.0	1605	56.24	28.54	5.48
3.0	1605	42.91	37.40	5.84
4.0	1605	39.77	40.36	5.95
4.1	1605	40.37	39.76	5.93
4.2	1605	39.4	40.74	5.96
5.0	1605	36.17	44.37	6.09
5.1	1605	37.45	42.86	6.04
5.2	1605	47.33	33.91	5.71
6.0	1605	54.18	29.62	5.53
6.5	1605	91.6	17.52	4.87
7.0	1605	90.81	17.67	4.88
8.0	1605	76.39	21.01	5.09
9.0	1605	81.47	19.70	5.01
10.0	1605	47.61	33.71	5.70

Method 2a

Section	Bend Type	Z (3)	Dm, mm	f	dm,ft	ds,ft
All	Straight	0.25	2	2.49	4.06	1.02

Method 2b

Section	Fbo, ft/s²	dfo, ft	Z (3)	ds, ft
1.0	2.2	6.43	0.6	3.86
2.0	2.2	7.18	0.6	4.31
3.0	2.2	8.60	0.6	5.16
4.0	2.2	9.05	0.6	5.43
4.1	2.2	8.96	0.6	5.37
4.2	2.2	9.10	0.6	5.46
5.0	2.2	9.64	0.6	5.78
5.1	2.2	9.42	0.6	5.65
5.2	2.2	8.06	0.6	4.83
6.0	2.2	7.36	0.6	4.42
6.5	2.2	5.19	0.6	3.11
7.0	2.2	5.22	0.6	3.13
8.0	2.2	5.85	0.6	3.51
9.0	2.2	5.61	0.6	3.37
10.0	2.2	8.02	0.6	4.81

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Table 7

Scour Depth Calculations

Method 3

Section	Bend Type	Area (2) ft^2	Top Width(2) ft	dm, ft	z (3)	ds, ft
1.0	Straight	205.18	66.4	3.09	0.25	**0.77**
2.0	Straight	187.61	56.24	3.34	0.25	**0.83**
3.0	Straight	163.75	42.91	3.82	0.25	**0.95**
4.0	Straight	160.94	39.77	4.05	0.25	**1.01**
4.1	Straight	167.37	40.37	4.15	0.25	**1.04**
4.2	Straight	165.71	39.4	4.21	0.25	**1.05**
5.0	Straight	141.7	36.17	3.92	0.25	**0.98**
5.1	Straight	139.59	37.45	3.73	0.25	**0.93**
5.2	Straight	136.32	47.33	2.88	0.25	**0.72**
6.0	Straight	136.67	54.18	2.52	0.25	**0.63**
6.5	Straight	222.94	91.6	2.43	0.25	**0.61**
7.0	Straight	226.16	90.81	2.49	0.25	**0.62**
8.0	Straight	190.5	76.39	2.49	0.25	**0.62**
9.0	Straight	238.02	81.47	2.92	0.25	**0.73**
10.0	Straight	155.57	47.61	3.27	0.25	**0.82**

Method 4

Section	Q, ft^3/s	Area (2) ft^2	Vm, ft/s^2	Vc, ft/s^2	dm,ft	ds, ft
1.0	1605	205.18	7.82	3	3.09	**4.97**
2.0	1605	187.61	8.55	3	3.34	**6.18**
3.0	1605	163.75	9.80	3	3.82	**8.65**
4.0	1605	160.94	9.97	3	4.05	**9.41**
4.1	1605	167.37	9.59	3	4.15	**9.11**
4.2	1605	165.71	9.69	3	4.21	**9.37**
5.0	1605	141.70	11.33	3	3.92	**10.87**
5.1	1605	139.59	11.50	3	3.73	**10.56**
5.2	1605	136.32	11.77	3	2.88	**8.42**
6.0	1605	136.67	11.74	3	2.52	**7.35**
6.5	1605	222.94	7.20	3	2.43	**3.41**
7.0	1605	226.16	7.10	3	2.49	**3.40**
8.0	1605	190.50	8.43	3	2.49	**4.51**
9.0	1605	238.02	6.74	3	2.92	**3.65**
10.0	1605	155.57	10.32	3	3.27	**7.97**

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Table 7

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Scour Depth Calculations

Summary of Methods - Scour Depths, ft

Section	Method 1	Method 2a	Method 2b	Method 3	Method 4	Average Scour Depth, ft
1.0	5.26	1.02	3.86	0.77	4.97	**3.17**
2.0	5.48	1.02	4.31	0.83	6.18	**3.56**
3.0	5.84	1.02	5.16	0.95	8.65	**4.32**
4.0	5.95	1.02	5.43	1.01	9.41	**4.56**
4.1	5.93	1.02	5.37	1.04	9.11	**4.49**
4.2	5.96	1.02	5.46	1.05	9.37	**4.57**
5.0	6.09	1.02	5.78	0.98	10.87	**4.95**
5.1	6.04	1.02	5.65	0.93	10.56	**4.84**
5.2	5.71	1.02	4.83	0.72	8.42	**4.14**
6.0	5.53	1.02	4.42	0.63	7.35	**3.79**
6.1	4.87	1.02	3.11	0.61	3.41	**2.60**
7.0	4.88	1.02	3.13	0.62	3.40	**2.61**
8.0	5.09	1.02	3.51	0.62	4.51	**2.95**
9.0	5.01	1.02	3.37	0.73	3.65	**2.75**
10.0	5.70	1.02	4.81	0.82	7.97	**4.06**

Notes:

1) See main text for description of methods and equations.

2) From HEC-2 Runs with no "rocks" in channel (See Attachment D)

3) From Table 7 in Pemberton et. al.

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Canonie Environmental
By JWS Date 5/10/94 Subject Riprap Size Design Natural Sheet A-1 of A-32
Chkd By jmp Date 5/20/94 Southwest Channel - Atlas Proj No 88-067-12

ATTACHMENT A

EXCERPTS FROM

EM 1110-1601-2

NUREG 4480

NUREG 4620

LINSLEY ET. AL AND LINDEBURG

PEMBERTON, et. al. "COMPUTING DEGRADATION AND LOCAL SCOUR"

REPRINT WITH CHANGE 1 thru 4 INCLUDED.

ENGINEER MANUAL

A-2

EM 1110-2-1601

1 JULY 1970

ENGINEERING AND DESIGN

HYDRAULIC DESIGN OF FLOOD CONTROL CHANNELS

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS

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the interaction of the local boundary shear and the size and gradation of the riprap material.

(2) Average boundary shear. The average boundary shear over the wetted perimeter of a channel cross section (from ref 3) is given by

$$\bar{\tau}_o = \gamma RS \tag{30}$$

where

$\bar{\tau}_o$ = average boundary shear, psf
γ = unit weight of water, pcf
R = hydraulic radius, ft
S = slope of energy gradient

By utilizing equations 1 and 6, equation 30 becomes

$$\bar{\tau}_o = \frac{\gamma V^2}{\left(32.6 \log_{10} \frac{12.2R}{k}\right)^2} \tag{31}$$

where

V = average cross-sectional velocity, fps
k = equivalent channel boundary surface roughness, ft

(3) Local boundary shear. In a straight trapezoidal channel with equal bottom and side roughness, the boundary shear varies over the wetted perimeter as shown in plate 31. By substituting in equation 31 the depth Y (in feet) for R, the average local velocity in the vertical $\bar{v}$ (in feet per second) for V, and the average stone theoretical diameter D_{50} (in feet) for k, the local boundary shear at any point on the wetted perimeter can be determined by the equation

$$\tau_o = \frac{\gamma \bar{v}^2}{\left(32.6 \log_{10} \frac{12.2y}{D_{50}}\right)^2} \tag{32}$$

The average local velocity in the vertical at any point should be determined as illustrated in Appendix IV. The subsection width used to determine $\bar{v}$ should not be too great. Where there is a significant difference in roughness over the wetted perimeter, as may occur in a channel with riprap bank revetment and a natural invert, a local effective friction coefficient as determined from Hydraulic Design Chart 631-4 or Appendix IV should be used in computing values of $\bar{v}$. A graphic solution of equation 32 is presented in plate 32.

(4) Boundary shear in bends. The distribution of local boundary shear in a bend of a trapezoidal channel with equal bottom and side roughness is indicated in plates 33 and 34 (compiled from data in refs 53, 54, and 55). * Average boundary shear values obtained by equation 31 should be multiplied * by the indicated ratios of $\tau_b/\bar{\tau}_o$ to obtain local boundary shear values in a bend.

(5) Riprap design shear. The riprap design shear is defined as that amount of local boundary shear that the in-place riprap will safely withstand. The design shear for riprap placed on an essentially level channel bottom is given by reference 56.

Ref ASCE

$$\tau = a\ (\gamma_s - \gamma) D_{50} \qquad (33)$$

where

γ_s = the unit weight of stone saturated surface dry (SSD)

coefficient "a" = 0.040

The design shear for riprap placed on channel side slopes is given by the following equation taken from reference 3

$$\tau' = \tau \left(1 - \frac{\sin^2 \phi}{\sin^2 \theta}\right)^{0.5} \qquad (34)$$

where

ϕ = the angle of the side slope with the horizontal

θ = the angle of repose of the riprap, normally about 40 deg

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APPENDIX IV

Notes on Derivation and Use of Hydraulic Properties by the Alpha Method

1. General. Appendix A of reference 89† is reproduced here, with minor modifications and rearrangements, to illustrate use of the "Alpha" method for determining the local boundary shear and composite roughness. The Alpha computations are applicable to uniform and gradually varied flow problems. Computations for effective average channel roughness k with and without considering the energy correction factor are included as well as computations for Manning's n. The necessary basic equations and a computation procedure are given in the paragraphs that follow. Illustrations of the Alpha method applied to the effective channel roughness problem are given in plates IV-1 through IV-4.

2. Basic Procedure and Equations. a. The cross section (plate IV-1) is divided into subsections bounded by vertical lines extending from water surface to the wetted perimeter. The mean velocity in the vertical of the subsection is given by V_n and the subsection discharge by $V_n A_n$. The integer subscript n defines the channel subsection. As explained in Chow[3] (para 6-5), a simplifying assumption becomes necessary. It is assumed that the energy grade line has the same slope across the entire cross section, that S in the familiar Chezy equation ($V = C\,(RS)^{1/2}$) is constant at each subsection, and that the following proportion may be written

$$V_n :: \left(CR^{1/2}\right)_n \qquad \text{(IV-1)}$$

where C is Chezy's coefficient and R is the hydraulic radius.

---

† Raised numbers refer to similarly numbered references in Appendix I.

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b. The resistance equation for hydraulically rough channels (para 8c) is

$$C = 32.6 \log_{10} \frac{12.2R}{k}$$

where

C = Chezy's coefficient

R = hydraulic radius, ft

k = equivalent roughness dimension, ft

This equation is plotted in plate IV-2.

c. As $\left(CR^{1/2}\right)_n$ is proportional to V_n, then $\left(CR^{1/2}\right)_n A_n$ is proportional to Q_n. From this the following equations are derived†

$$Q_n = \frac{Q_T \left(CR^{1/2}\right)_n A_n}{\sum\left[\left(CR^{1/2}\right)_i A_i\right]} \qquad \text{(IV-2)}$$

$$V_n = \frac{Q_T \left(CR^{1/2}\right)_n}{\sum\left[\left(CR^{1/2}\right)_i A_i\right]} \text{ or } \frac{Q_n}{A_n} \qquad \text{(IV-3)}$$

$$\left(CR^{1/2}\right)_{mean} = \frac{\sum\left[\left(CR^{1/2}\right)_i A_i\right]}{\sum A_i} \qquad \text{(IV-4)}$$

$$S = \frac{\overline{V}^2}{\left[\left(CR^{1/2}\right)_{mean}\right]^2} \qquad \text{(IV-5)}$$

$$\overline{R} = \frac{\sum\left[R_i \left(CR^{1/2}\right)_i A_i\right]}{\sum\left[\left(CR^{1/2}\right)_i A_i\right]} \qquad \text{(IV-6)}$$

---

† The subscript i assumes all values of n.

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3. Backwater Computation. a. All the cross-section hydraulic parameters necessary for backwater computations are computed in plates IV-1 and IV-3. Computing the same parameters at several water-surface elevations and plotting the results permits ready interpolation for intermediate values. The method is programmed for digital computer use[89,90] if manual computations for a particular project are too time consuming.

b. The boundary and hydraulic characteristics of a channel reach are assumed to be those obtained by averaging the conditions existing at each end of the reach. This procedure implies that the roughness dimensions k assigned to the upstream and downstream sections extend to the midsection of the reach. Therefore, it is important that the reach limits be carefully selected. Two different sets of subsection roughness values should be assigned in cases where the boundary condition changes abruptly such as at the beginning or end of an improved reach. One set of values would apply in the improved reach and the other in the natural channel.

4. Roughness Relation. The roughness dimension k may be taken as equivalent spherical diameter of the average size bed material when the hydraulic losses in the flow regime are attributable to friction alone. In a flow regime where hydraulic losses in addition to friction are present, k may still be used if the losses result in a reasonably uniform slope of the energy grade line. In this case, k will be larger dimensionally than the equivalent spherical diameter of the average size bed material. As Chezy C and Manning's n are equatable $\left(\frac{C}{1.486} = \frac{R^{1/6}}{n}\right)$, k may be determined from a knowledge of Manning's coefficient n. While k remains fairly constant with changing R, n varies with the one-sixth power of R. Therefore, it is better to extrapolate from known conditions to unknown by the use of k rather than n. The k must be evaluated for each subsection. Subsections should be chosen with this in mind so that differing bed materials or bed conditions producing frictionlike losses, such as ripples, dunes, or other irregularities will appear in separate subsections. Hydraulic losses tending to cause breaks in the energy grade line, such as expansion and contraction,

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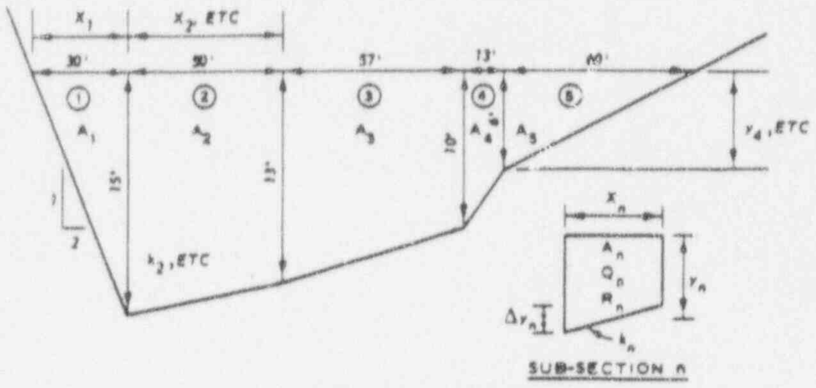

CHANNEL GEOMETRY

$Q_T = \Sigma Q_n = 20{,}000$ CFS

SUBSECTION	①	②	③	④	⑤
X_n, FT	30.0	50.0	57.0	13.0	60.0
y_n, FT	7.5	14.0	11.5	8.0	3.0
AREA A_n, FT^2	225.0	700.0	655.0	104.0	180.0
k_n	1.33	2.0	2.5	3.0	4.0
P_n	33.5	50.0	57.0	13.6	60.3
HYDRAULIC RADIUS R_n	6.7	14.0	11.5	7.7	3.0
C (PLATE III-2)	59	63	57	48	31
$(CR^{1/2})_n$	153	236	193	134	54
$(CR^{1/2})_n A_n \times 10^{-3}$	34.4	165.2	126.4	13.9	9.7
$(CR^{1/2})^3_n A_n \times 10^{-9}$	0.81	9.20	4.71	0.25	0.03
$(CR^{3/2})_n A_n \times 10^{-6}$	0.23	2.31	1.45	0.11	0.03

$A_n = X_n y_n$, WETTED PERIMETER $P_n = \left[X_n^2 + (\Delta y_n)^2\right]^{1/2}$

$R_n = \frac{A_n}{P_n}$, k_n = EFFECTIVE ROUGHNESS HEIGHT

$Q_n = A_n V_n$, $A = \Sigma A_i$, $Q_T = \Sigma Q_i$

GEOMETRIC PROPERTIES

ALPHA METHOD
GEOMETRIC COMPUTATIONS

Plate IV-1

A-9

1. CALCULATE THE AVERAGE VELOCITY, $\bar{V}$.

$\bar{V} = Q_T/A$

$\bar{V} = (20{,}000)/(1864.0) = 10.7$ FPS

2. CALCULATE THE DISCHARGE THROUGH EACH SUB-SECTION, Q_n.

$$Q_n = \frac{Q_T (CR^{1/2})_n A_n}{\Sigma[(CR^{1/2})_i A_i]} = \frac{20{,}000 (CR^{1/2})_n A_n}{349{,}600}$$

$Q_1 = 0.0572(34400) = 1968$ CFS
$Q_2 = 0.0572(165200) = 9449$
$Q_3 = 0.0572(126400) = 7230$
$Q_4 = 0.0572(13900) = 795$
$Q_5 = 0.0572(9700) = 555$

$\Sigma Q_n = 19{,}997$

3. CALCULATE THE VELOCITY THROUGH EACH SUB-SECTION

$$V_n = \frac{Q_n}{A_n}$$

$V_1 = (1968)/(225.0) = 8.7$ FPS
$V_2 = (9449)/(700.0) = 13.5$
$V_3 = (7230)/(655.0) = 11.0$
$V_4 = (795)/(104.0) = 7.6$
$V_5 = (555)/(180.0) = 3.1$

4. CALCULATE THE MEAN SLOPE OF ENERGY GRADE LINE, S.

$$S = \frac{(\bar{V})^2}{(CR^{1/2})^2_{MEAN}}$$

$$(CR^{1/2})_{MEAN} = \frac{\Sigma[(CR^{1/2})_i A_i]}{A} = \frac{349{,}600}{1864.0} = 188$$

$$S = (10.7)^2/(188)^2 = 0.00324$$

5. CALCULATE THE MEAN HYDRAULIC RADIUS, $\bar{R}$.

$$\bar{R} = \frac{\Sigma[(CR^{3/2})_i A_i]}{\Sigma[(CR^{1/2})_i A_i]}$$

$\bar{R} = (4.13 \times 10^6)/(0.3496 \times 10^6) = 11.8$ FT

6. CALCULATE THE AVERAGE SHEAR FORCE $\bar{\tau}_0$

$\bar{\tau}_0 = \gamma \bar{R} S$

$= (62.5)(11.8)(0.00324) = 2.39$ LB/FT^2

ALPHA METHOD
HYDRAULIC PROPERTIES

Plate IV-3

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NUREG/CR-4620
ORNL/TM-10067

Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments

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profiles can be estimated. The computational procedure is based on the solution of the one-dimensional energy equation with energy losses due to friction. The HEC-2 procedure is similar to the Standard Step Method for computing water surface elevations. The program was developed for flood plain management, floodway encroachment evaluation and flood hazard designations.

4.7 DETERMINATION OF THE MANNING ROUGHNESS COEFFICIENT

The greatest difficulty in applying the Manning formula and other flow models such as HEC-2 is the determination of the boundary roughness coefficient, n. The n value is an estimate of flow resistance. There is not an exact procedure or method for determination of flow resistance. It is imperative to recognize that the selection of an appropriate n value requires careful judgment and reason.

The n values commonly available were formulated for flows in natural and artificial channels. Factors affecting Manning's roughness coefficient include surface roughness, vegetation, channel irregularity, channel alignment, flow depth, silting and scouring, obstructions and channel shape. Chow (1959) and Barnes (1967) present a comprehensive list of n values for open channel applications. Values of n range from 0.017 for smooth channels free from growth to 0.07 for cobble bed streams (Chow, 1959). Equations 4.39 and 4.40 are extremely sensitive to the n value. Therefore the selection of an appropriate n value may require several iterations.

The Manning formula is commonly used to estimate discharge for overland flow, particularly over large areas in which runoff channelization has not yet initiated. Overland or sheet flow is characterized by a flow depth less than 1.0 ft. and is significantly influenced by the boundary shear or resistance to flow. The n value may vary with flow depth.

Morris and Wiggert (1972) published a list of n values that have been adopted by the U.S. Bureau of Reclamation and are presented in Table 4.2. These values apply to well-seasoned, straight channels on mild slopes with flow depths less than 3.0 ft.

A series of values for the Manning Coefficient, n, were adopted by the Department of the Interior (DOI, 1975) for natural channels and streams. These values are presented in Table 4.3.

One of the most difficult Manning's roughness values to determine is for riprap. Riprap serves as an alternative surface stability technique that provides considerable resistance to flow resulting in velocity and energy dissipation. An expression for determining the value of the Manning coefficient, n, for riprap was presented by the Corps of Engineers (COE, 1970) and by Anderson et al. (1970) is:

$$n = 0.0395\ (d_{50})^{1/6} \qquad (4.41)$$

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Erosion Protection of Uranium Tailings Impoundments

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cannot satisfy these criteria, two or more filter layers may be necessary. The finer filter overlies the top layer of the radon suppression cover and the coarser filter lies between the finer filter and the riprap.

The grain-size curve of the filter material should have a smooth s-shape without pronounced breaks and should be roughly parallel to the grain-size curve of the soil being protected, although other smooth shapes may be used.

Thickness of Filter. The filter layer should have a minimum thickness of 12 in. and be at least equal to one-half the riprap layer thickness. Where two filter layers are required, the finer filter layer should have a minimum thickness of 12 in. and be at least equal to one-half the coarser filter layer thickness.

The use of these layer thicknesses assumes that the underlying radon suppression cover is structurally stable and capable of supporting the loads imposed by the construction equipment and the filter and riprap layers. If this is not the case, larger filter layer thicknesses may be needed to support construction equipment or the riprap. Larger filter layer thicknesses may also account for larger differential settlements caused by consolidation of the underlying materials. The greater layer thickness should be determined in the field based on the actual condition of the radon suppression cover.

Toe Protection

A riprap toe protection is required at the base of all impoundment side slopes. In general, the toe protection can be one of two types as shown in Figure 10.

For Method A, the riprap layer constructed on the slope may extend below grade to a depth of 1.5 times the estimated depth of scour at the impoundment perimeter. The angle of the below-grade protection may be steeper than the relatively flat slope angle, if the stability of the impoundment after scour is adequate. The sizing of the riprap is based on the actual slope used, assuming that the full design-estimated depth of scour has occurred.

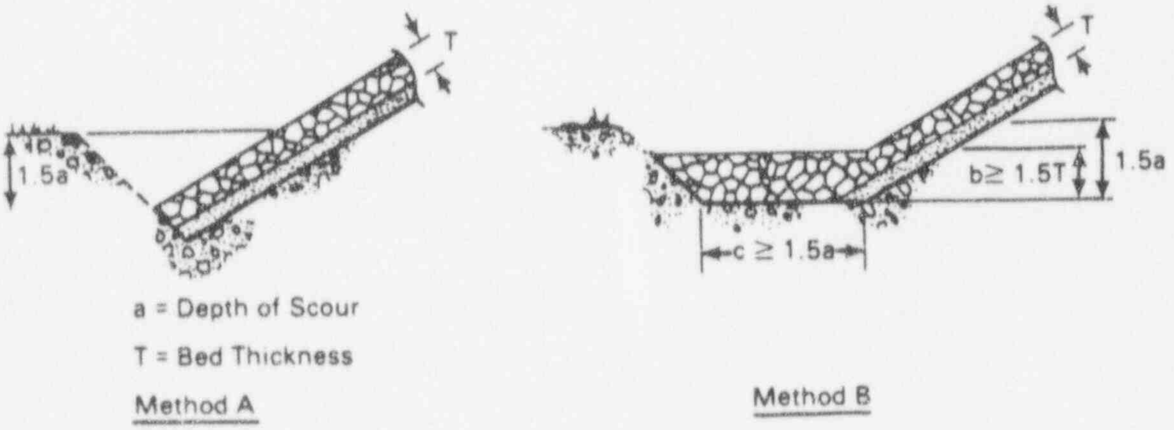

FIGURE 10. Toe Protection Methods

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A second approach, Method B, includes a horizontal riprap toe. The width of the horizontal protection should be at least equal to the estimated depth of scour times 1.5. The thickness of the layer should be at least 1.5 times the thickness of the riprap on the slope.

Gully Erosion Protection

The remaining unprotected side slope surfaces above maximum flood elevation require protection from gully erosion. These surface areas are the most vulnerable to gullying because of their steepness. Once gullies are initiated, the process can proceed rapidly (one year or several years) toward a breach in the impoundment. Each impoundment will require some minimum thickness of rock riprap completely covering the side slopes for the purpose of preventing gully erosion. This will be the case irregardless of whether flooding is a consideration. Because of the threat of this potentially destructive process, the application of rock riprap is recommended for the long-term protection of the side slopes. However, the problem is complicated by other factors.

Gullies that form from land surface depressions and rills can actively be prevented by rock riprap applied to the side slopes of impoundments since they are the direct result of overland flow. Gullies caused by differential settlement, slope failure, and piping cannot always be prevented by rock riprap because they are not the direct result of rainfall-runoff. However, in these situations, the presence of an engineered rock cover could mitigate the effects of these processes by self-adjustment of the rock cover itself. This would help prevent further erosion by surface runoff by the shifting of individual rocks to accommodate the new surface configuration. Although rock armor may prevent further damage caused by differential settlement, slope failure, and piping, it is best that preventive measures for these types of failures be considered in the design of the embankment foundation and earthen cover.

Design Suggestions for Gully Erosion Protection

A study by Walters and Skaggs (1986) determined that there are no procedures available to design rock riprap to protect against overland and gully erosion. The study results indicated that movement of runoff over a soil cover armored by rock may involve both interflow through the rock layer and filter and cascading flow over the rock surface. Not enough information is available at this time to indicate whether the movement of the runoff through the rock layer can be described by the equations of porous media flow. The interstitial voids in the rock layer can be extremely large and would allow runoff to move through rapidly.

The lack of information on the hydraulic roughness (Manning's n) for flow over the rock surface poses another problem. The results of field and laboratory testing are very limited for unprotected soil surfaces and nonexistent for rock surfaces. Therefore, the inability to predict the flow characteristics over and through the rock layer would limit any analysis to very rough assumptions.

14

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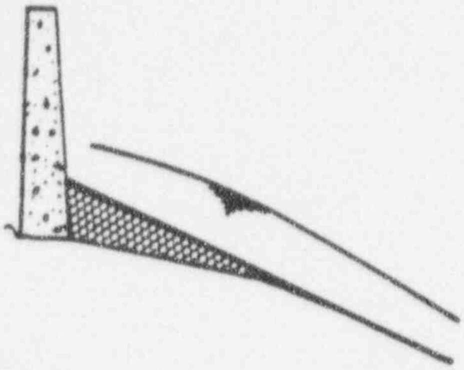

COMPUTING DEGRADATION AND LOCAL SCOUR

TECHNICAL GUIDELINE FOR BUREAU OF RECLAMATION

U.S. Department of the Interior
Bureau of Reclamation

Inch-pound units

$$L_g = \frac{37.05}{0.00112}$$

$$L_g = 33\,100 \text{ ft}$$

Metric units

$$L_g = \frac{1.625\ (6.94)}{0.00112}$$

$$L_g = 10\,100 \text{ m}$$

and for the subreaches:

Inch-pound units

$$L_1 = \frac{22.8}{2\ (0.00112)} = 10\,200 \text{ ft}$$

$$L_2 = \frac{3\ (22.8)}{8\ (0.00112)} = 7\,600 \text{ ft}$$

$$L_3 = \frac{3\ (22.8)}{4\ (0.00112)} = 15\,300 \text{ ft}$$

Metric units

$$L_1 = \frac{6.94}{2\ (0.00112)} = 3\,100 \text{ m}$$

$$L_2 = \frac{3\ (6.94)}{8\ (0.00112)} = 2\,300 \text{ m}$$

$$L_3 = \frac{3(6.94)}{4\ (0.00112)} = 4\,700 \text{ m}$$

CHANNEL SCOUR DURING PEAK FLOODFLOWS

The design of any structure located either along the riverbank and flood plain or across a channel requires a river study to determine the response of the riverbed and banks to large floods. A knowledge of fluvial morphology combined with field experience is important in both the collection of adequate field data and selection of appropriate studies for predicting the erosion potential. In most studies, two processes must be considered, (1) natural channel scour, and (2) scour induced by structures placed by man either in or adjacent to the main river channel.

Natural scour occurs in any moveable bed river but is more severe when associated with restrictions in river widths, caused by morphological channel changes, and influenced by erosive flow patterns resulting from channel alinement such as a bend in a meandering river. Rock outcrops along the bed or banks of a stream can restrict the normal river movement and thus effect any of the above influencing factors. Manmade structures can have varying degrees of influence, usually dependent upon either the restriction placed upon the normal river movement or by turbulence in flow pattern directly related to the structure. Examples of structures that influence river movement would be (1) levees placed to control flood plain flows, thus increasing main channel discharges; (2) spur dikes, groins, riprapped banks, or bridge abutments used to control main channel movement; or (3) pumping plants or headworks to canals placed on a riverbank. Scour of the bed or banks caused by these structures is that created by higher local velocities or excessive turbulence at the strucutre. Structures placed directly in the river consist of (1) piers and piling for either highways or railroad bridges; (2) dams across the river for diversion or storage, (3) grade control structures such as rock cascades, gabion controls or concrete baffled apron drop

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structures; or (4) occasionally a powerline or tower structure placed in the flood plain but exposed to channel erosion with extreme shifting or movement of a river. All of the above may be subject to higher local velocities, but usually are subject to the more critical local scour caused by turbulence and helicoidal flow patterns.

The prediction of river channel scour due to floods is necessary for the design of many Reclamation structures. These Reclamation guidelines on scour represent a summary of some of the more applicable techniques which are described in greater detail in the reference publications by T. Blench (1969), National Cooperative Highway Research Program Synthesis 5 (1970), C. R. Neill (1973), D. B. Simons and F. Senturk (1977), and S. C. Jain (1981). The paper by S. C. Jain (1981) summarized many of the empirical equations developed for predicting scour of a streambed around a bridge pier. It should be recognized that the many equations are empirically developed from experimental studies. Some are regime-type based on practical conditions and considerable experience and judgment. Because of the complexity of scouring action as related to velocity, turbulence, and bed materials, it is difficult to prescribe a direct procedure. Reclamation practice is to compute scour by several methods and utilize judgment in averaging the results or selection of the most applicable procedures.

The equations for predicting local channel scour usually can be grouped into those applicable to the two previously described processes of either a natural channel scour or scour caused by a manmade structure. A further breakdown of these processes is shown in table 6 where Type A equations are those used for natural river erosion and Types B, C, and D cover various manmade structures.

The importance of experience and judgment in conducting a scour study cannot be overemphasized. It should be recognized that the techniques described in these guidelines merely provide a set of practical tools in guiding the investigator to estimate the amount of scour for use in design. The collection of adequate field data to define channel hydraulics and bed or bank materials to be scoured govern the accuracy of any study. They should be given as much emphasis as the methodology used in the analytical study. Field data are needed to compute water surface profiles for a reach of river in the determination of channel hydraulics for use in a scour study. With no restrictions in channel width, scour is computed from the average channel hydraulics for a reach. If a structure restricts the river width, scour is computed from the channel hydraulics at the restriction. In all cases, scour estimates should be based upon the portion of discharge in and hydraulic characteristics of the main channel only.

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Table 6. - Classification of scour equation for various structure designs

Equation type	Scour	Design
A	Natural channel for restrictions and bends	Siphon crossing or any buried pipeline. Stability study of a natural bank. Waterway for one-span bridge.
B	Bankline structures	Abutments to bridge or siphon crossing. Bank slope protection such as riprap, etc. Spur dikes, groins, etc. Pumping plants. Canal headworks.
C	Midchannel structures	Piling for bridge. Piers for flume over river. Powerline footings. Riverbed water intake structures.
D	Hydraulic structures across channel	Dams and diversion dams. Erosion controls. Rock cascade drops, gabion controls, and concrete drops.

Although each scour problem must be analyzed individually, there are some general flow and sediment transport characteristics to be considered in making the judgmental decision on methodology. The general conclusion reached by Lane and Borland (1954) was that floods do not cause a general lowering of streambed, and rivers such as the Rio Grande may scour at the narrow sections but fill up at the wider downstream sections during a major flood. Another general sediment transport characteristic is the influence of a large sediment load on scour which includes the variation of sediment transport associated with a high peak, short duration flood hydrograph. The large sediment concentrations usually of clay and silt size material will occur on the rising stage of the hydrograph up and through the peak of the flood while the falling stage of the flood with deposition of coarser sediments in the bed of the channel may be accompanied by greater scour of the wetted channel banks. Channel scour also occurs when the capacity of streamflow with extreme high velocities in portions of the channel cross section will transport the bed material at a greater rate than replacement materials are supplied. Thus, maximum depth of channel scour during the flood is a function of the channel geometry, obstruction created by a structure (if any), the velocity of flow, turbulence, and size of bed material.

Design Flood

The first step in local scour study for design of a structure is selection of design flood frequency. Reclamation criteria for design of most structures

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shown in table 6 varies from a design flood estimated on a frequency basis from 50 to 100 years. This pertains to an adequate waterway for passage of the floodflow peak. The scour calculations for these same structures are always made for a 100-year flood peak. The use of the 100-year flood peak for scour is based on variability of channel hydraulics, bed material, and general complexity of the erosive process. The exception in the use of the 100-year flood peak for estimating scour would be the scour hole immediately below a large dam or a major structure where loss of structure could involve lives or represent a catastrophic event. In this case, the scour for use in design should be determined for a flow equal to 50 percent of the structure design flood.

Equation Types A and B (See Table 6)

Natural river channel scour estimates are required in design of a buried pipe, buried canal siphon, or a bankline structure. For most siphon crossings of a river, the cost of burying a siphon will dictate either the selection of a natural narrow reach of river or a restriction in width created by constructing canal bankline levees across a portion of the flood plain. A summary of available methods for computing scour at constrictions is given by Neill (1973). The four methods for estimating general scour at constricted waterways described by Neill (1973) are considered the proper approach for estimating scour for use in either design of a siphon crossing or where general scour is needed of the riverbed for a bankline structure. The four methods supplemented with Reclamation's procedure for application are given below:

Field measurments of scour method. - This method consists of observing or measuring the actual scoured depths either at the river under investigation or a similar type river. The measurements are taken during as high a flow as possible to minimize the influence of extrapolation.

A Reclamation unpublished study by Abbott (1963) analyzed U.S. Geological Survey discharge measurement notes from several streams in the southwestern United States, including the Galisteo Creek at Domingo, New Mexico, and developed an empirical curve enveloping observed scour at the gaging station. This envelope curve for use in siphon design was further supported by observed scour from crest-stage and scour gages on Gallegos, Kutz, Largo, Chaco, and Gobernador Canyons in northwest New Mexico collected during the period from 1963 to 1969. The scour gages consisted of a series of deeply anchored buried flexible tapes across the channel section that were resurveyed after a flood to determine the depth of scour at a specific location. The results of these measurements are shown on figure 8 along with the envelope curve for Galisteo Creek that support scour estimates for wide sandbed (D_{50} varying from 0.5 to 0.7 mm) ephemeral streams in the southwestern United States by the equation.

$$d_s = K\,(q)^{0.24} \tag{24}$$

where:

d_s = Depth of scour below streambed, ft (m)
K = 2.45 inch-pound units (1.32 metric units)
q = Unit water discharge, ft^3/s per ft of width (m^3/s per m of width)

A-20

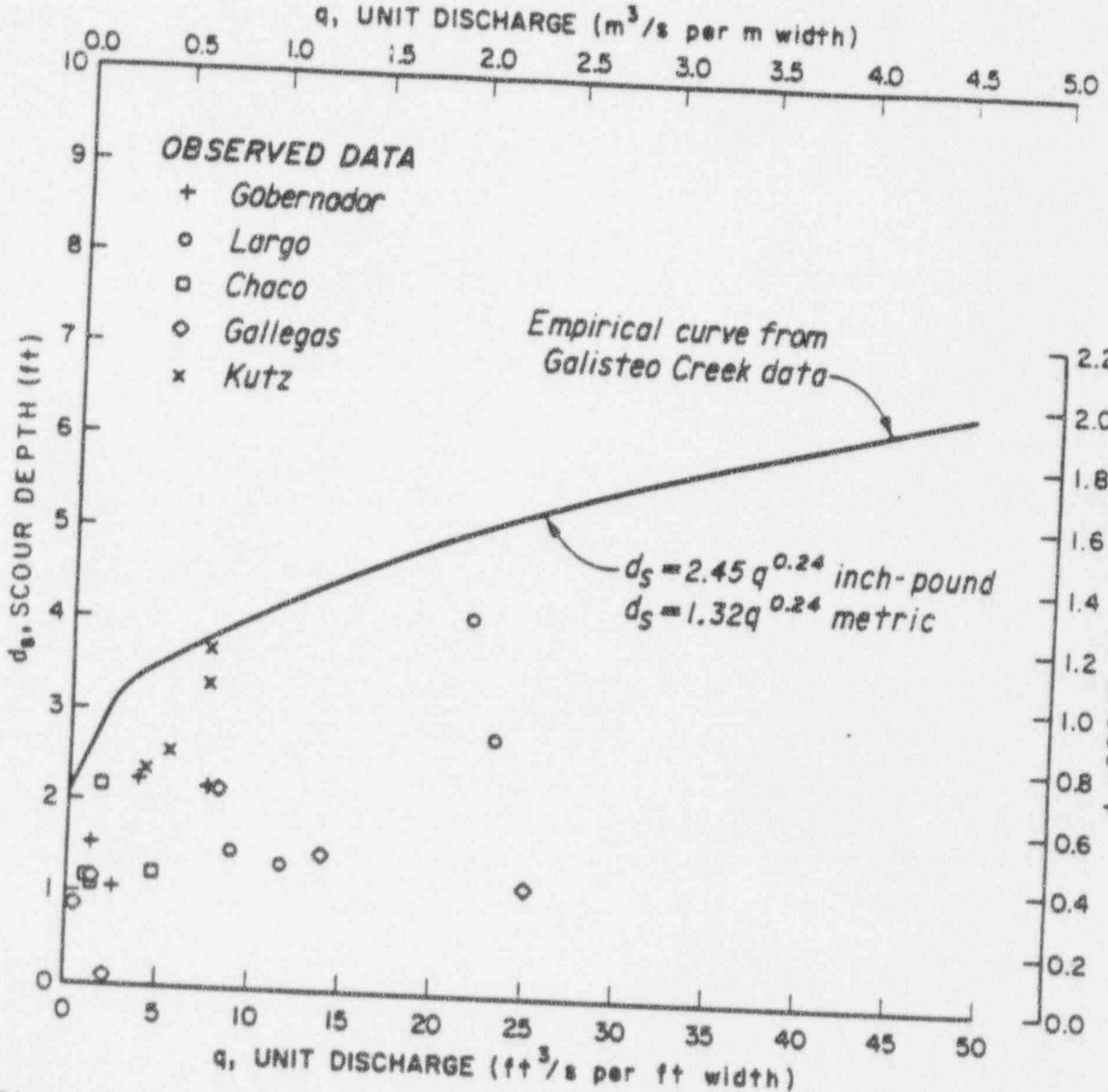

Figure 8. - Navajo Indian Irrigation Project - scour versus unit discharge.

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The use of equation 24 except as a check on other methods would be limited to channels similar to those observed on relatively steep slopes ranging from 0.004 to 0.008 ft/ft (m/m). Because of shallow depths of flow and medium to coarse sand size bed material the bedload transport should also be very high.

Regime equations supported by field measurements method. - This approach as suggested by Neill (1973) on recommendations by Blench (1969) involves obtaining field measurements in an incised reach of river from which the bankfull discharge and hydraluics can be determined. From the bankfull hydraulics in the incised reach of river, the flood depths can be computed by:

$$d_f = d_i \left(\frac{q_f}{q_i}\right)^m \tag{25}$$

where:

d_f = Scoured depth below design floodwater level
d_i = Average depth at bankfull discharge in incised reach
q_f = Design flood discharge per unit width
q_i = Bankfull discharge in incised reach per unit width
m = Exponent varying from 0.67 for sand to 0.85 for coarse gravel

This method has been expanded for Reclamation use to include the empirical regime equation by Lacey (1930) and the method of zero bed-sediment transport by Blench (1969) in the form of the Lacey equation:

$$d_m = 0.47 \left(\frac{Q}{f}\right)^{1/3} \tag{26}$$

where:

d_m = Mean depth at design discharge, ft (m)
Q = Design discharge, ft^3/s (m^3/s)
f = Lacey's silt factor equals $1.76 (D_m)^{1/2}$ where D_m equal mean grain size of bed material in millimeters

and the Blench equation for "zero bed factor":

$$d_{fo} = \frac{q_f^{\ 2/3}}{F_{bo}^{\ 1/3}} \tag{27}$$

where:

d_{fo} = Depth for zero bed sediment transport, ft (m)
q_f = Design flood discharge per unit width, ft^3/s per ft (m^3/s per m)
F_{bo} = Blench's "zero bed factor" in ft/s^2 (m/s^2) from figure 9

The maximum natural channel scour depth for design of any structure placed below the streambed (i.e., siphon) or along the bank of a channel must

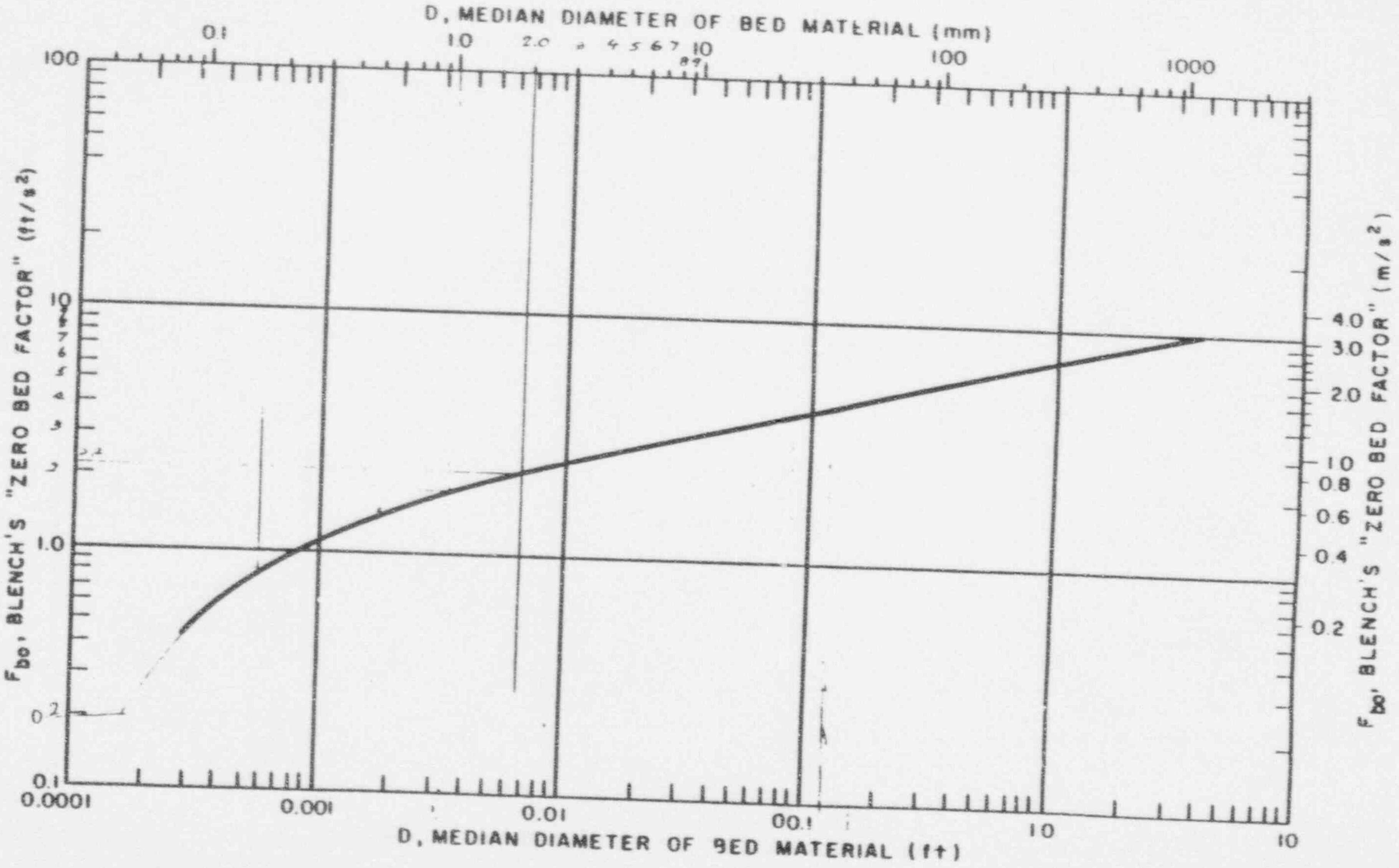


CHART FOR ESTIMATING F_{bo} (AFTER BLENCH)

Figure 9. - Chart for estimating F_{bo} (after Blench, 1969).

consider the probable concentration of floodflows in some portion of the natural channel. Equations 25, 26, or 27 for predicting this maximum depth are to be adjusted by the empirical multiplying factors, Z, shown for formula Types A and B (table 6), in table 7. An illustration of maximum scour depth associated with a flood discharge is shown in a sketch of a natural channel, figure 10. As shown in table 7 and on figure 10, the d_s equals depth of scour below streambed.

$$d_s = Z\ d_f \tag{28}$$

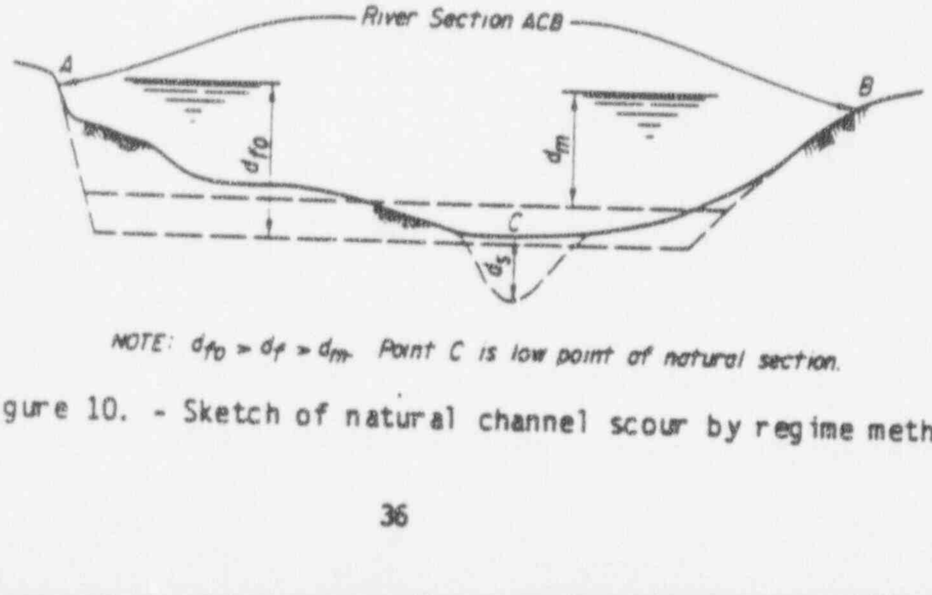
$$d_s = Z\ d_m \tag{29}$$

$$d_s = Z\ d_{fo} \tag{30}$$

Table 7. - Multiplying factors, Z, for use in scour depths by regime equations

Condition	Value of Z		
	Neill $d_s = Z\ d_f$	Lacey $d_s = Z\ d_m$	Blench $d_s = Z\ d_{fo}$
Equation Types A and B			
Straight reach	0.5	0.25	} 1/ 0.6
Moderate bend	0.6	0.5	
Severe bend	0.7	0.75	
Right angle bends		1.0	1.25
Vertical rock bank or wall		1.25	
Equation Types C and D			
Nose of piers	1.0		0.5 to 1.0
Nose of guide banks	0.4 to 0.7	1.50 to 1.75	1.0 to 1.75
Small dam or control across river		1.5	0.75 to 1.25

1/ Z value selected by USBR for use on bends in river.



NOTE: $d_{fo} > d_f > d_m$. Point C is low point of natural section.

Figure 10. - Sketch of natural channel scour by regime method.

Although not shown on figure 10, the d_f from Neill's equation 25 is usually less than the d_{fo} from Blench's equation 27 but greater than the d_m from Lacey's equation 26.

The design of a structure under a river channel such as a siphon is based on applying the scoured depth, d_s, as obtained from table 7 to the low point in a surveyed section, as shown by point C on figure 10. This criteria is considered by Reclamation as an adequate safety factor for use in design. In an alluvial streambed, designs should also be based on scour occuring at any location in order to provide for channel shifting with time.

Mean velocity from field measurements method. - This approach represents an adjustment in surveyed channel geometry based on an extrapolated design flow velocity. In Reclamation's application of this method, a series of at least four cross sections are surveyed and backwater computations made for the design discharge by use of Reclamation's Water Surface Profile Computer Program. In addition to the surveyed cross sections observed, water surface elevations at a known or measured discharge are needed to provide a check on Manning's "n" channel roughness coefficient. This procedure allows for any proposed waterway restrictions to be analyzed for channel hydraulic characteristics including mean velocity at the design discharge. The usual Reclamation application of this method is to determine the mean channel depth, d_m, from the computer output data and apply the Z values defined by Lacey in table 7 to compute a scour depth, d_s, by equation 29 where $d_s = Z\ d_m$.

Examples of more unique solutions to scour problems were Reclamation studies on the Colorado River near Parker, Arizona, and Salt River near Granite Reef Diversion Dam, Arizona, where an adjustment in "n" based on particle size along with a Z value from table 7 provided a method of computing bed scour. The selection of a particle size "n" associated with scour in the above two examples was computed from the Strickler (1923) equation for roughness of a channel based on diameter of particles where:

$$K = \frac{C}{D_{90}^{1/6}} \qquad (31)$$

$C \approx 26$ from Nikuradse (1933) and "n" = 1/K. The appropriate "n" values for the two rivers based on particle size and engineering judgment were selected as follows:

River	D (mm)	Particle size "n"	Selected "n"
Colorado	0.2	0.01	0.014
Salt	18	0.02	0.02

In the Colorado River study, the existing channel "n" value of 0.022 was adjusted down to 0.014 due to bed material particle size to give a computed water surface at design discharge representative of a scoured channel. With a Z value of 0.5, the scoured section in the form of a trianglular section combined with the accepted "n" of 0.022 provided a close check on the water surface computed without scour. An illustration

A-25

of this technique is shown in sketch on figure 11a. Another example is shown on figure 11b for a Salt River scour study where the particle size "n" of 0.02 gave a reduced mean depth. Scour was assumed to be in the shape of a triangle where the average depth of scour would be equal the depth at an "n" equal to 0.02 subtracted from depth at an "n" equal to 0.03. (See example problem in subsequent paragraph.)

4 Competent or limiting velocity control to scour method. - This method assumes that scour will occur in the channel cross section until the mean velocity is reduced to that where little or no movement of bed material is taking place. It gives the maximum limit to scour existing in only the deep scour hole portion of the channel cross section and is similar to the Blench equation 27 for a "zero bed factor."

The empirical curves, figure 12, derived by Neill (1973) for competent velocity with sand or coarser bed material (>0.30 mm) represent a combining of regime criteria, Shields (1936) criterion for material >1.0 mm, and a mean velocity formula relating mean velocity V_m to the shear velocity. The competent velocities for erosion of cohesive materials recommended by Neill (1973) are given in table 8. The scour depth or increase in area of scoured channel section with corresponding increase in depth for competent velocity, V_c, is determined by relationship of mean velocity, V_m, to V_c in the equation:

$$d_s = d_m\left(\frac{V_m}{V_c} - 1\right) \tag{32}$$

where:

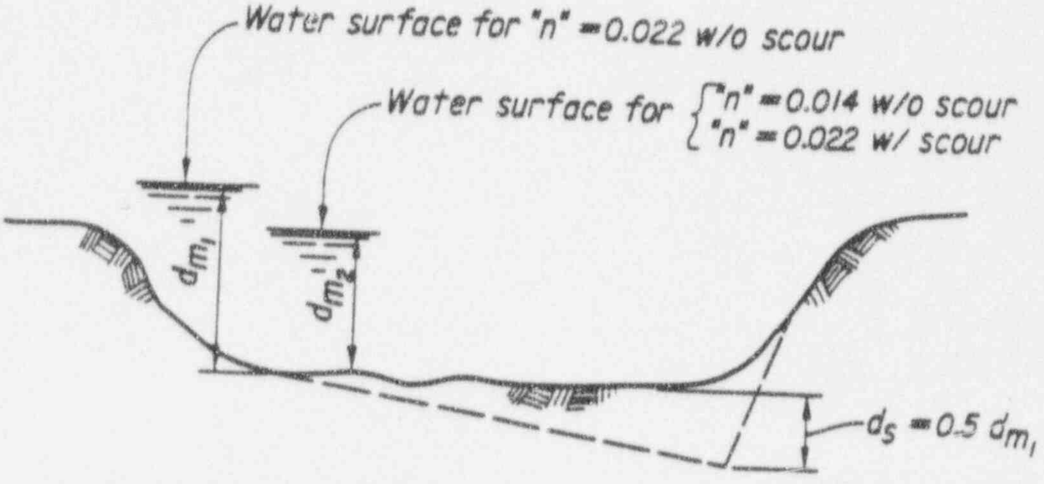
d_s = Scour depth below streambed, ft (m)
d_m = Mean depth, ft (m)

Table 8. - Tentative guide to competent velocities for erosion of cohesive materials* (after Neill, 1973)

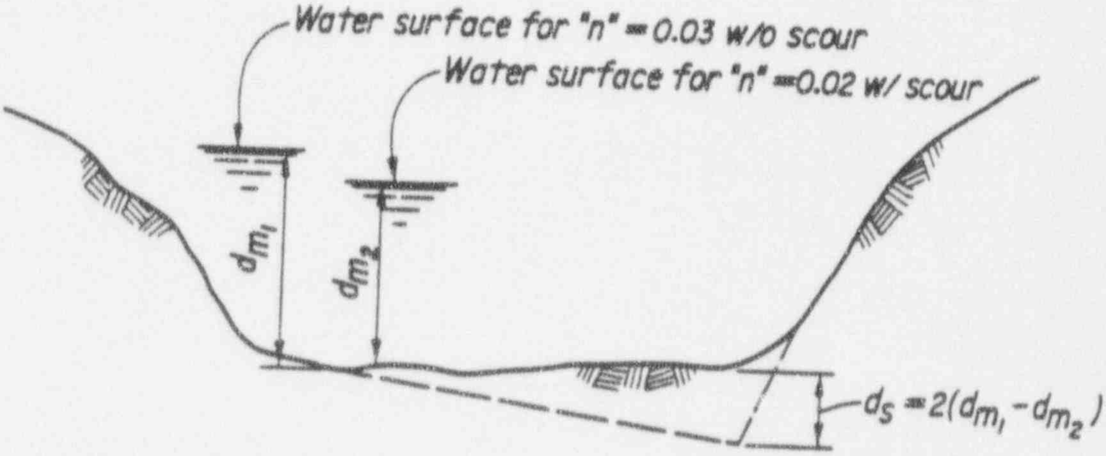
Depth of flow		Competent mean velocity					
		Low values - easily erodible material		Average values		High values - resistant material	
ft	m	ft/s	m/s	ft/s	m/s	ft/s	m/s
5	1.5	1.9	0.6	3.4	1.0	5.9	1.8
10	3	2.1	0.65	3.9	1.2	6.6	2.0
20	6	2.3	0.7	4.3	1.3	7.4	2.3
50	15	2.7	0.8	5.0	1.5	8.6	2.6

* Notes: (1) This table is to be regarded as a rough guide only, in the absence of data based on local experience. Account must be taken of the expected condition of the material after exposure to weathering and saturation. (2) It is not considered advisable to relate the suggested low, average, and high values to soil shear strength or other conventional indices, because of the predominating effects of weathering and saturation on the erodibility of many cohesive soils.

H-26



a. Colorado River Study



b. Salt River Study

Figure 11. - Sketch of scour from water surface profile computations and reduced "n" for scour.

The use of figure 12 and table 8 recommended by Neill (1973) has had limited application in Reclamation, but appears to be a potential useful technique for many Reclamation studies on scour and armoring of the channel.

Equation Type C (See Table 6)

The principal references for design of midchannel structures for scour such as at bridge piers are National Cooperative Highway Research Program Synthesis 5 (1970), C. R. Neill (1973), Federal Highway Administration, Training and Design Manual (1975), Federal Highway Administration (1980), and S. C. Jain (1981). The numerous empirical relationships for computing scour at bridge piers include one or more of the following hydraulic parameters: pier width and skewness, flow depth, velocity, and size of sediment. The many relations available were further broken down by Jain (1981) to two different approaches: (1) regime, and (2) rational.

The Federal Highway Administration has funded numerous research projects to assist in improving their designs of bridge piers. This research has not resulted in any one recommended procedure. Reclamation's need for scour estimates at midchannel structures is limited. The procedures adopted are to try at least two techniques and apply engineering judgment in selecting an average or most reliable method. The regime approach is to use either equations 26, 27, 28, or 30 and a Z value from table 7. An appropriate Z value to use for piers is 1.0 as found for the railway bridge piers applied to the Lacey equation 29 reported by Central Board of Irrigation and Power (1971).

The rational equation selected for scour at piers is described by Jain (1981) in the form:

$$\frac{d_s}{b} = 1.84 \left(\frac{d}{b}\right)^{0.3} \left(F_c\right)^{0.25} \qquad (33)$$

where:

d_s = Depth of scour below streambed, ft (m)
b = Pier size, ft (m)
d = Flow depth, ft (m)
$F_c = V_c/\sqrt{gd}$ = Threshold Froude number
V_c = Threshold velocity, ft/s (m/s) from figure 12
g = Acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)

Equation Type D (See Table 6)

Immediately downstream from any hydraulic structure the riverbed is subject to the erosive action created by the structure. Some type of stilling basin or energy dissipator as described by Reclamation (1977) is provided in the design of such structures to dissipate the energy thereby reducing the erosion potential. There still remains at most structures, below the point where the structure ends and the natural riverbed material begins, a potential for scour. The magnitude of this scour hole will depend on a combination of flow velocity, turbulence, and vortices generated by the structure. Simons and Senturk (1977) describe many of the available equations.

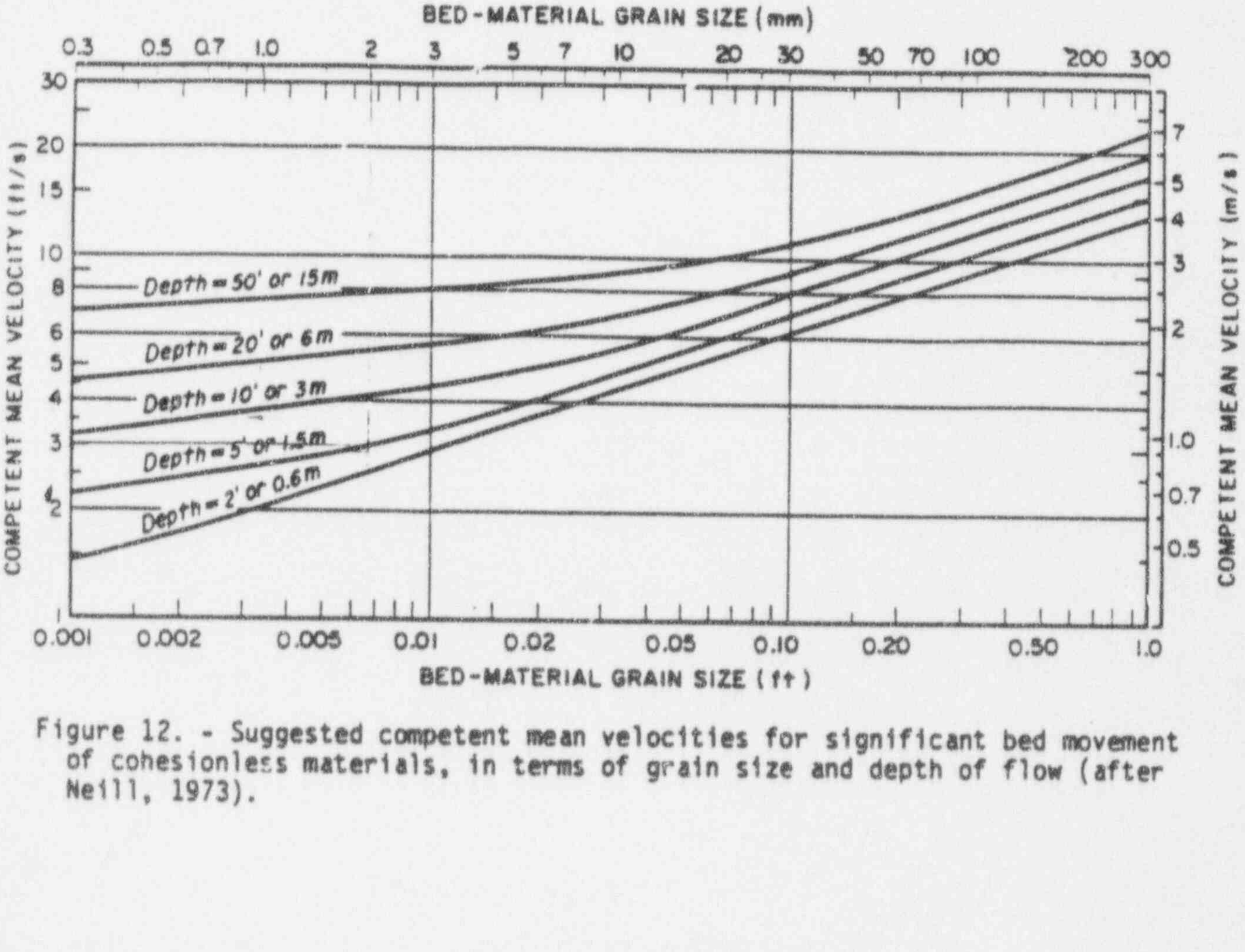


Figure 12. - Suggested competent mean velocities for significant bed movement of cohesionless materials, in terms of grain size and depth of flow (after Neill, 1973).

A-29

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HYDROLOGY FOR ENGINEERS

Third Edition

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Stanford University
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A-30

Table A-18 Values of n for the Manning Formula [Eq. (4-7)]

Channel condition	n†
Plastic, glass, drawn tubing	0.009
Neat cement, smooth metal	0.010
Planed timber, asbestos pipe	0.011
Wrought iron, welded steel, canvas	0.012
Ordinary concrete, asphalted cast iron	0.013
Unplaned timber, vitrified clay, glazed brick	0.014
Cast-iron pipe, concrete pipe	0.015
Riveted steel, brick, dressed stone	0.016
Rubble masonry	0.017
Smooth earth	0.018
Firm gravel	0.020
Corrugated metal pipe and flumes	0.023
Natural channels:	
Clean, straight, full stage, no pools	0.029
As above with weeds and stones	0.035
Winding, pools and shallows, clean	0.039
As above at low stages	0.047
Winding, pools and shallows, weeds and stones	0.042
As above, shallow stages, large stones	0.052
Sluggish, weedy, with deep pools	0.065
Very weedy and sluggish	0.112

† Values quoted are averages of many determinations; variations of as much as 20 percent must be expected, especially in natural channels.

A 31

CIVIL ENGINEERING REFERENCE MANUAL

Sixth Edition

Michael R. Lindeburg, P.E.

PROFESSIONAL PUBLICATIONS, INC.
Belmont, CA 94002

A-32

Appendix A: Design Use Values of Manning's n

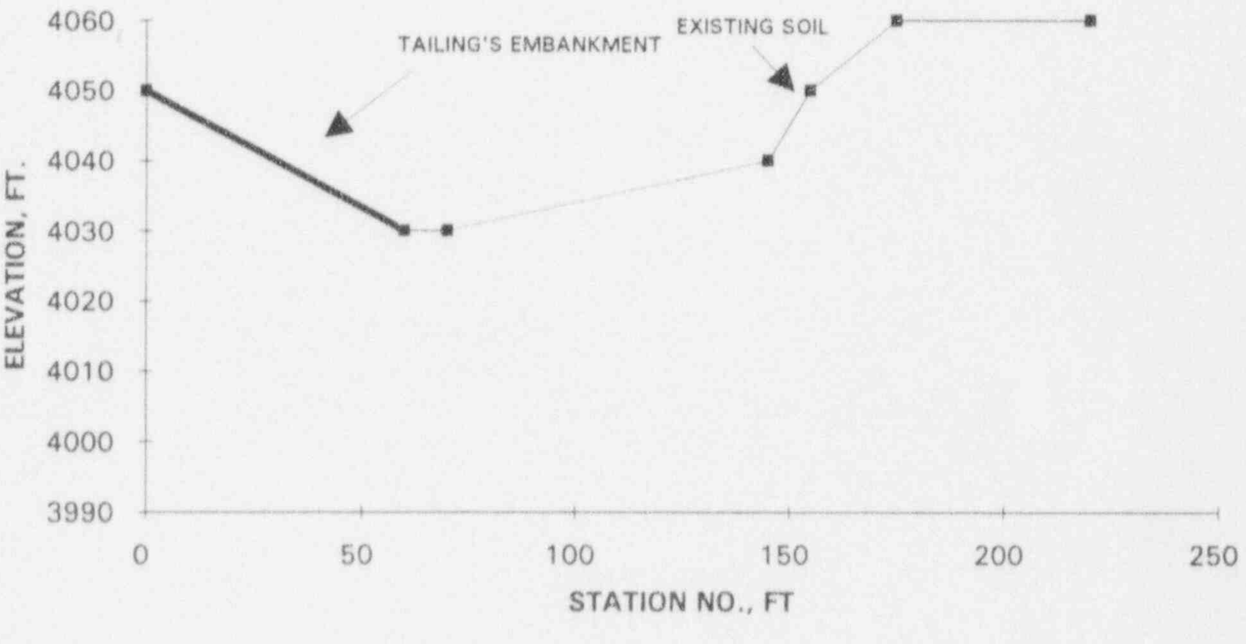
channel material	n
clean, uncoated cast iron	0.013–0.015
clean, coated cast iron	0.012–0.014
dirty, tuberculated cast iron	0.015–0.035
riveted steel	0.015–0.017
lock-bar and welded	0.012–0.013
galvanized iron	0.015–0.017
brass and glass	0.009–0.013
wood stave	
small diameter	0.011–0.012
large diameter	0.012–0.013
concrete	
with rough joints	0.016–0.017
dry mix, rough forms	0.015–0.016
wet mix, steel forms	0.012–0.014
very smooth, finished	0.011–0.012
vitrified sewer	0.013–0.015
common-clay drainage tile	0.012–0.014
asbestos	0.011
planed timber	0.011
canvas	0.012
unplaned timber	0.014
brick	0.016
rubble masonry	0.017
smooth earth	0.018
firm gravel	0.023
corrugated metal pipe	0.022
natural channels, good condition	0.025
natural channels with stones and weeds	0.035 ←
very poor natural channels	0.060

ATTACHMENT B

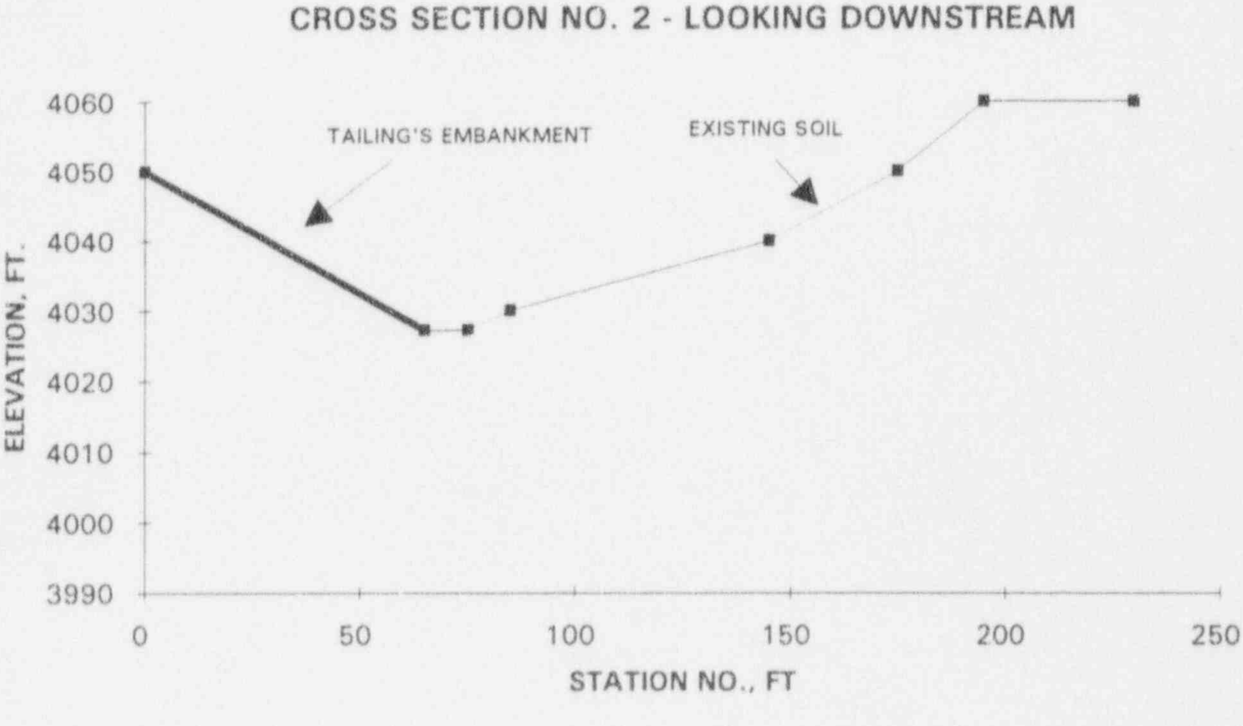
NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL CROSS SECTIONS

B-2

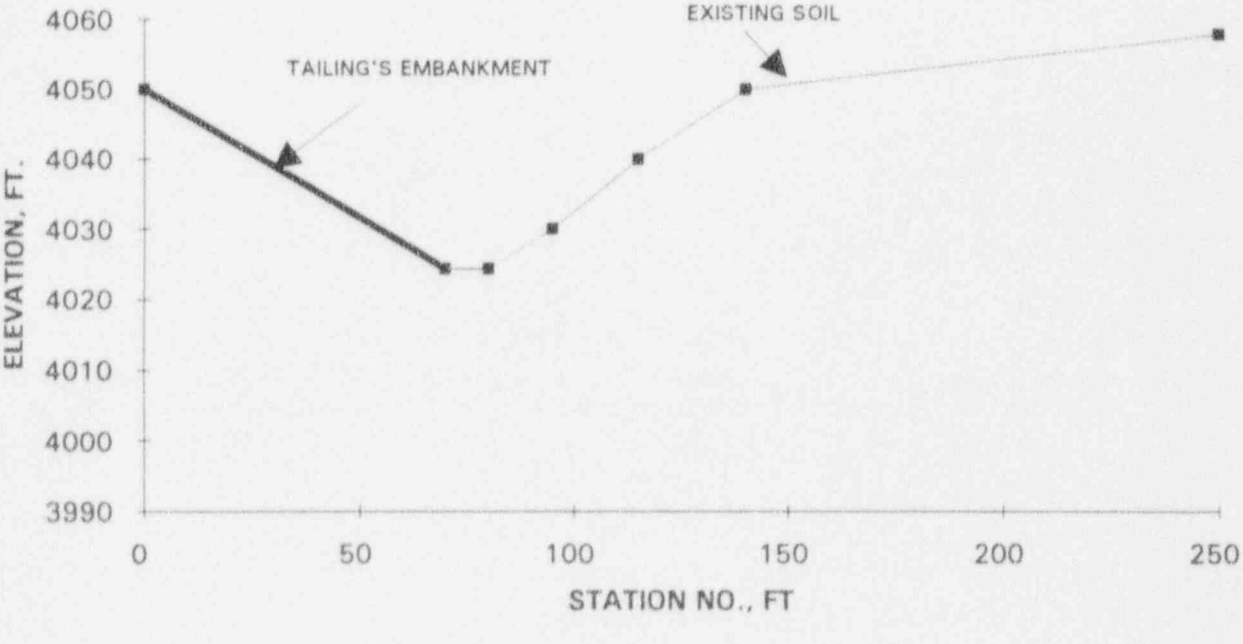
CROSS SECTION NO. 1 - LOOKING DOWNSTREAM



B-3

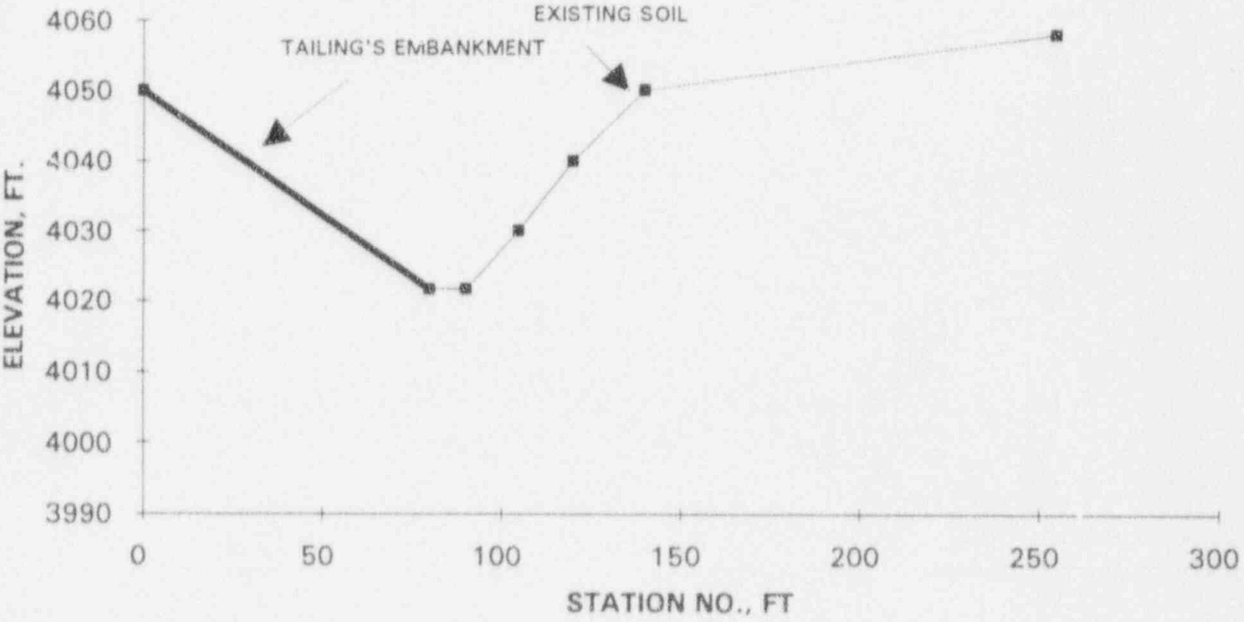

CROSS SECTION NO. 2 - LOOKING DOWNSTREAM
TAILING'S EMBANKMENT
EXISTING SOIL
ELEVATION, FT.
4060
4050
4040
4030
4020
4010
4000
3990
0
50
100
150
200
250
STATION NO., FT

CROSS SECTION NO. 3 - LOOKING DOWNSTREAM



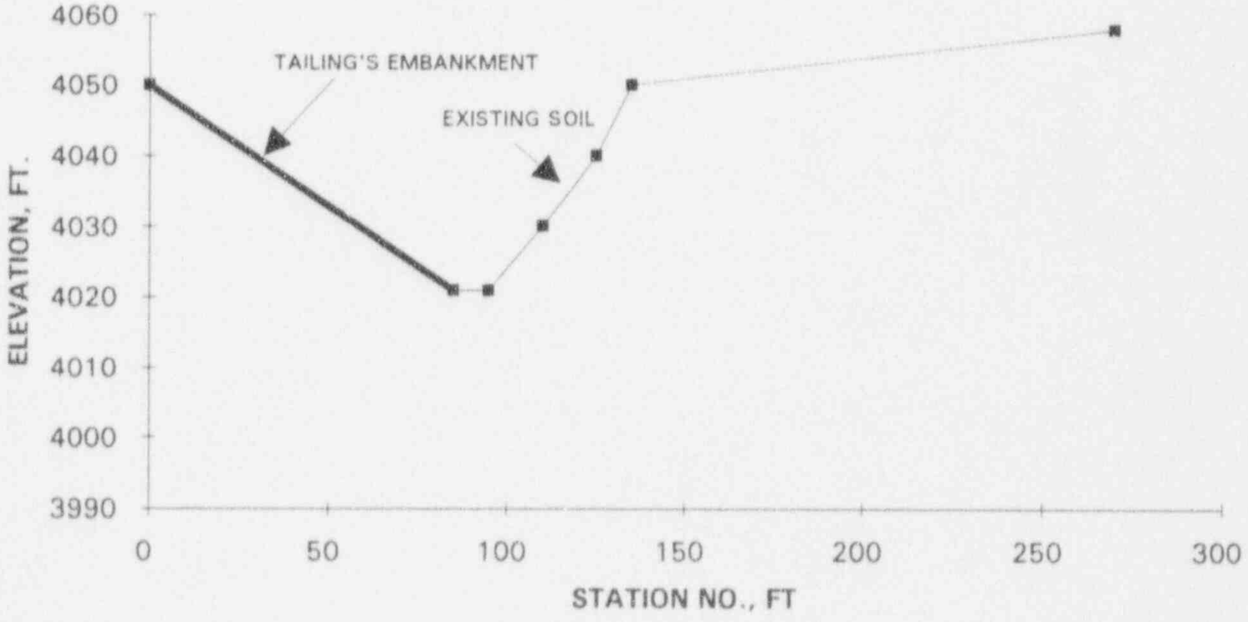
B-5

CROSS SECTION NO. 4 - LOOKING DOWNSTREAM

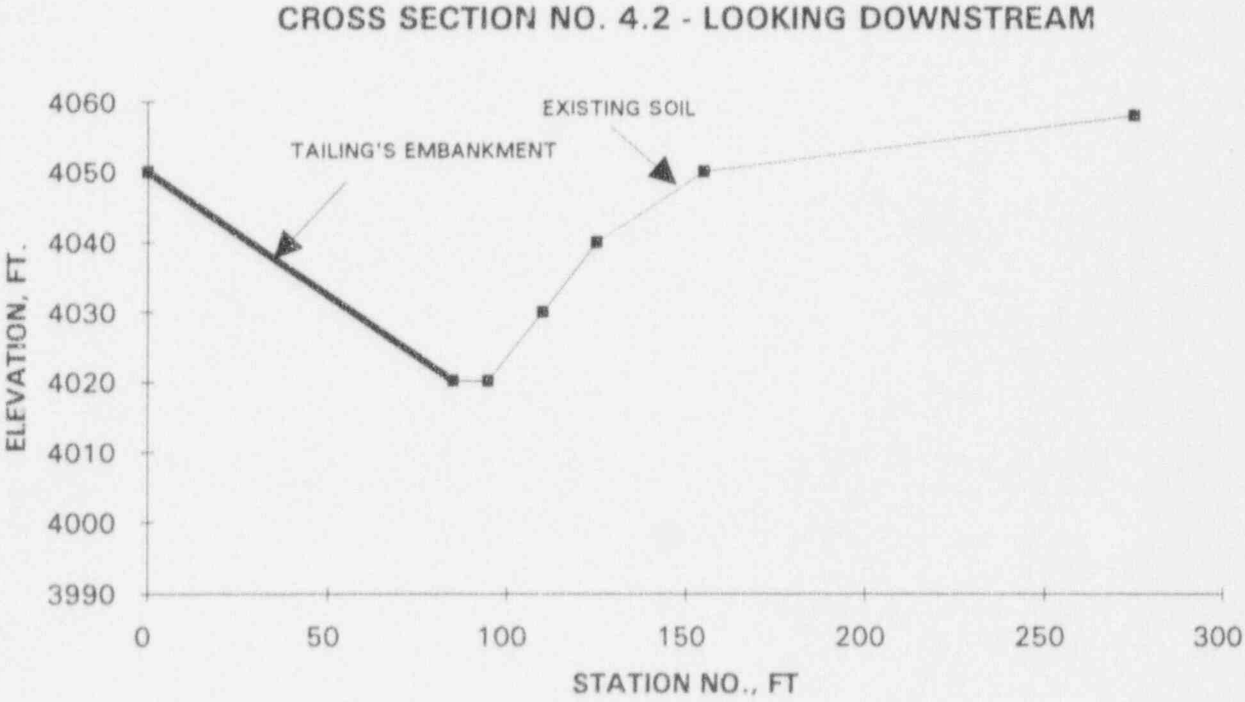


B-6

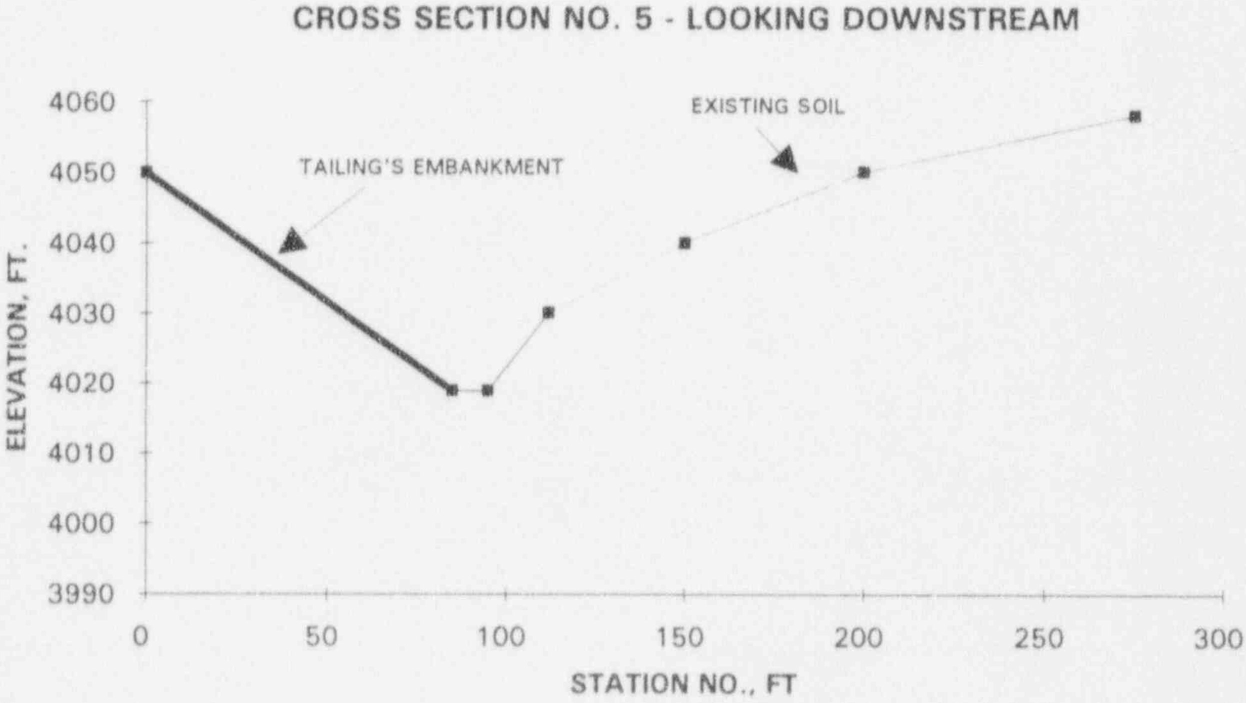
CROSS SECTION NO. 4.1 - LOOKING DOWNSTREAM



B-7

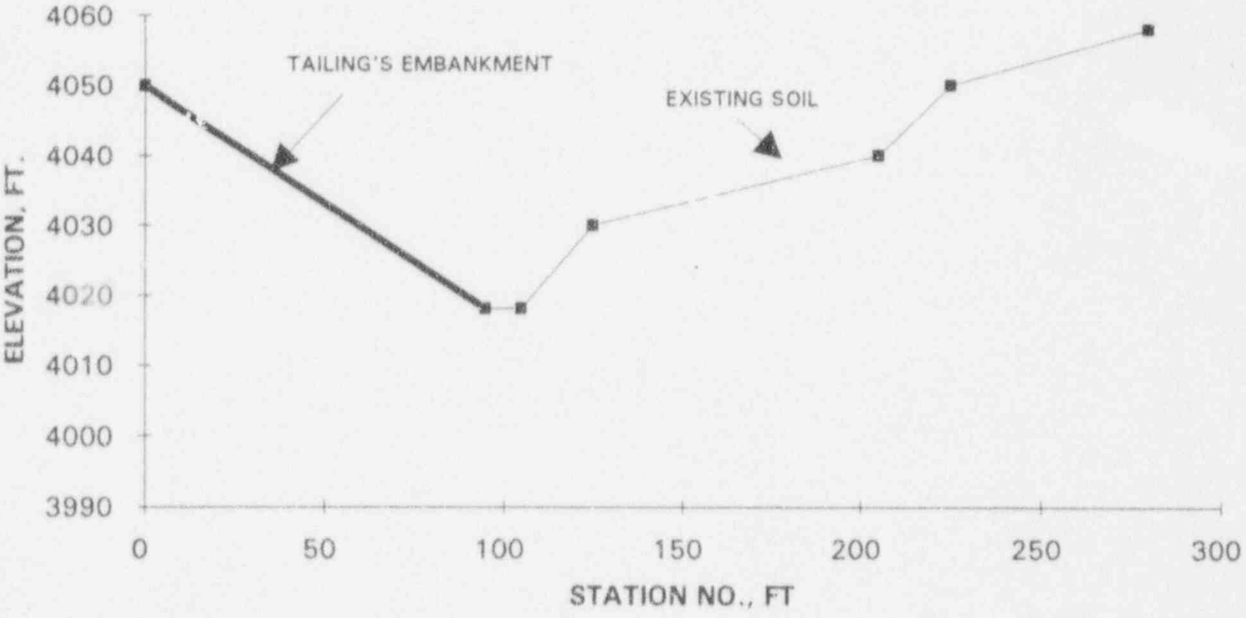

CROSS SECTION NO. 4.2 - LOOKING DOWNSTREAM
TAILING'S EMBANKMENT
EXISTING SOIL
ELEVATION, FT.
4060
4050
4040
4030
4020
4010
4000
3990
0
50
100
150
200
250
300
STATION NO., FT

B-8

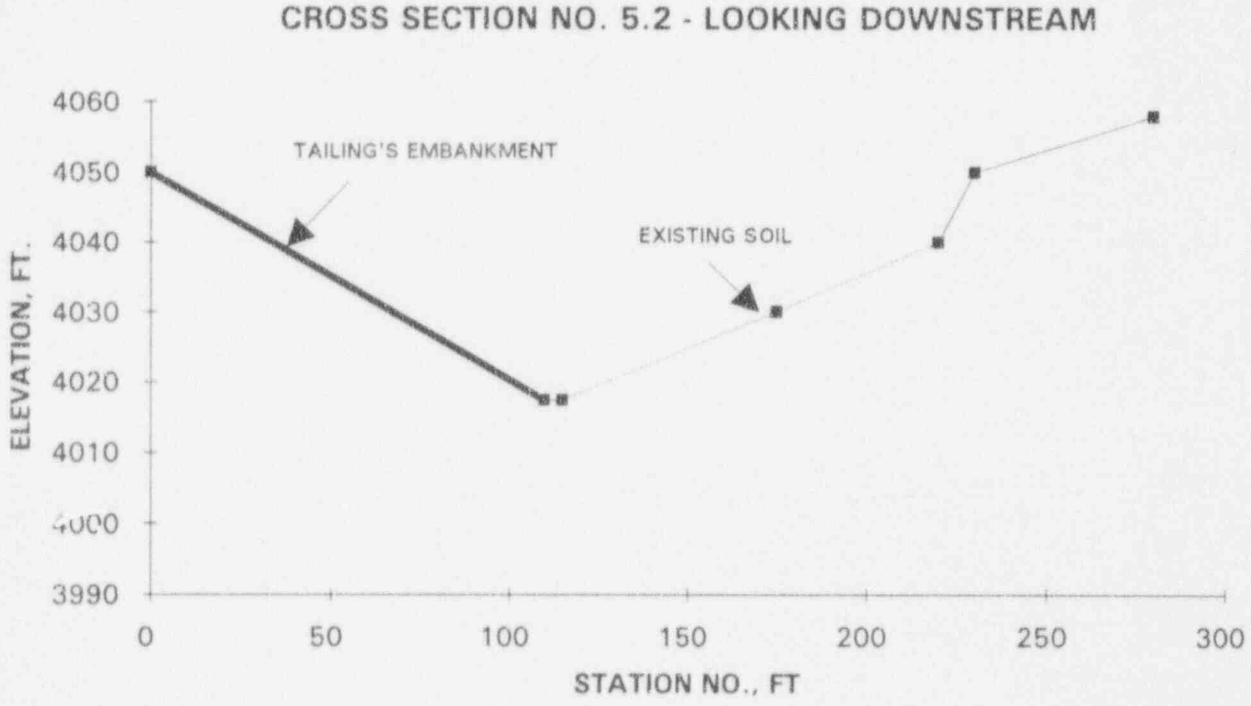

CROSS SECTION NO. 5 - LOOKING DOWNSTREAM
TAILING'S EMBANKMENT
EXISTING SOIL
ELEVATION, FT.
4060
4050
4040
4030
4020
4010
4000
3990
0
50
100
150
200
250
300
STATION NO., FT

B-9

CROSS SECTION NO. 5.1 - LOOKING DOWNSTREAM

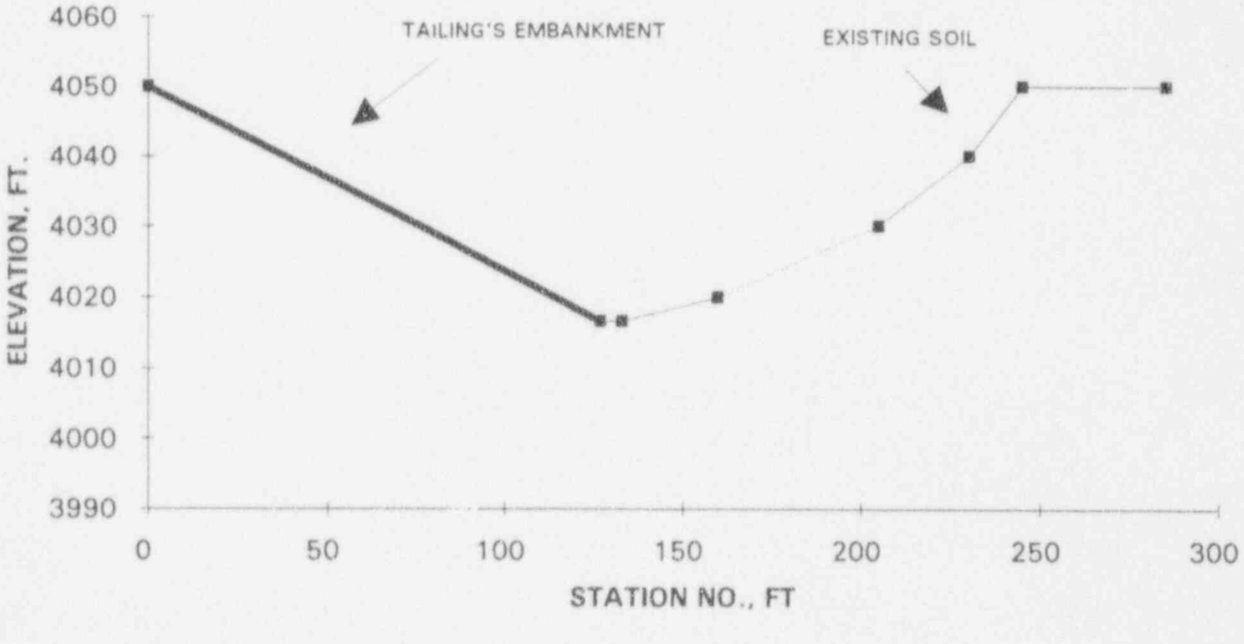


B-10


CROSS SECTION NO. 5.2 - LOOKING DOWNSTREAM
TAILING'S EMBANKMENT
EXISTING SOIL
ELEVATION, FT.
4060
4050
4040
4030
4020
4010
4000
3990
STATION NO., FT
0
50
100
150
200
250
300

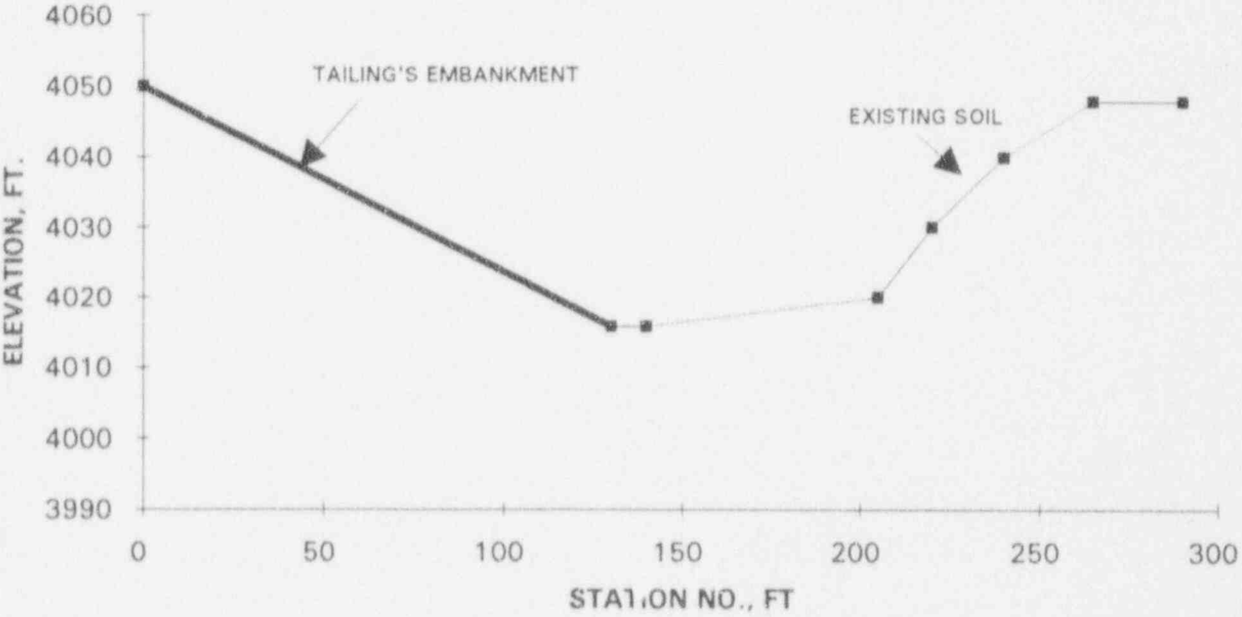
B-11

CROSS SECTION NO. 6 - LOOKING DOWNSTREAM



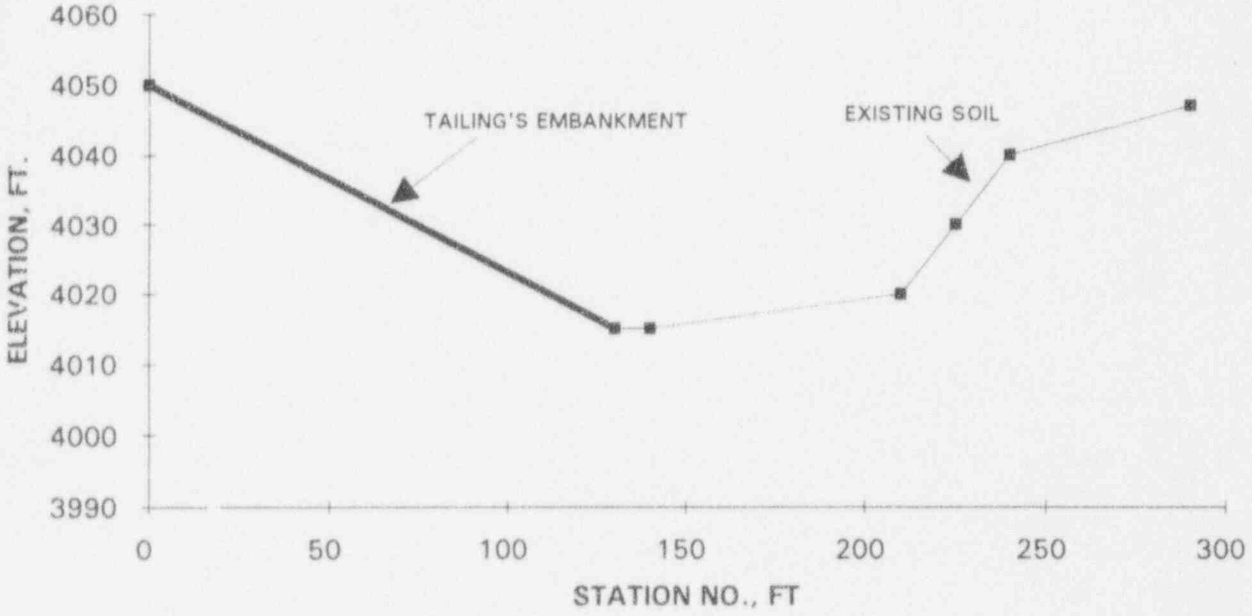
B-12

CROSS SECTION NO. 6.5 - LOOKING DOWNSTREAM



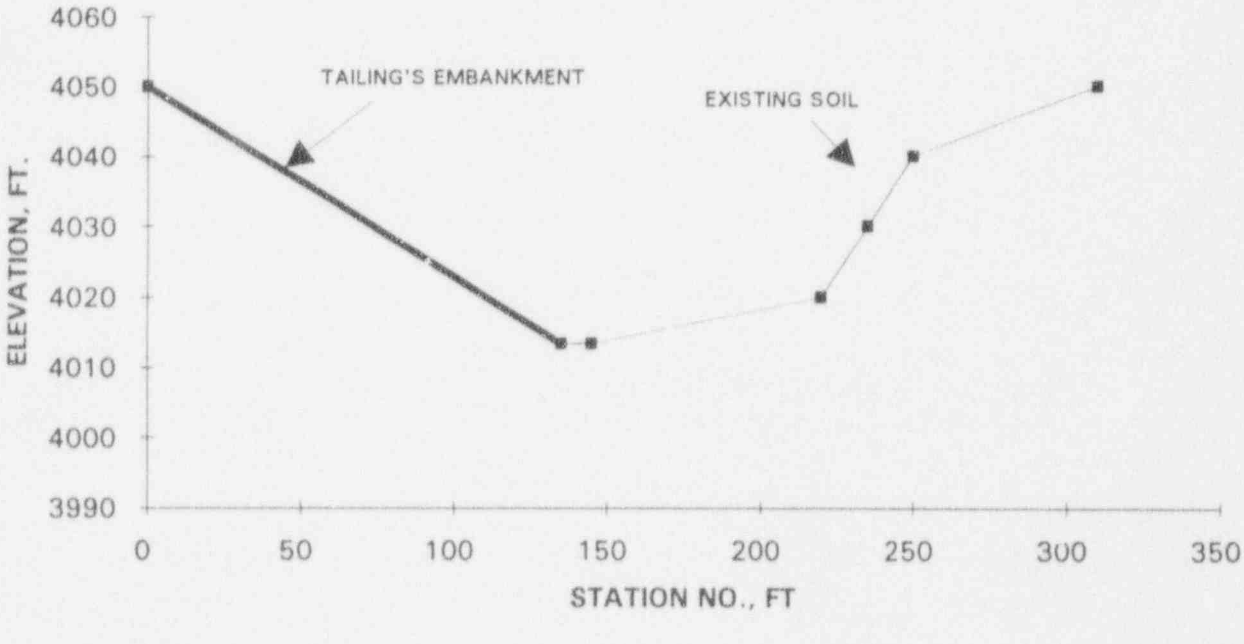
B-13

CROSS SECTION NO. 7 - LOOKING DOWNSTREAM

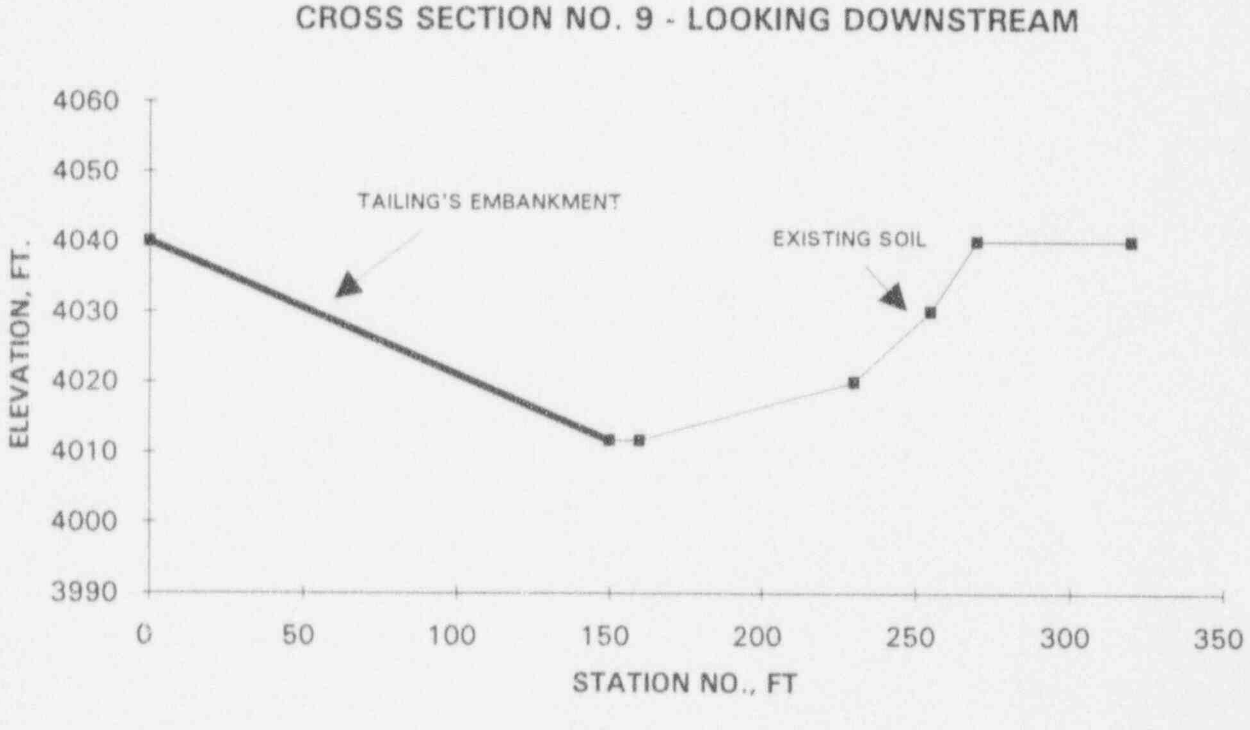


B-14

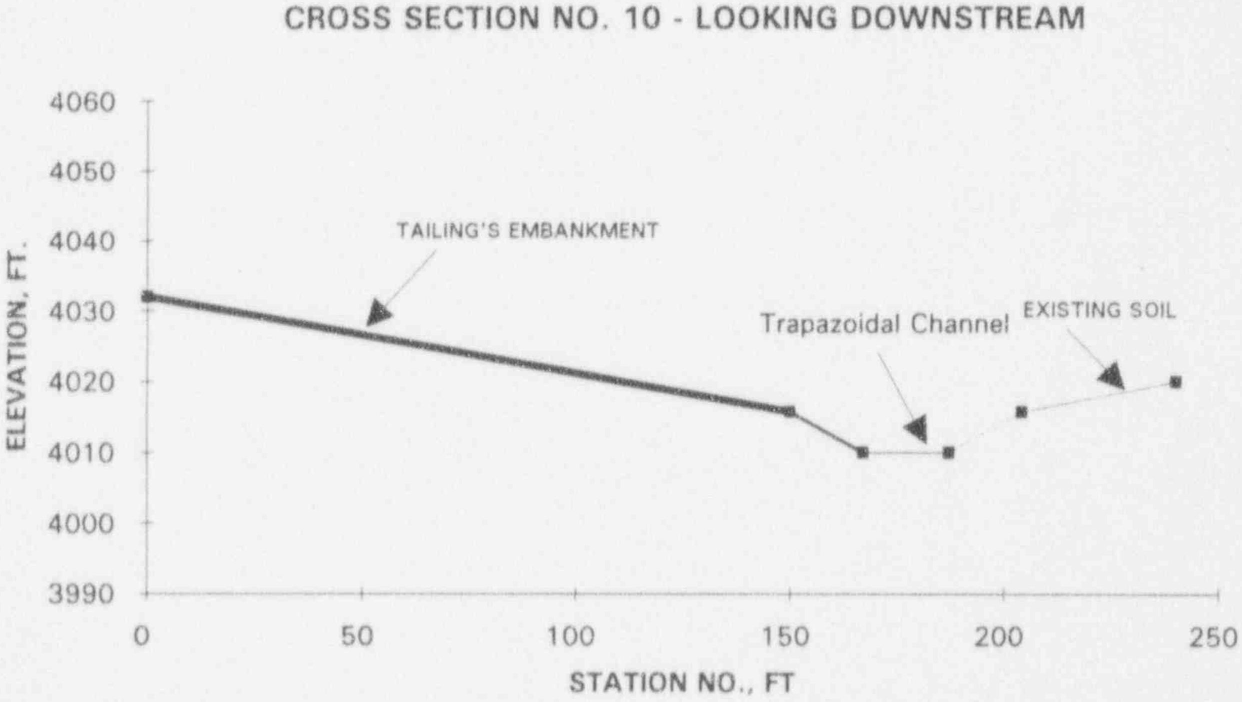
CROSS SECTION NO. 8 - LOOKING DOWNSTREAM



B-15


CROSS SECTION NO. 9 - LOOKING DOWNSTREAM
TAILING'S EMBANKMENT
EXISTING SOIL
ELEVATION, FT.
4060
4050
4040
4030
4020
4010
4000
3990
0
50
100
150
200
250
300
350
STATION NO., FT

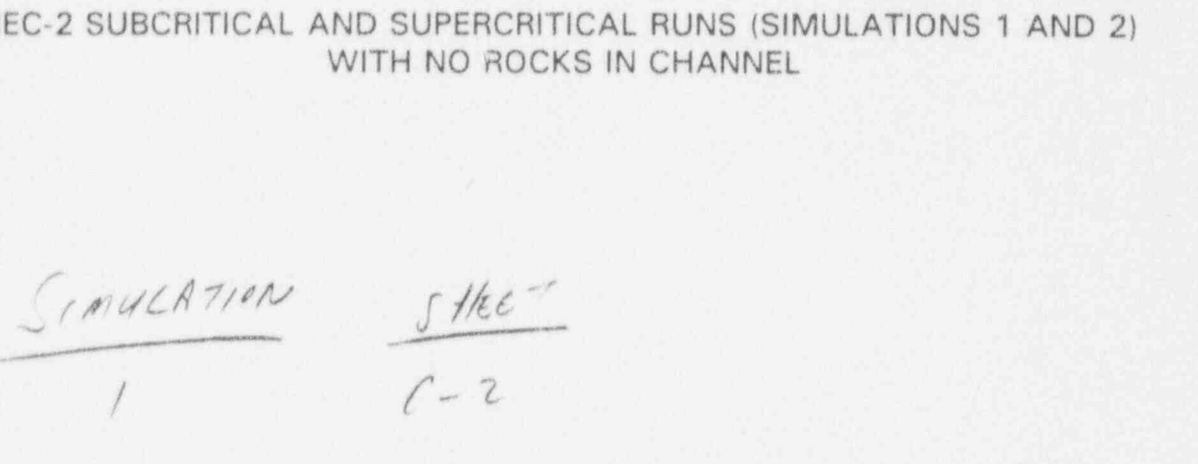
B-16


CROSS SECTION NO. 10 - LOOKING DOWNSTREAM
ELEVATION, FT.
4060
4050
4040
4030
4020
4010
4000
3990
0
50
100
150
200
250
STATION NO., FT
TAILING'S EMBANKMENT
Trapazoidal Channel
EXISTING SOIL

ATTACHMENT C

HEC-2 SUBCRITICAL AND SUPERCRITICAL RUNS (SIMULATIONS 1 AND 2) WITH NO ROCKS IN CHANNEL

Simulation	Sheet
1	C-2
2	C-13



C-2

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HEC2 S/N: 1916530006        HMVersion: 6.50    Data File: H:SWSUB.IN

*****************************************                  ****************************************
* HEC-2 WATER SURFACE PROFILES          *                  * U.S. ARMY CORPS OF ENGINEERS         *
*                                       *                  * HYDROLOGIC ENGINEERING CENTER        *
* Version   4.6.2;  May 1991            *                  * 609 SECOND STREET, SUITE D           *
*                                       *                  * DAVIS, CALIFORNIA 95616-4687         *
* RUN DATE    19MAY94    TIME  16:48:05 *                  *           (916) 756-1104             *
*****************************************                  ****************************************


                    X     X XXXXXXX  XXXXX           XXXXX
                    X     X X       X     X         X     X
                    X     X X       X                     X
                    XXXXXXX XXXX    X         XXXXX   XXXXX
                    X     X X       X               X
                    X     X X       X     X         X
                    X     X XXXXXXX  XXXXX          XXXXXXX
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SIMULATION 1

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                   ::::::::::::::::::::::::::::::::::::::::::::::::
                   ::::::::::::::::::::::::::::::::::::::::::::::::
                   :::                                          :::
                   :::   FULL MICRO-COMPUTER IMPLEMENTATION     :::
                   :::                                          :::
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                            H A E S T A D   M E T H O D S
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          37 Brookside Road  *  Waterbury, Connecticut  06708  *  (203) 755-1666
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C-3

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                                                                THIS RUN EXECUTED 19MAY94    16:48:05

**************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
**************************************


FR
T1 SOUTHWEST CHANNEL
T2 ATLAS MINERALS 88-067 5/12/94
T3      SUBCRITICAL RUN - NO WEDGE

J1  ICHECK      INQ       NINV      IDIR      STRT      METRIC     HVINS     Q        WSEL       FQ

      0.         0.        0.         0        -1.        0.        1.5    1605.    4014.61       0.

J2  NPROF      IPLOT      PRFVS     XSECV     XSECH       FN       ALLDC     IBW      CHNIM     ITRACE

     0.         0.        0.         0         0          0        -1


NC     0.03       0.03      0.03
NH        2      0.038     204.2      0.035       325      0.00         0          0          0          0
X1       10          8         0        325         0         0         0          0          0          0
GR     4032          0    4015.7        150      4010     167.1      4010      187.1     4015.7      204.2
GR     4020        240      4030        270      4037       325

NH        2      0.034       150      0.035       320         0         0          0          0          0
X1        9          7         0        320       150       150       150          0          0          0
GR     4040          0    4011.7      150.0    4011.7       160      4020        230       4030        255
GR     4040        270    4040.0      320.0

NH        2      0.034     135.0      0.035     310.0         0         0          0          0          0
X1        8          7       0.0      310.0     160.0       160       160          0          0          0
GR     4050          0    4013.4      135.0    4013.4       145      4020        220       4030        235
GR     4040        250    4050.0      310.0

NH        2      0.034     130.0      0.035     290.0         0         0          0          0          0
X1        7          7       0.C      290.0     150.0       150       150          0          0          0
GR     4050          0    4015.1      130.0    4015.1       140      4020        210       4030        225
GR     4040        240    4047.0      290.0

NH        2      0.034     130.0      0.035     290.0         0         0          0          0          0
X1      6.5          8       0.0      290.0      72.0        72        72
GR     4050          0    4015.9      130.0    4015.9       140      4020        205       4030        220
GR     4040        240    4048.0      265.0    4048.0       290
```

n n1 STA1 n2

STA 2 - manning's n info

Elev.

STA. NO.

#. of STA.

X-sec NO.

Beg. STA.

End STA

RBank LBank Center (Reach lengths)

UAP 5/20/92

C-4

```
NH       2     0.042     127.0     0.035     285.0
X1       6         8       0.0     285.0      75.0        75        75
GR    4050         0    4016.7     127.0    4016.7       133      4020       160      4030       205
GR    4040       230    4050.0     245.0    4050.0       285

NH       2     0.042     110.0     0.035     280.0
X1     5.2         7       0.0     280.0      66.0        66        66
GR    4050         0    4017.4     110.0    4017.4       115      4030       175      4040       220
GR    4050       230    4058.0     280.0

NH       2     0.042      95.0     0.035     280.0
X1     5.1         7       0.0     280.0      66.0        66        66
GR    4050         0    4018.1      95.0    4018.1       105      4030       125      4040       205
GR    4050       225    4058.0     280.0

NH       2     0.038      85.0     0.035     275.0
X1       5         7       0.0     275.0      66.0        66        66
GR    4050         0    4018.9      85.0    4018.9        95      4030       112      4040       150
GR    4050       200    4058.0     275.0

NH       2     0.038      85.0     0.035     275.0
X1     4.2         7       0.0     275.0     120.0       120       120
GR    4050         0    4020.2      85.0    4020.2        95      4030       110      4040       125
GR    4050       155    4058.0     275.0

NH       2     0.038      85.0     0.035     270.0
X1     4.1         7       0.0     270.0      66.0        66        66
GR    4050         0    4020.9      85.0    4020.9        95      4030       110      4040       125
GR    4050       135    4058.0     270.0

NH       2     0.038      80.0     0.035     255.0
X1       4         7       0.0     255.0      66.0        66        66
GR    4050         0    4021.6      80.0    4021.6        90      4030       105      4040       120
GR    4050       140    4058.0     255.0

NH       2     0.034      70.0     0.035     250.0         0         0         0         0         0
X1       3         7       0.0     250.0     250.0       250       250         0         0         0
GR    4050         0    4024.4      70.0    4024.4        80      4030        95      4040       115
GR    4050       140      4058       250

NH       2     0.034      65.0     0.035     230.0         0         0         0         0         0
X1       2         8       0.0     230.0     260.0       260       260         0         0         0
GR    4050         0    4027.2      65.0    4027.2        75      4030        85      4040       145
GR    4050       175    4060.0     195.0    4060.0       230

NH       2     0.034      60.0     0.035     220.0         0         0         0         0         0
X1       1         7       0.0     220.0     250.0       250       250         0         0         0
GR    4050         0    4030.0      60.0    4030.0        70      4040       145      4050       155
GR    4060       175    4060.0     220.0
```

VAP 5/20/92

C-5

```
 Run Date:  19MAY94    Run Time: 16:48:05    HMVersion: 6.50    Data File:   H:SWSUB.IN                                   Page    3

  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

*PROF 1

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS


1490 NH CARD USED
*SECNO 10.000
3720 CRITICAL DEPTH ASSUMED
    10.000       4.60    4014.60    4014.60    4014.61    4016.25       1.65       0.00       0.00    4032.00
    1605.0        0.0     1605.0        0.0        0.0      155.6        0.0        0.0        0.0    4037.00
      0.00       0.00      10.32       0.00      0.000      0.038      0.000      0.000    4010.00     153.29
  0.014959         0.         0.         0.          0          4          0       0.00      47.61     200.91

1490 NH CARD USED
*SECNO 9.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.58

     9.000       5.20    4016.90    4016.12       0.00    4017.60       0.71       1.35       0.00    4040.00
    1605.0        0.0     1605.0        0.0        0.0      238.0        0.0        0.7        0.2    4040.00
      0.01       0.00       6.74       0.00      0.000      0.035      0.000      0.000    4011.70     122.42
  0.006000       150.       150.       150.          2          8          0       0.00      81.47     203.89

1490 NH CARD USED
*SECNO 8.000
     8.000       4.40    4017.80    4017.67       0.00    4018.91       1.10       1.30       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      190.5        0.0        1.5        0.5    4050.00
      0.01       0.00       8.43       0.00      0.000      0.035      0.000      0.000    4013.40     118.73
  0.011656       160.       160.       160.          3         15          0       0.00      76.39     195.12

1490 NH CARD USED
*SECNO 7.000
     7.000       4.49    4019.59    4019.13       0.00    4020.37       0.78       1.46       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      226.2        0.0        2.2        0.8    4047.00
      0.02       0.00       7.10       0.00      0.000      0.035      0.000      0.000    4015.10     113.29
  0.008277       150.       150.       150.          2         11          0       0.00      90.81     204.10

1490 NH CARD USED
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C-6

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  Run Date:  19MAY94    Run Time: 16:48:05    HMVersion: 6.50    Data File:   H:SWSUB.IN                                    Page    4

    SECNO      DEPTH      CWSEL      CRIWS      WSELK       EG         HV         HL        OLOSS      L-BANK ELEV
    Q          QLOB       QCH        QROB       ALOB        ACH        AROB       VOL       TWA        R-BANK ELEV
    TIME       VLOB       VCH        VROB       XNL         XNCH       XNR        WTN       ELMIN      SSTA
    SLOPE      XLOBL      XLCH       XLOBR      ITRIAL      IDC        ICONT      CORAR     TOPWID     ENDST

*SECNO 6.500
     6.500       4.28    4020.18    4019.82       0.00    4020.98       0.80       0.61       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      222.9        0.0        2.6        1.0    4048.00
      0.02       0.00       7.20       0.00      0.000      0.035      0.000      0.000    4015.90     113.67
  0.008784        72.        72.        72.          2         15          0       0.00      91.60     205.27

1490 NH CARD USED
*SECNO 6.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     6.000       4.87    4021.57    4021.57       0.00    4023.01       1.43       0.84       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      167.1        0.0        2.9        1.1    4050.00
      0.02       0.00       9.60       0.00      0.000      0.037      0.000      0.000    4016.70     108.41
  0.014736        75.        75.        75.          0          8          0       0.00      58.67     167.08

1490 NH CARD USED
*SECNO 5.200
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     5.200       5.69    4023.09    4023.09       0.00    4024.65       1.56       0.97       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      160.2        0.0        3.1        1.2    4058.00
      0.02       0.00      10.02       0.00      0.000      0.038      0.000      0.000    4017.40      90.80
  0.014697        66.        66.        66.          0          8          0       0.00      51.31     142.10

1490 NH CARD USED
*SECNO 5.100
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     5.100       6.00    4024.10    4024.10       0.00    4026.03       1.93       0.99       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      144.0        0.0        3.4        1.2    4058.00
      0.03       0.00      11.15       0.00      0.000      0.038      0.000      0.000    4018.10      77.12
  0.015295        66.        66.        66.          0          8          0       0.00      37.96     115.09

1490 NH CARD USED
*SECNO 5.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     5.000       6.14    4025.04    4025.04       0.00    4027.03       1.99       0.96       0.00    4050.00
    1605.0        0.0     1605.0        0.0        0.0      141.7        0.0        3.6        1.3    4058.00
      0.03       0.00      11.33       0.00      0.000      0.036      0.000      0.000    4018.90      68.22
  0.013810        66.        66.        66.          0          8          0       0.00      36.17     104.40
```

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```
   SECNO       DEPTH       CWSEL       CRIWS       WSELK       EG          HV          HL          OLOSS       L-BANK ELEV
   Q           QLOB        QCH         QROB        ALOB        ACH         AROB        VOL         TWA         R-BANK ELEV
   TIME        VLOB        VCH         VROB        XNL         XNCH        XNR         WTN         ELMIN       SSTA
   SLOPE       XLOBL       XLCH        XLOBR       ITRIAL      IDC         ICONT       CORAR       TOPWID      ENDST


1490 NH CARD USED
*SECNO 4.200
     4.200        6.71     4026.91     4026.29        0.00     4028.37        1.46        1.34        0.00     4050.00
    1605.0         0.0      1605.0         0.0         0.0       165.7         0.0         4.0         1.4     4058.00
      0.03        0.00        9.69        0.00       0.000       0.036       0.000       0.000     4020.20       65.87
  0.009206        120.        120.        120.           3           5           0        0.00       39.40      105.27


1490 NH CARD USED
*SECNO 4.100
     4.100        6.65     4027.55     4026.93        0.00     4028.97        1.43        0.60        0.00     4050.00
    1605.0         0.0      1605.0         0.0         0.0       167.4         0.0         4.3         1.5     4058.00
      0.03        0.00        9.59        0.00       0.000       0.036       0.000       0.000     4020.90       65.59
  0.009121         66.         66.         66.           2          11           0        0.00       40.37      105.95


1490 NH CARD USED
*SECNO 4.000
     4.000        6.46     4028.06     4027.62        0.00     4029.61        1.54        0.63        0.00     4050.00
    1605.0         0.0      1605.0         0.0         0.0       160.9         0.0         4.5         1.5     4058.00
      0.03        0.00        9.97        0.00       0.000       0.036       0.000       0.000     4021.60       61.78
  0.010119         66.         66.         66.           2          11           0        0.00       39.77      101.55


1490 NH CARD USED
*SECNO 3.000
     3.000        6.15     4030.55     4030.17        0.00     4032.04        1.49        2.43        0.00     4050.00
    1605.0         0.0      1605.0         0.0         0.0       163.7         0.0         5.4         1.7     4058.00
      0.04        0.00        9.80        0.00       0.000       0.035       0.000       0.000     4024.40       53.18
  0.009348        250.        250.        250.           2          11           0        0.00       42.91       96.10


1490 NH CARD USED
*SECNO 2.000
     2.000        5.99     4033.19     4032.67        0.00     4034.33        1.14        2.29        0.00     4050.00
    1605.0         0.0      1605.0         0.0         0.0       187.6         0.0         6.5         2.0     4060.00
      0.05        0.00        8.56        0.00       0.000       0.035       0.000       0.000     4027.20       47.92
  0.008319        260.        260.        260.           2          11           0        0.00       56.24      104.15


1490 NH CARD USED
*SECNO 1.000
     1.000        5.37     4035.37     4034.78        0.00     4036.32        0.95        1.99        0.00     4050.00
    1605.0         0.0      1605.0         0.0         0.0       205.2         0.0         7.6         2.4     4060.00
      0.06        0.00        7.82        0.00       0.000       0.035       0.000       0.000     4030.00       43.89
  0.007617        250.        250.        250.           2          15           0        0.00       66.40      110.29
```

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```
PROFILE FOR STREAM   SUBCRITICAL RUN - NO WE


PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA


ELEVATION  4010.     4015.     4020.     4025.     4030.     4035.     4040.     4045.     4050.     4055.
    SECNO   CUMDIS

    10.00     0.  I        W.  E      .         .         .   L     .   R     .         .         .         .         .
             20.  I         W  E      .         .         .     L   .    R    .         .         .         .         .
             40.  .I        W  E      .         .         .       L .     R   .         .         .         .         .
             60.  .I        CW  E     .         .         .         L     R   .         .         .         .         .
             80.  . I       .CW E     .         .         .         .  L   R  .         .         .         .         .
            100.  . I       .CW E     .         .         .         .    L  R .         .         .         .         .
            120.  .  I      . CW E    .         .         .         .      L R.         .         .         .         .
            140.  .  I      . CW E    .         .         .         .        LR         .         .         .         .
     9.00   160.  .  I      . C WE    .         .         .         .         L         .         .         .         .
            180.  .   I     .  CW E   .         .         .         .         .  L      .         .         .         .
            200.  .   I     .  CW E   .         .         .         .         .    L    .         .         .         .
            220.  .    I    .  CW E   .         .         .         .         .       L .         .         .         .
            240.  .    I    .   CW E  .         .         .         .         .         L         .         .         .
            260.  .     I   .   CW E  .         .         .         .         .         .  L      .         .         .
            280.  .     I   .    W E  .         .         .         .         .         .    L    .         .         .
            300.  .     I   .    W E  .         .         .         .         .         .       L .         .         .
     8.00   320.  .      I  .    CW E .         .         .         .         .         .         L         .         .
            340.  .      I  .     W E .         .         .         .         .         .        RL         .         .
            360.  .       I .     CW E.         .         .         .         .         .       R L         .         .
            380.  .       I .      W E.         .         .         .         .         .       R L         .         .
            400.  .        I.      CWE.         .         .         .         .         .      R  L         .         .
            420.  .        I.      CW E         .         .         .         .         .     R   L         .         .
            440.  .         I       W E         .         .         .         .         .    R    L         .         .
     7.00   460.  .         I       CW.E        .         .         .         .         .   R     L         .         .
            480.  .         .I       CWE        .         .         .         .         .    R    L         .         .
            500.  .         .I       CWE        .         .         .         .         .    R    L         .         .
            520.  .         . I      CW E       .         .         .         .         .     R   L         .         .
     6.50   540.  .         . I       W E       .         .         .         .         .     R   L         .         .
            560.  .         . I       .W E      .         .         .         .         .      R  L         .         .
            580.  .         .  I      . W E     .         .         .         .         .       R L         .         .
            600.  .         .  I      . CW E    .         .         .         .         .        RL         .         .
     6.00   620.  .         .  I      .  W  E   .         .         .         .         .         L         .         .
            640.  .         .   I     .   W  E  .         .         .         .         .         L    R    .         .
            660.  .         .   I     .    W  E .         .         .         .         .         L         R         .
     5.20   680.  .         .    I    .     W  E.         .         .         .         .         L         .     R   .
            700.  .         .    I    .      W  E         .         .         .         .         L         .     R   .
            720.  .         .     I   .      W  .E        .         .         .         .         L         .     R   .
     5.10   740.  .         .     I   .       W . E       .         .         .         .         L         .     R   .
            760.  .         .      I  .        W.  E      .         .         .         .         L         .     R   .
            780.  .         .      I  .        W.  E      .         .         .         .         L         .     R   .
            800.  .         .       I .         W   E     .         .         .         .         L         .     R   .
     5.00   820.  .         .       I .         W   E     .         .         .         .         L         .     R   .
            840.  .         .       I .         CW   E    .         .         .         .         L         .     R   .
            860.  .         .        I.         .W   E    .         .         .         .         L         .     R   .
            880.  .         .        I.         .CW  E    .         .         .         .         .         .     R   .
            900.  .         .         I         . CW  E   .         .         .         .         L         .     R   .
            920.  .         .         I         . CW  E   .         .         .         .         L         .     R   .
     4.20   940.  .         .         I         .  CW  E  .         .         .         .         L         .     R   .
            960.  .         .         .I        .  CW  E  .         .         .         .         L         .     R   .
            980.  .         .         .I        .  C W E  .         .         .         .         L         .     R   .
     4.10  1000.            .         . I       .   CW  E .         .         .         .         L         .     R   .
           1020.            .         . I       .   CW  E .         .         .         .         L         .     R   .
           1040.  .         .         .  I      .    CW  E.         .         .         .         L         .     R   .
     4.00  1060.  .         .         .  I      .    CW  E.         .         .         .         L         .     R   .
           1080.  .         .         .   I     .     CW  E         .         .         .         L         .     R   .
           1100.  .         .         .   I     .     CW  E         .         .         .         L         .     R   .
           1120.  .         .         .    I    .     CW  E         .         .         .         L         .     R   .
           1140.  .         .         .    I    .      CW .E        .         .         .         L         .     R   .
           1160.  .         .         .    I    .      CW .E        .         .         .         L         .     R   .
           1180.  .         .         .     I   .       CW. E       .         .         .         L         .     R   .
           1200.  .         .         .     I   .       CW. E       .         .         .         L         .     R   .
           1220.  .         .         .      I  .        W. E       .         .         .         L         .     R   .
           1240.  .         .         .      I  .        CW  E      .         .         .         L         .     R   .
           1260.  .         .         .       I .        CW  E      .         .         .         L         .     R   .
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      1280.  .         .         .       I .         CW E      .         .         .         L         .     R   .
      1300.  .         .         .        I.         CW  E     .         .         .         L         .     R   .
3.00  1320.  .         .         .        I.         CW  E     .         .         .         L         .     R   .
      1340.  .         .         .        I.         .CW E     .         .         .         L         .     R   .
      1360.  .         .         .         I         .CW  E    .         .         .         L         .      R  .
      1380.  .         .         .         I         .CW  E    .         .         .         L         .      R  .
      1400.  .         .         .         .I        . CW E    .         .         .         L         .      R  .
      1420.  .         .         .         .I        . CW  E   .         .         .         L         .       R .
      1440.  .         .         .         .I        .  CW E   .         .         .         L         .       R .
      1460.  .         .         .         . I       .  CW  E  .         .         .         L         .       R .
      1480.  .         .         .         . I       .  CW  E  .         .         .         L         .       R .
      1500.  .         .         .         .  I      .   CW E  .         .         .         L         .        R.
      1520.  .         .         .         .  I      .   CW  E .         .         .         L         .        R.
      1540.  .         .         .         .   I     .    CW E .         .         .         L         .        R.
      1560.  .         .         .         .   I     .    CW E .         .         .         L         .         R
2.00  1580.  .         .         .         .   I     .    CW  E.         .         .         L         .         R
      1600.  .         .         .         .    I    .     CW E.         .         .         L         .         R
      1620.  .         .         .         .    I    .     CW E.         .         .         L         .         R
      1640.  .         .         .         .     I   .     CW  E         .         .         L         .         R
      1660.  .         .         .         .     I   .      CW E         .         .         L         .         R
      1680.  .         .         .         .      I  .      CW E         .         .         L         .         R
      1700.  .         .         .         .      I  .      CW .E        .         .         L         .         R
      1720.  .         .         .         .       I .       CW.E        .         .         L         .         R
      1740.  .         .         .         .       I .       CW.E        .         .         L         .         R
      1760.  .         .         .         .       I .       C W E       .         .         L         .         R
      1780.  .         .         .         .        I.        CW E       .         .         L         .         R
      1800.  .         .         .         .        I.        CW E       .         .         L         .         R
1.00  1820.  .         .         .         .         I         CW E      .         .         L         .         R
```

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                                                              THIS RUN EXECUTED 19MAY94    16:48:07
**************************************
 HEC-2 WATER SURFACE PROFILES

 Version  4.6.2;  May 1991
**************************************

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

 SUBCRITICAL RUN - NO WE

SUMMARY PRINTOUT TABLE  150

     SECNO     XLCH    ELTRD    ELLC    ELMIN       Q     CWSEL    CRIWS     EG     10*KS     VCH     AREA    .01K
*   10.000     0.00     0.00    0.00  4010.00  1605.00  4014.60  4014.60  4016.25  149.59   10.32   155.57  131.23
*    9.000   150.00     0.00    0.00  4011.70  1605.00  4016.90  4016.12  4017.60   60.00    6.74   238.02  207.21
     8.000   160.00     0.00    0.00  4013.40  1605.00  4017.80  4017.67  4018.91  116.56    8.43   190.50  148.66
     7.000   150.00     0.00    0.00  4015.10  1605.00  4019.59  4019.13  4020.37   82.77    7.10   226.16  176.42
     6.500    72.00     0.00    0.00  4015.90  1605.00  4020.18  4019.82  4020.98   87.84    7.20   222.94  171.24
*    6.000    75.00     0.00    0.00  4016.70  1605.00  4021.57  4021.57  4023.01  147.36    9.60   167.12  132.21
*    5.200    66.00     0.00    0.00  4017.40  1605.00  4023.09  4023.09  4024.65  146.97   10.02   160.23  132.39
*    5.100    66.00     0.00    0.00  4018.10  1605.00  4024.10  4024.10  4026.03  152.95   11.15   143.95  129.78
*    5.000    66.00     0.00    0.00  4018.90  1605.00  4025.04  4025.04  4027.03  138.10   11.33   141.70  136.58
     4.200   120.00     0.00    0.00  4020.20  1605.00  4026.91  4026.29  4028.37   92.06    9.69   165.71  167.28
     4.100    66.00     0.00    0.00  4020.90  1605.00  4027.55  4026.93  4028.97   91.21    9.59   167.37  168.05
     4.000    66.00     0.00    0.00  4021.60  1605.00  4028.06  4027.62  4029.61  101.19    9.97   160.94  159.55
     3.000   250.00     0.00    0.00  4024.40  1605.00  4030.55  4030.17  4032.04   93.48    9.80   163.75  166.01
     2.000   260.00     0.00    0.00  4027.20  1605.00  4033.19  4032.67  4034.33   83.19    8.56   187.61  175.98
     1.000   250.00     0.00    0.00  4030.00  1605.00  4035.37  4034.78  4036.32   76.17    7.82   205.18  183.90
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 SUBCRITICAL RUN - NO WE

SUMMARY PRINTOUT TABLE  150

      SECNO        Q        CWSEL     DIFWSP     DIFWSX     DIFKWS    TOPWID      XLCH

*     10.000    1605.00   4014.60      0.00       0.00      -0.01      47.61       0.00

*      9.000    1605.00   4016.90      0.00       2.30       0.00      81.47     150.00

       8.000    1605.00   4017.80      0.00       0.91       0.00      76.39     160.00

       7.000    1605.00   4019.59      0.00       1.78       0.00      90.81     150.00

       6.500    1605.00   4020.18      0.00       0.59       0.00      91.60      72.00

*      6.000    1605.00   4021.57      0.00       1.40       0.00      58.67      75.00

*      5.200    1605.00   4023.09      0.00       1.52       0.00      51.31      66.00

*      5.100    1605.00   4024.10      0.00       1.01       0.00      37.96      66.00

*      5.000    1605.00   4025.04      0.00       0.94       0.00      36.17      66.00

       4.200    1605.00   4026.91      0.00       1.87       0.00      39.40     120.00

       4.100    1605.00   4027.55      0.00       0.63       0.00      40.37      66.00

       4.000    1605.00   4028.06      0.00       0.52       0.00      39.77      66.00

       3.000    1605.00   4030.55      0.00       2.48       0.00      42.91     250.00

       2.000    1605.00   4033.19      0.00       2.65       0.00      56.24     260.00

       1.000    1605.00   4035.37      0.00       2.18       0.00      66.40     250.00
```

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 SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO=     10.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

WARNING SECNO=      9.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=      6.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      6.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=      5.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.200  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=      5.100  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.100  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=      5.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY
```

```
HEC2 S/N: 1916530006        HMVersion: 6.50    Data File: H:SWSUP.IN

**********************************************                               ******************************************
*  HEC-2 WATER SURFACE PROFILES              *                               *  U.S. ARMY CORPS OF ENGINEERS          *
*                                            *                               *  HYDROLOGIC ENGINEERING CENTER         *
*  Version   4.6.2;  May 1991                *                               *  609 SECOND STREET, SUITE D            *
*                                            *                               *  DAVIS, CALIFORNIA 95616-4687          *
*  RUN DATE    19MAY94    TIME    16:47:51   *                               *          (916) 756-1104                *
**********************************************                               ******************************************



                              X     X  XXXXXXX   XXXXX           XXXXX
                              X     X  X        X     X         X     X
                              X     X  X        X                     X
                              XXXXXXX  XXXX     X         XXXXX   XXXXX
                              X     X  X        X               X
                              X     X  X        X     X         X
                              X     X  XXXXXXX   XXXXX          XXXXXXX
```

SIMULATION 2

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                             :::::::::::::::::::::::::::::::::::::::::::::
                             :::::::::::::::::::::::::::::::::::::::::::::
                             :::                                       :::
                             :::    FULL MICRO-COMPUTER IMPLEMENTATION  :::
                             :::                                       :::
                             :::::::::::::::::::::::::::::::::::::::::::::
                             :::::::::::::::::::::::::::::::::::::::::::::


                                   ==============================
                                   H A E S T A D   M E T H O D S
                                   ==============================

                     37 Brookside Road  *  Waterbury, Connecticut  06708  *  (203) 755-1666
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 Run Date:  19MAY94    Run Time: 16:47:51    HMVersion: 6.50    Data File:   H:SWSUP.IN                                  Page    1



                                                                                        HIS RUN EXECUTED 19MAY94     16:47:51
****************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
****************************************


R
1 SOUTHWEST CHANNEL
2 ATLAS MINERALS 88-067 5/12/94
3       SUPERCRITICAL RUN - NO WEDGE

1  ICHECK     INQ        NINV      IDIR       STRT      METRIC     HVINS      Q         WSEL       FQ

     0.        0.         0.         1        -1.          0        1.0     1605.    4034.8        0.

C    0.03       0.03       0.03
H       2      0.034        60      0.035        220
1     1.0        7.0        0.0     220.0      250.0       250.0      250.0       0.0        0.0        0.0
R  4050.0        0.0     4030.0      60.0     4030.0        70.0     4040.0     145.0     4050.0      155.0
R  4060.0      175.0     4060.0     220.0

H       2      0.034        65      0.035        230
1     2.0          8        0.0     230.0      260.0       260.0      260.0
R  4050.0        0.0     4027.2      65.0     4027.2        75.0     4030.0      85.0     4040.0      145.0
R  4050.0      175.0     4060.0     195.0     4060.0       230.0

H       2      0.034        70      0.035        250
1     3.0          7          0       250        250         250        250
R  4050.0        0.0     4024.4      70.0     4024.4        80.0     4030.0      95.0     4040.0      115.0
R  4050.0      140.0       4058       250

H       2      0.038        80      0.035        255
1     4.0          7          0       255         66          66         66
R  4050.0        0.0     4021.6      80.0     4021.6        90.0     4030.0     105.0     4040.0      120.0
R  4050.0      140.0     4058.0     255.0

H       2      0.038        85      0.035        270
1     4.1          7          0       270         66          66         66
R  4050.0        0.0     4020.9      85.0     4020.9        95.0     4030.0     110.0     4040.0      125.0
R  4050.0      135.0     4058.0     270.0

H       2      0.038        85      0.035        275
1     4.2          7          0       275        120         120        120
R  4050.0        0.0     4020.2      85.0     4020.2        95.0     4030.0     110.0     4040.0      125.0
R  4050.0      155.0     4058.0     275.0
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WAP 5/24/94

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NH       2     0.038        85     0.035     275.0
X1     5.0         7         0       275        66        66        66
GR  4050.0       0.0    4018.9      85.0    4018.9      95.0    4030.0     112.0    4040.0     150.0
GR  4050.0     200.0    4058.0     275.0

NH       2     0.042        95     0.035     280.0
X1     5.1         7         0       280        66        66        66
GR  4050.0       0.0    4018.1      95.0    4018.1     105.0    4030.0     125.0    4040.0     205.0
GR  4050.0     225.0    4058.0     280.0

NH       2     0.042       110     0.035     280.0
X1     5.2         7         0       280        66        66        66
GR  4050.0       0.0    4017.4     110.0    4017.4     115.0    4030.0     175.0    4040.0     220.0
GR  4050.0     230.0    4058.0     280.0

NH       2     0.042       127     0.035     285.0
X1     6.0       8.0       0.0     285.0      75.0      75.0      75.0       0.0       0.0       0.0
GR  4050.0       0.0    4016.7     127.0    4016.7     133.0    4020.0     160.0    4030.0     205.0
GR  4040.0     230.0    4050.0     245.0    4050.0     285.0

NH       2     0.034       130     0.035     290.0
X1     6.5       8.0       0.0     290.0      72.0      72.0      72.0
GR  4050.0       0.0    4015.9     130.0    4015.9     140.0    4020.0     205.0    4030.0     220.0
GR  4040.0     240.0    4048.0     265.0    4048.0     290.0

NH       2     0.034       130     0.035       290
X1     7.0       7.0       0.0     290.0     150.0     150.0     150.0       0.0       0.0       0.0
GR  4050.0       0.0    4015.1     130.0    4015.1     140.0    4020.0     210.0    4030.0     225.0
GR  4040.0     240.0    4047.0     290.0

NH       2     0.034       135     0.035       310
X1     8.0       7.0       0.0     310.0     160.0     160.0     160.0       0.0       0.0       0.0
GR  4050.0       0.0    4013.4     135.0    4013.4     145.0    4020.0     220.0    4030.0     235.0
GR  4040.0     250.0    4050.0     310.0

NH       2     0.034       150     0.035     320.0
X1     9.0       7.0       0.0     320.0     150.0     150.0     150.0       0.0       0.0       0.0
GR  4040.0       0.0    4011.7     150.0    4011.7     160.0    4020.0     230.0    4030.0     255.0
GR  4040.0     270.0    4040.0     320.0

NH     2.0     0.038     204.2     0.035     325.0
X1    10.0       8.0       0.0     325.0       0.0       0.0       0.0
GR  4032.0       0.0    4015.7     150.0    4010.0     167.1    4010.0     187.1    4015.7     204.2
GR  4020.0     240.0    4030.0     270.0    4037.0     325.0
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WP 5/20/94

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   SECNO       DEPTH       CWSEL      CRIWS      WSELK       EG         HV         HL         OLOSS      L-BANK ELEV
   Q           QLOB        QCH        QROB       ALOB        ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME        VLOB        VCH        VROB       XNL         XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE       XLOBL       XLCH       XLOBR      ITRIAL      IDC        ICONT      CORAR      TOPWID     ENDST

*PROF 1



1490 NH CARD USED
*SECNO 1.000
3720 CRITICAL DEPTH ASSUMED
     1.000      4.78   4034.78    4034.78    4034.80    4036.20       1.42       0.00       0.00    4050.00
    1605.0       0.0    1605.0        0.0        0.0      167.8        0.0        0.0        0.0    4060.00
      0.00      0.00      9.56       0.00      0.000      0.035      0.000      0.000    4030.00      45.66
  0.013059        0.        0.         0.          0          4          0       0.00      60.20     105.86

1490 NH CARD USED
*SECNO 2.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     2.000      5.49   4032.69    4032.69       0.00    4034.24       1.55       3.20       1.60    4050.00
    1605.0       0.0    1605.0        0.0        0.0      160.4        0.0        0.9        0.3    4060.00
      0.01      0.00     10.00       0.00      0.000      0.035      0.000      0.000    4027.20      49.35
  0.012555      250.      250.       250.         20          8          0       0.00      51.79     101.14

1490 NH CARD USED
*SECNO 3.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     3.000      5.77   4030.17    4030.17       0.00    4032.00       1.83       3.25       1.61    4050.00
    1605.0       0.0    1605.0        0.0        0.0      147.8        0.0        1.9        0.6    4058.00
      0.01      0.00     10.86       0.00      0.000      0.035      0.000      0.000    4024.40      54.22
  0.012409      260.      260.       260.         20          8          0       0.00      41.12      95.34

1490 NH CARD USED
*SECNO 4.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     4.000      6.02   4027.62    4027.62       0.00    4029.56       1.94       3.26       0.03    4050.00
    1605.0       0.0    1605.0        0.0        0.0      143.5        0.0        2.7        0.8    4058.00
      0.02      0.00     11.18       0.00      0.000      0.036      0.000      0.000    4021.60      63.05
  0.013759      250.      250.       250.         20          8          0       0.00      37.70     100.75
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 Run Date:  19MAY94    Run Time: 16:47:51    HMVersion: 6.50    Data File:   H:SWSUP.IN                                  Page    4

   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

490 NH CARD USED
SECNO 4.100
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    4.100       6.05    4026.95    4026.95       0.00    4028.88       1.93       0.91       0.08    4050.00
   1605.0        0.0     1605.0        0.0        0.0      143.9        0.0        2.9        0.9    4058.00
     0.02       0.00      11.15       0.00      0.000      0.036      0.000      0.000    4020.90      67.34
 0.013673        66.        66.        66.         20          5          0       0.00      37.62     104.96

490 NH CARD USED
SECNO 4.200
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    4.200       6.11    4026.31    4026.31       0.00    4028.27       1.95       0.90       0.38    4050.00
   1605.0        0.0     1605.0        0.0        0.0      143.1        0.0        3.1        0.9    4058.00
     0.02       0.00      11.22       0.00      0.000      0.036      0.000      0.000    4020.20      67.56
 0.013659        66.        66.        66.         20          5          0       0.00      36.80     104.36

490 NH CARD USED
SECNO 5.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    5.000       6.15    4025.05    4025.05       0.00    4027.03       1.98       1.64       0.69    4050.00
   1605.0        0.0     1605.0        0.0        0.0      142.1        0.0        3.5        1.0    4058.00
     0.03       0.00      11.29       0.00      0.000      0.036      0.000      0.000    4018.90      68.19
 0.013700       120.       120.       120.         20          5          0       0.00      36.22     104.42

490 NH CARD USED
SECNO 5.100
    5.100       5.88    4023.98    4024.12       0.00    4026.04       2.05       0.99       0.00    4050.00
   1605.0        0.0     1605.0        0.0        0.0      139.6        0.0        3.7        1.1    4058.00
     0.03       0.00      11.50       0.00      0.000      0.038      0.000      0.000    4018.10      77.47
 0.016606        66.        66.        66.          2          8          0       0.00      37.42     114.89

490 NH CARD USED
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 Run Date:  19MAY94    Run Time: 16:47:51    HMVersion: 6.50    Data File:   H:SWSUP.IN                                  Page    5

   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG        HV        HL        OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH       AROB      VOL       TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC       ICONT     CORAR     TOPWID     ENDST

*SECNO 5.200
    5.200       5.21    4022.61    4023.09       0.00   4024.77      2.15      1.27       0.00    4050.00
   1605.0        0.0     1605.0        0.0        0.0     136.3       0.0       3.9        1.2    4058.00
     0.03       0.00      11.77       0.00      0.000     0.038     0.000     0.000    4017.40      92.43
 0.022603        66.        66.        66.          4         8         0      0.00      47.36     139.79

1490 NH CARD USED
*SECNO 6.000
    6.000       4.33    4021.03    4021.55       0.00   4023.17      2.14      1.59       0.00    4050.00
   1605.0        0.0     1605.0        0.0        0.0     136.7       0.0       4.2        1.2    4050.00
     0.03       0.00      11.74       0.00      0.000     0.037     0.000     0.000    4016.70     110.47
 0.025768        66.        66.        66.          5        11         0      0.00      54.18     164.65

1490 NH CARD USED
*SECNO 6.500
    6.500       3.38    4019.28    4019.82       0.00   4021.15      1.88      2.02       0.00    4050.00
   1605.0        0.0     1605.0        0.0        0.0     146.1       0.0       4.4        1.3    4048.00
     0.03       0.00      10.99       0.00      0.000     0.035     0.000     0.000    4015.90     117.12
 0.028247        75.        75.        75.          5        11         0      0.00      76.45     193.57

1490 NH CARD USED
*SECNO 7.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    7.000       4.02    4019.12    4019.12       0.00   4020.28      1.16      1.39       0.02    4050.00
   1605.0        0.0     1605.0        0.0        0.0     186.0       0.0       4.7        1.5    4047.00
     0.03       0.00       8.63       0.00      0.000     0.035     0.000     0.000    4015.10     115.01
 0.013958        72.        72.        72.         20        11         0      0.00      82.47     197.48

1490 NH CARD USED
*SECNO 8.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    8.000       4.27    4017.67    4017.67       0.00   4018.91      1.24      2.07       0.03    4050.00
   1605.0        0.0     1605.0        0.0        0.0     179.7       0.0       5.3        1.7    4050.00
     0.04       0.00       8.93       0.00      0.000     0.035     0.000     0.000    4013.40     119.26
 0.013623       150.       150.       150.         20         8         0      0.00      74.23     193.49
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   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


1490 NH CARD USED
*SECNO 9.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     9.000       4.40   4016.10    4016.10       0.00    4017.38       1.28       2.16       1.10    4040.00
    1605.0        0.0    1605.0        0.0        0.0      176.7        0.0        6.0        2.0    4040.00
      0.04       0.00      9.08       0.00      0.000      0.035      0.000      0.000    4011.70     126.69
  0.013320       160.      160.       160.         20          8          0       0.00      70.39     197.08

1490 NH CARD USED
*SECNO 10.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    10.000       4.59   4014.59    4014.59       0.00    4016.25       1.66       2.12       0.90    4032.00
    1605.0        0.0    1605.0        0.0        0.0      155.2        0.0        6.5        2.2    4037.00
      0.05       0.00     10.34       0.00      0.000      0.038      0.000      0.000    4010.00     153.31
  0.015046       150.      150.       150.         20          8          0       0.00      47.57     200.89
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PROFILE FOR STREAM   SUPERCRITICAL RUN - NO


PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA


ELEVATION  4010.     4015.     4020.     4025.     4030.     4035.     4040.     4045.     4050.     4055.
    SECNO   CUMDIS

     1.00     0.  .         .         .         .         I         W E       .         .         L         .         R
             20.  .         .         .         .         I        W. E       .         .         L         .         R
             40.  .         .         .         .        I.        W. E       .         .         L         .         R
             60.  .         .         .         .        I.        W.E        .         .         L         .         R
             80.  .         .         .         .       I .       W .E        .         .         L         .         R
            100.  .         .         .         .       I .       W .E        .         .         L         .         R
            120.  .         .         .         .      I  .       W .E        .         .         L         .         R
            140.  .         .         .         .      I  .      W  E         .         .         L         .         R
            160.  .         .         .         .     I   .      W  E         .         .         L         .         R
            180.  .         .         .         .     I   .      W  E         .         .         L         .         R
            200.  .         .         .         .     I   .     W  E.         .         .         L         .         R
            220.  .         .         .         .    I    .     W  E.         .         .         L         .         R
            240.  .         .         .         .    I    .     W  E.         .         .         L         .         R
     2.00   260.  .         .         .         .   I     .    W  E .         .         .         L         .         R
            280.  .         .         .         .   I     .    W  E .         .         .         L         .         R
            300.  .         .         .         .   I     .    W  E .         .         .         L         .        R.
            320.  .         .         .         .  I      .   W  E  .         .         .         L         .        R.
            340.  .         .         .         .  I      .   W  E  .         .         .         L         .        R.
            360.  .         .         .         . I       .  W   E  .         .         .         L         .       R .
            380.  .         .         .         . I       .  W  E   .         .         .         L         .       R .
            400.  .         .         .         .I        .  W  E   .         .         .         L         .       R .
            420.  .         .         .         .I        . W   E   .         .         .         L         .       R .
            440.  .         .         .         .I        . W  E    .         .         .         L         .      R  .
            460.  .         .         .         I         . W  E    .         .         .         L         .      R  .
            480.  .         .         .         I         .W   E    .         .         .         L         .      R  .
            500.  .         .         .        I.         .W  E     .         .         .         L         .     R   .
     3.00   520.  .         .         .        I.         W   E     .         .         .         L         .     R   .
            540.  .         .         .       I .         W   E     .         .         .         L         .     R   .
            560.  .         .         .       I .         W  E      .         .         .         L         .     R   .
            580.  .         .         .      I  .        W.  E      .         .         .         L         .     R   .
            600.  .         .         .      I  .        W. E       .         .         .         L         .     R   .
            620.  .         .         .      I  .       W . E       .         .         .         L         .     R   .
            640.  .         .         .     I   .       W . E       .         .         .         L         .     R   .
            660.  .         .         .     I   .      W  .E        .         .         .         L         .     R   .
            680.  .         .         .    I    .      W  .E        .         .         .         L         .     R   .
            700.  .         .         .    I    .      W  E         .         .         .         L         .     R   .
            720.  .         .         .   I     .     W   E         .         .         .         L         .     R   .
            740.  .         .         .   I     .     W   E         .         .         .         L         .     R   .
     4.00   760.  .         .         .  I      .    W   E.         .         .         .         L         .     R   .
            780.  .         .         .  I      .    W   E.         .         .         .         L         .     R   .
            800.  .         .         . I       .   W   E .         .         .         .         L         .     R   .
            820.  .         .         . I       .   W   E .         .         .         .         L         .     R   .
     4.10   840.  .         .         . I           W   E .         .         .         .         L         .     R   .
            860.  .         .         .I        .   W  E  .         .         .         .         L         .     R   .
            880.  .         .         .I        .  W   E  .         .         .         .         L         .     R   .
     4.20   900.  .         .         I         .  W   E  .         .         .         .         L         .     R   .
            920.  .         .         I         . W   E   .         .         .         .         L         .     R   .
            940.  .         .         I         . W   E   .         .         .         .         L         .     R   .
            960.  .         .        I.         .W   E    .         .         .         .         L         .     R   .
            980.  .         .        I.         .W   E    .         .         .         .         L         .     R   .
           1000.  .         .       I .         .W  E     .         .         .         .         L         .     R   .
     5.00  1020.  .         .       I .         W   E     .         .         .         .         L         .     R   .
           1040.  .         .      I  .        WC  E      .         .         .         .         L         .     R   .
           1060.  .         .      I  .        W.  E      .         .         .         .         L         .     R   .
     5.10  1080.  .         .     I   .       W . E       .         .         .         .         L         .     R   .
           1100.  .         .     I   .      WC .E        .         .         .         .         L         .     R   .
           1120.  .         .    I    .     WC  .E        .         .         .         .         L         .     R   .
           1140.  .         .    I    .    WC   E         .         .         .         .         L         .     R   .
     5.20  1160.  .         .    I    .    WC   E         .         .         .         .         L         .     R   .
           1180.  .         .   I     .   WC   E.         .         .         .         .         L         .R        .
           1200.  .         .   I     .  WC   E .         .         .         .         .         L     R   .         .
     6.00  1220.  .         .  I      . WC  E   .         .         .         .         .         L         .         .
           1240.  .         .  I      .WC  E    .         .         .         .        RL         .         .
           1260.  .         .  I      WC  E     .         .         .         .       R L         .         .
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       1280.  .         . I      WC  E      .         .         .         .         .      R  L         .         .
 6.50  1300.  .         . I      WC E       .         .         .         .         .     R   L         .         .
       1320.  .         .I      WC. E       .         .         .         .         .    R    L         .         .
       1340.  .         .I      WC.E        .         .         .         .         .    R    L         .         .
 7.00  1360.  .         I       W .E        .         .         .         .         .   R     L         .         .
       1380.  .         I       W E         .         .         .         .         .    R    L         .         .
       1400.  .        I.      W  E         .         .         .         .         .     R   L         .         .
       1420.  .        I.      W E.         .         .         .         .         .     R   L         .         .
       1440.  .       I .      W E.         .         .         .         .         .      R  L         .         .
       1460.  .       I .     W  E.         .         .         .         .         .       R L         .         .
       1480.  .      I  .     W E .         .         .         .         .         .        RL         .         .
       1500.  .      I  .     W E .         .         .         .         .         .         L         .         .
 8.00  1520.  .      I  .    W  E .         .         .         .         .         .         L         .         .
       1540.  .     I   .    W E  .         .         .         .         .         .       L .         .         .
       1560.  .     I   .    W E  .         .         .         .         .         .    L    .         .         .
       1580.  .     I   .   W  E  .         .         .         .         .         .  L      .         .         .
       1600.  .    I    .   W E   .         .         .         .         .         L         .         .         .
       1620.  .    I    .  W  E   .         .         .         .         .       L .         .         .         .
       1640.  .   I     .  W  E   .         .         .         .         .    L    .         .         .         .
       1660.  .   I     .  W E    .         .         .         .         .  L      .         .         .         .
 9.00  1680.  .  I      . W  E    .         .         .         .         L         .         .         .         .
       1700.  .  I      . W E     .         .         .         .       LR.         .         .         .         .
       1720.  . I       .W  E     .         .         .         .     L R .         .         .         .         .
       1740.  . I       .W  E     .         .         .         .   L   R .         .         .         .         .
       1760.  . I       .W  E     .         .         .         .L     R  .         .         .         .         .
       1780.  .I        W  E      .         .         .        L.      R   .         .         .         .         .
       1800.  .I        W  E      .         .         .      L  .     R    .         .         .         .         .
10.00  1820.  I        W.  E      .         .         .   L     .   R     .         .         .         .         .
```

C-22

```
                                                                  THIS RUN EXECUTED 19MAY94     16:47:53
****************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
****************************************

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

 SUPERCRITICAL RUN - NO

SUMMARY PRINTOUT TABLE  150

     SECNO      XLCH      ELTRD      ELLC     ELMIN        Q       CWSEL     CRIWS       EG       10*KS       VCH      AREA      .01K
*    1.000      0.00       0.00      0.00   4030.00   1605.00   4034.78   4034.78   4036.20    130.59      9.56    167.83    140.45
*    2.000    250.00       0.00      0.00   4027.20   1605.00   4032.69   4032.69   4034.24    125.55     10.00    160.44    143.24
*    3.000    260.00       0.00      0.00   4024.40   1605.00   4030.17   4030.17   4032.00    124.09     10.86    147.79    144.08
*    4.000    250...       0.00      0.00   4021.60   1605.00   4027.62   4027.62   4029.56    137.59     11.18    143.54    136.83
*    4.100     66.00       0.00      0.00   4020.90   1605.00   4026.95   4026.95   4028.88    136.73     11.15    143.94    137.26
*    4.200     66.00       0.00      0.00   4020.20   1605.00   4026.31   4026.31   4028.27    136.59     11.22    143.06    137.33
*    5.000    120.00       0.00      0.00   4018.90   1605.00   4025.05   4025.05   4027.03    137.00     11.29    142.13    137.13
     5.100     66.00       0.00      0.00   4018.10   1605.00   4023.98   4024.12   4026.04    166.06     11.50    139.59    124.55
     5.200     66.00       0.00      0.00   4017.40   1605.00   4022.61   4023.09   4024.77    226.03     11.77    136.32    106.76
     6.000     66.00       0.00      0.00   4016.70   1605.00   4021.03   4021.55   4023.17    257.68     11.74    136.67     99.99
     6.500     75.00       0.00      0.00   4015.90   1605.00   4019.28   4019.82   4021.15    282.47     10.99    146.05     95.50
*    7.000     72.00       0.00      0.00   4015.10   1605.00   4019.12   4019.12   4020.28    139.58      8.63    186.04    135.85
*    8.000    150.00       0.00      0.00   4013.40   1605.00   4017.67   4017.67   4018.91    136.23      8.93    179.72    137.51
*    9.000    160.00       0.00      0.00   4011.70   1605.00   4016.10   4016.10   4017.38    133.20      9.08    176.73    139.07
*   10.000    150.00       0.00      0.00   4010.00   1605.00   4014.59   4014.59   4016.25    150.46     10.54    155.24    130.85
```

```
 SUPERCRITICAL RUN - NO

SUMMARY PRINTOUT TABLE  150

     SECNO         Q       CWSEL     DIFWSP     DIFWSX     DIFKWS     TOPWID      XLCH

*     1.000   1605.00    4034.78       0.00       0.00      -0.02      60.20      0.00
*     2.000   1605.00    4032.69       0.00      -2.09       0.00      51.79    250.00
*     3.000   1605.00    4030.17       0.00      -2.52       0.00      41.12    260.00
*     4.000   1605.00    4027.62       0.00      -2.55       0.00      37.70    250.00
*     4.100   1605.00    4026.95       0.00      -0.67       0.00      37.62     66.00
*     4.200   1605.00    4026.31       0.00      -0.63       0.00      36.80     66.00
*     5.000   1605.00    4025.05       0.00      -1.26       0.00      36.22    120.00
      5.100   1605.00    4023.98       0.00      -1.07       0.00      37.42     66.00
      5.200   1605.00    4022.61       0.00      -1.37       0.00      47.36     66.00
      6.000   1605.00    4021.03       0.00      -1.58       0.00      54.18     66.00
      6.500   1605.00    4019.28       0.00      -1.76       0.00      76.45     75.00
*     7.000   1605.00    4019.12       0.00      -0.15       0.00      82.47     72.00
*     8.000   1605.00    4017.67       0.00      -1.46       0.00      74.23    150.00
*     9.000   1605.00    4016.10       0.00      -1.57       0.00      70.39    160.00
*    10.000   1605.00    4014.59       0.00      -1.50       0.00      47.57    150.00
```

```
SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO=      1.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

CAUTION SECNO=      2.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      2.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      2.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      3.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      3.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      3.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      4.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      4.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      4.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      4.100  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      4.100  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      4.100  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      4.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      4.200  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      4.200  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      5.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      5.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      7.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      7.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      7.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      8.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      8.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      8.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      9.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      9.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      9.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=     10.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=     10.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=     10.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL
```

Canonie Environmental
By JWS Date 5/10/94 Subject Riprap Size Design Natural Sheet D-1 of D-9
Chkd By VKP Date 5/20/94 Southwest Channel - Atlas Proj No 88-067-12

ATTACHMENT D

PREDICTED ROCK VOLUME CALCULATIONS AND HEC-2 CROSS SECTIONS ILLUSTRATING PLACEMENT OF ROCKS

CanonieEnvironmental

0-2

By BWH Date 4/13/94 Subject ATLAS CORP MOAB - AFFECTS OF ROCK FALLS TO SW RUNOFF DRAINAGE CHANNEL Sheet No. 1 of 2

Chkd. By ____ Date ________ Proj. No 88-067-12

1/4 X 1/4

Rock Volume Determination and Assumptions

- observed and measured boulders along southwest side of pile and north of hwy. 279 (vicinity of SW drainage channel). Photos (attached) taken of boulders in area. We are assuming these boulders rolled into area during past 50 years, since construction of road and mill.

volume of rock as follows:

Photo #	dimensions (ft)	vol. ft³	tot. vol. ft³
1	4 × 5 × 3	60	60
2	2 × 1 × 2	4	
	1.5 × 1 × 1	1.5	
	2 × 2 × 2	8	
	2 × 1.5 × .5	1.5	
	3 × 2 × 2	12	
	2 × 2 × 2	8	
	2 × 2 × 1	4	39
3	6 X 3 X3	54	54
4	8 × 12 × 4	384	384
5	8 × 5 × 4	160	160

Tot. vol - say 50 years 697 ft³

In 1000 yrs $\frac{1000}{50}$ 20 × 697 13,940 ft³

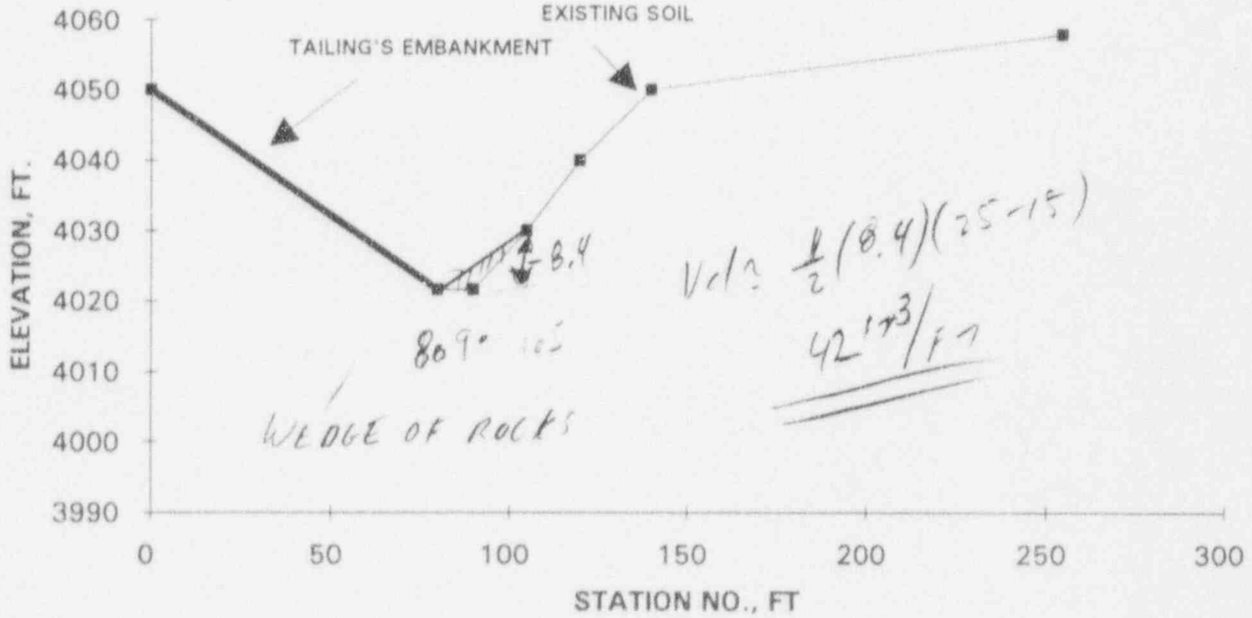
Tot yd³ ≈ 500 yd³

B-3

/

CROSS SECTION NO. 4 - LOOKING DOWNSTREAM

WITH "WEDGE" OF ROCKS



$Vol \approx \frac{1}{2}(8.4)(25-15)$

$42\ FT^3/FT$

AVG VOL. IN SEC. 4.0, 4.1, 4.2, 5.0:

$\left(\frac{42+46}{2}\right)66 + \left(\frac{46+75}{2}\right)66 + \left(\frac{75+56}{2}\right)120 =$

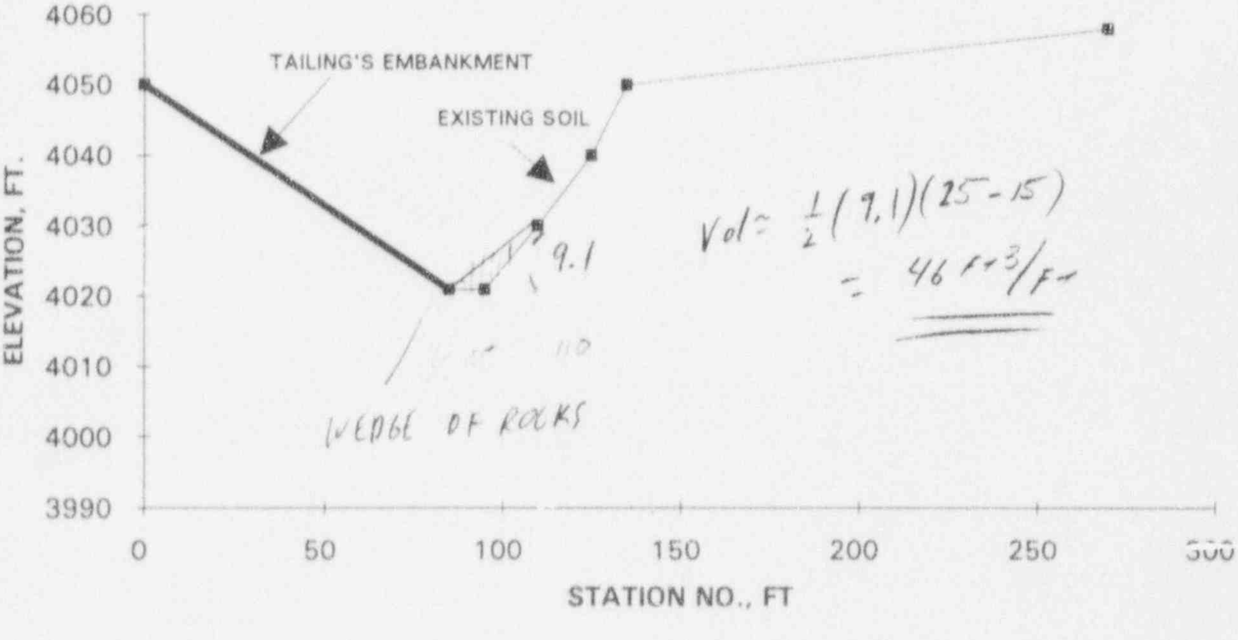
Vol. 4.0
Vol. 4.1
Channel Length
between 4.0 & 4.1

$= 14757\ FT^3$

$= 547\ CY$

D-4

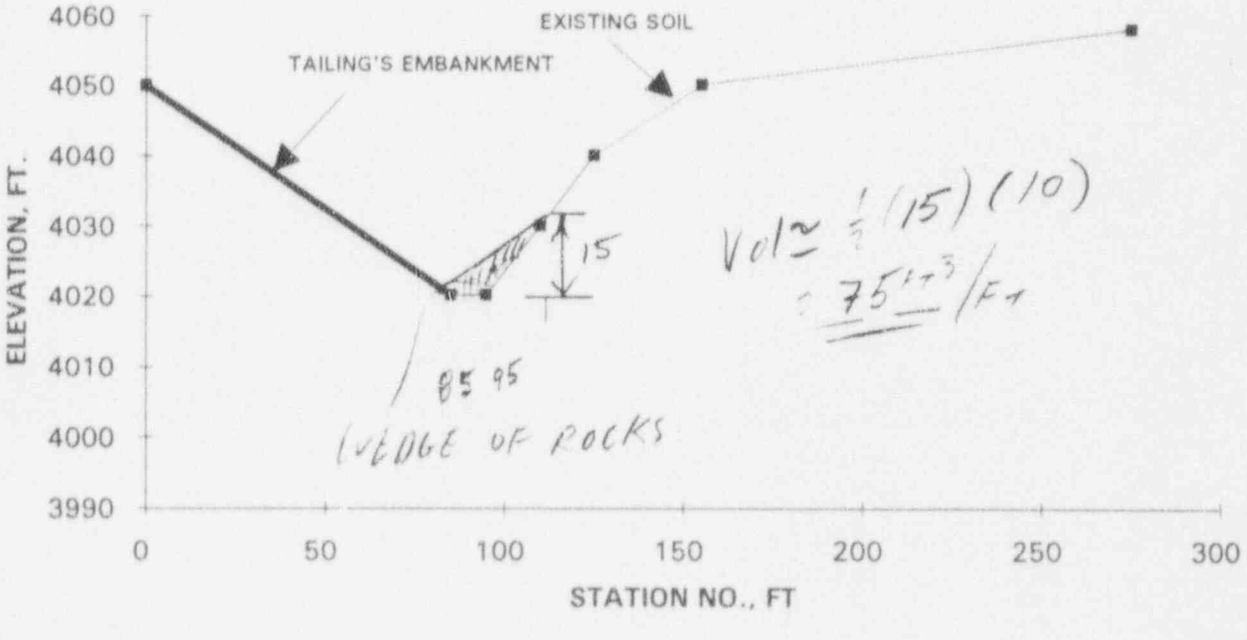
CROSS SECTION NO. 4.1 - LOOKING DOWNSTREAM



$$Vol = \frac{1}{2}(9.1)(25-15)$$
$$= \underline{\underline{46\ ft^3/ft}}$$

D-5

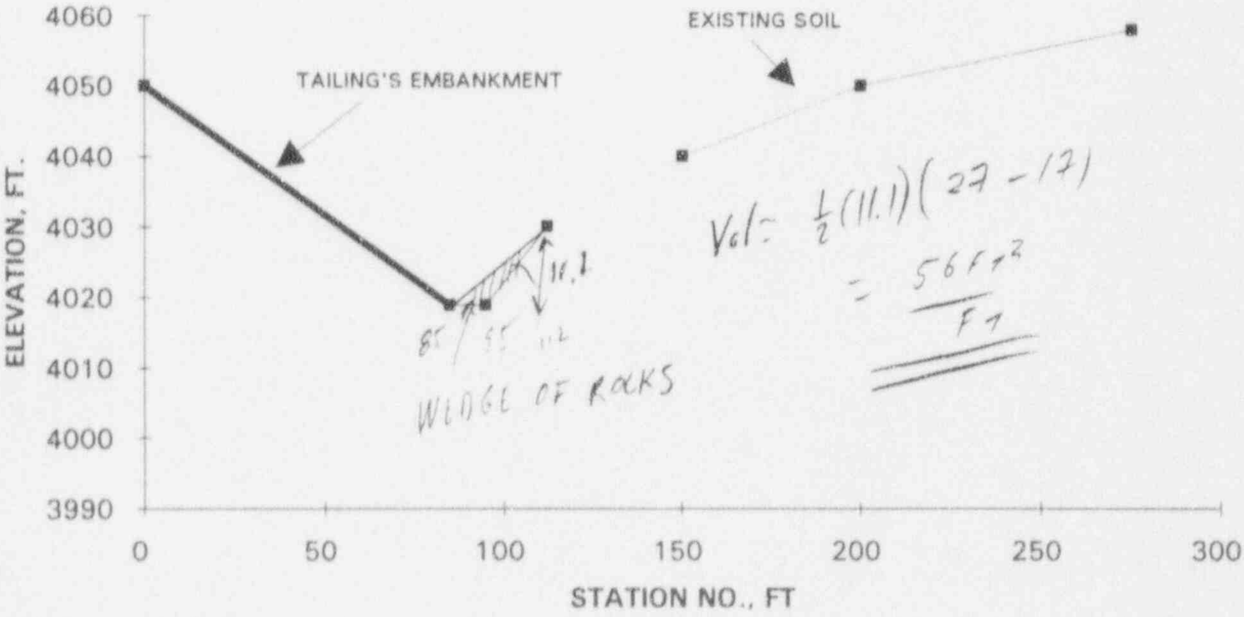
CROSS SECTION NO. 4.2 - LOOKING DOWNSTREAM



]

A-6

CROSS SECTION NO. 5 - LOOKING DOWNSTREAM



$Vol = \frac{1}{2}(11.1)(27-17)$

$= \underline{\underline{56\ FT^2/FT}}$

AVG Vol IN SEC 5.0, 5.1, 5.2, 6.0

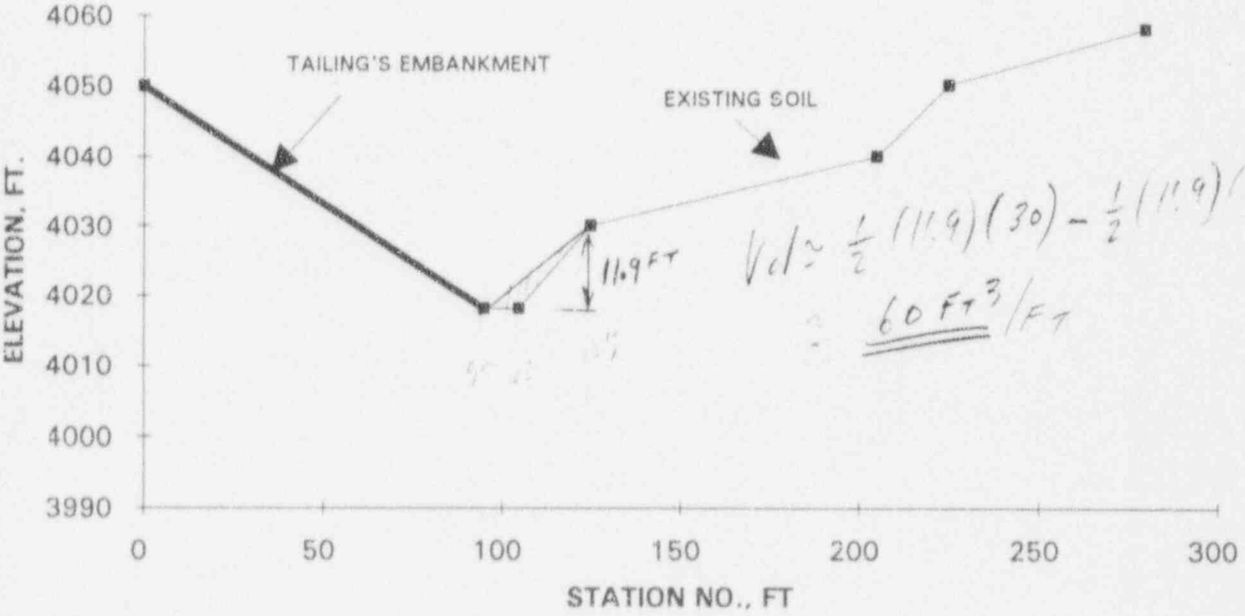
$\approx \left(\frac{56+60}{2}\right)66 + \left(\frac{60+68}{2}\right)66 + \left(\frac{68+54}{2}\right)66$

$= 12078\ FT^3$

$= \underline{\underline{447\ CY}}$

D-7

CROSS SECTION NO. 5.1 - LOOKING DOWNSTREAM

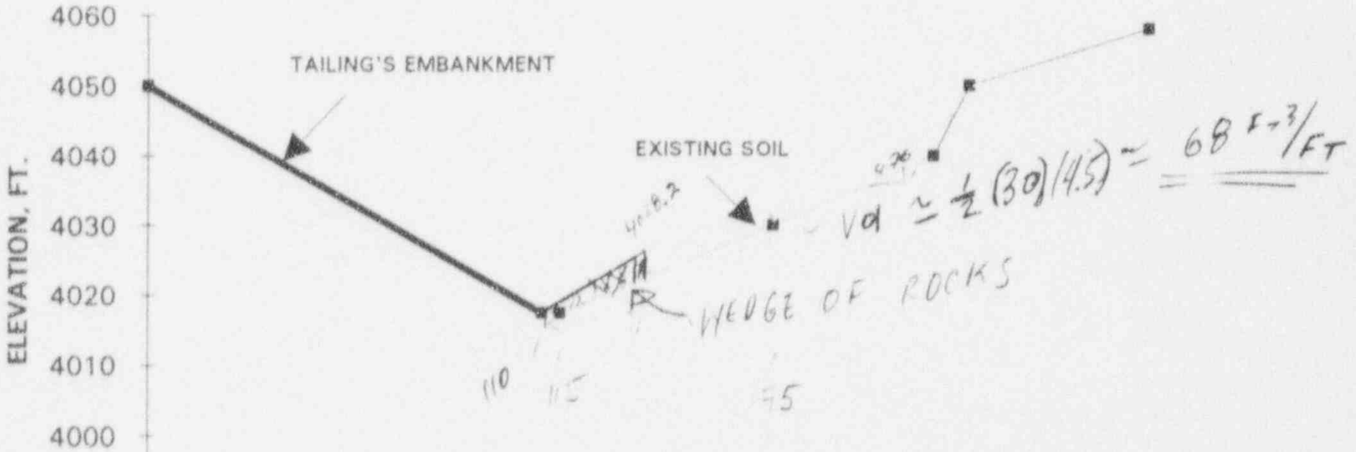


Vol ≈ $\frac{1}{2}(11.9)(30) - \frac{1}{2}(11.9)(20)$

≈ $\underline{\underline{60\ FT^3}}/FT$

D-8

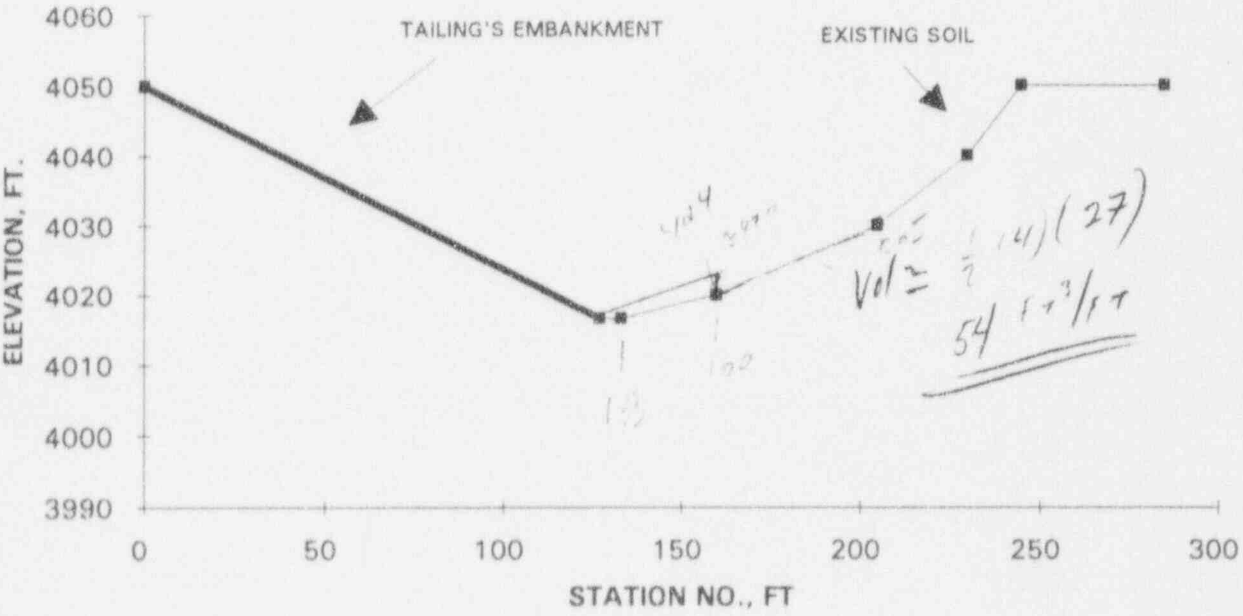
CROSS SECTION NO. 5.2 - LOOKING DOWNSTREAM



140 28
140.1 4023.5

D-9

CROSS SECTION NO. 6 - LOOKING DOWNSTREAM



Vol = ½ (4)(27)

54 ft³/ft

ATTACHMENT E

HEC-2 SUBCRITICAL AND SUPERCRITICAL RUNS (SIMULATIONS 3 AND 4; AND 5 AND 6) WITH ROCKS IN CHANNEL

SIMULATION	SHEET NO
3	E-2
4	E-14
5	E-26
6	E-38

```
HEC2 S/N: 1916530006        HMVersion: 6.50    Data File: H:SWSUB45.IN
```

E-2

```
*******************************************                                  ****************************************
* HEC-2 WATER SURFACE PROFILES            *                                  * U.S. ARMY CORPS OF ENGINEERS         *
*                                         *                                  * HYDROLOGIC ENGINEERING CENTER        *
* Version   4.6.2;  May 1991              *                                  * 609 SECOND STREET, SUITE D           *
*                                         *                                  * DAVIS, CALIFORNIA 95616-4687         *
* RUN DATE    19MAY94    TIME   17:30:03  *                                  *          (916) 756-1104              *
*******************************************                                  ****************************************

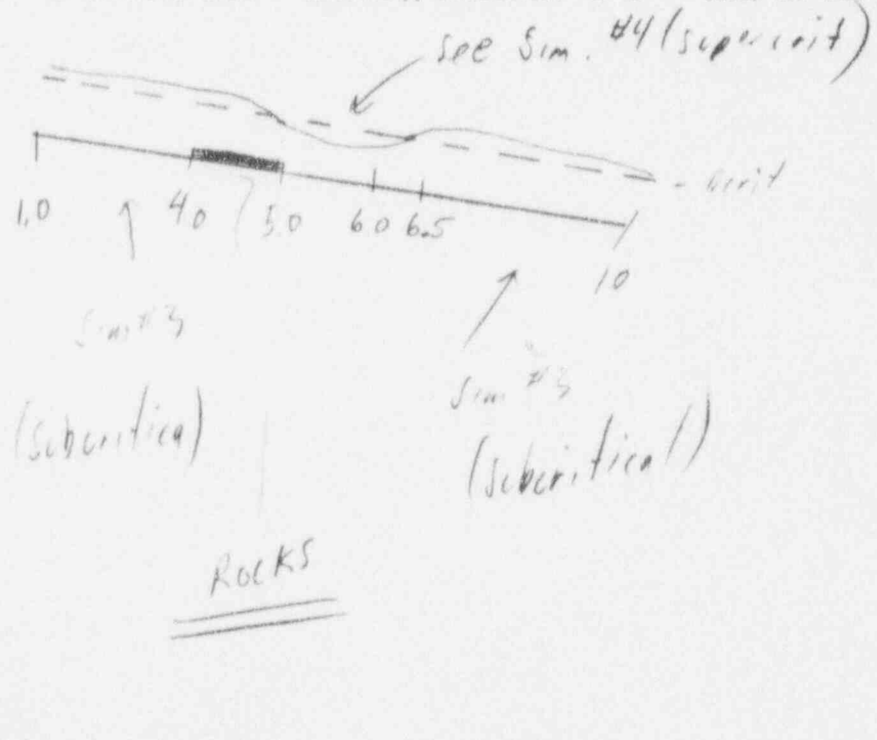

                    X     X  XXXXXXX   XXXXX           XXXXX
                    X     X  X        X     X         X     X
                    X     X  X        X                     X
                    XXXXXXX  XXXX     X         XXXXX   XXXXX
                    X     X  X        X                X
                    X     X  X        X     X          X
                    X     X  XXXXXXX   XXXXX           XXXXXXX
```

SIMULATION B

```
                 ::::::::::::::::::::::::::::::::::::::::::::
                 ::::::::::::::::::::::::::::::::::::::::::::
                 :::                                      :::
                 :::   FULL MICRO-COMPUTER IMPLEMENTATION  :::
                 :::                                      :::
                 ::::::::::::::::::::::::::::::::::::::::::::
                 ::::::::::::::::::::::::::::::::::::::::::::

                        ============================
                        H A E S T A D   M E T H O D S
                        ============================

          37 Brookside Road  *  Waterbury, Connecticut  06708  *  (203) 755-1666
```



E-3

```
                                                                THIS RUN EXECUTED 19MAY94    17:30:03

**************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
**************************************


PR
T1 SOUTHWEST CHANNEL
T2 ATLAS MINERALS 88-067 5/13/94
T3      SUBCRITICAL RUN WITH WEDGE SEC 4.0.4.1,4.2, and 5.0

J1  ICHECK     INQ       NINV     IDIR      STRT     METRIC    HVINS     Q        WSEL       FQ

      0.        0.        0.        0        -1.        0.       1.5    1605.  4014.61       0.

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH      FN      ALLDC     IBW      CHNIM     ITRACE

     0.        0.        0.        0         0         0        -1


NC     0.03      0.03      0.03
NH        2     0.038     204.2     0.035       325      0.00         0         0         0         0
X1       10         8         0       325         0         0         0         0         0         0
GR     4032         0    4015.7       150      401C     167.1      4010     187.1    4015.7     204.2
GR     4020       240      4030       270      4037       325

NH        2     0.034       150     0.035       320         0         0         0         0         0
X1        9         7         0       320       150       150       150         0         0         0
GR     4040         0    4011.7     150.0    4011.7       160      4020       230      4030       255
GR     4040       270    4040.0     320.0

NH        2     0.034     135.0     0.035     310.0         0         0         0         0         0
X1        8         7       0.0     310.0     160.0       160       160         0         0         0
GR     4050         0    4013.4     135.0    4013.4       145      4020       220      4030       235
GR     4040       250    4050.0     310.0

NH        2     0.034     130.0     0.035     290.0         0         0         0         0         0
X1        7         7       0.0     290.0     150.0       150       150         0         0         0
GR     4050         0    4015.1     130.0    4015.1       140      4020       210      4030       225
GR     4040       240    4047.0     290.0

NH        2     0.034     130.0     0.035     290.0         0         0         0         0         0
X1      6.5         8       0.0     290.0      72.0        72        72
GR     4050         0    4015.9     130.0    4015.9       140      4020       205      4030       220
GR     4040       240    4048.0     265.0    4048.0       290
```

WAY
5/20/94

E-4

```
NH        2     0.042     127.0     0.035     285.0
X1        6         8       0.0     285.0      75.0        75        75
GR     4050         0    4016.7     127.0    4016.7       133      4020       160      4030       205
GR     4040       230    4050.0     245.0    4050.0       285

NH        2     0.042     110.0     0.035     280.0
X1      5.2         7       0.0     280.0      66.0        66        66
GR     4050         0    4017.4     110.0    4017.4      115.    4030.0       175      4040       220
GR     4050       230    4058.0     280.0

NH        2     0.042      95.0     0.035     280.0
X1      5.1         7       0.0     280.0      66.0        66        66
GR     4050         0    4018.1      95.0    4018.1      105.    4030.0       125      4040       205
GR     4050       225    4058.0     280.0

NH        2     0.042     112.0     0.035     275.0
X1        5         6       0.0     275.0      66.0        66        66
GR     4050         0    4018.9      85.0    4030.0       112      4040       150      4050       200
GR   4058.0     275.0

NH        2     0.038     118.0     0.035     275.0
X1      4.2         6       0.0     275.0     120.0       120       120
GR     4050         0    4020.2      85.0    4035.0       118      4040       125      4050       155
GR   4058.0     275.0

NH        2     0.038     110.0     0.035     270.0
X1      4.1         6       0.0     270.0      66.0        66        66
GR     4050         0    4020.9      85.0    4030.0       110      4040       125      4050       135
GR   4058.0     270.0

NH        2     0.038     105.0     0.035     255.0
X1        4         6       0.0     255.0      66.0        66        66
GR     4050         0    4021.6      80.0    4030.0       105      4040       120      4050       140
GR   4058.0     255.0

NH        2     0.034      70.0     0.035     250.0         0         0         0         0         0
X1        3         7       0.0     250.0     250.0       250       250         0         0         0
GR     4050         0    4024.4      70.0    4024.4        80      4030        95      4040       115
GR     4050       140      4058       250

NH        2     0.034      65.0     0.035     230.0         0         0         0         0         0
X1        2         8       0.0     230.0     260.0       260       260         0         0         0
GR     4050         0    4027.2      65.0    4027.2        75      4030        85      4040       145
GR     4050       175    4060.0     195.0    4060.0       230

NH        2     0.034      60.0     0.035     220.0         0         0         0         0         0
X1        1         7       0.0     220.0     250.0       250       250         0         0         0
GR     4050         0    4030.0      60.0    4030.0        70      4040       145      4050       155
GR     4060       175    4060.0     220.0
```

5/20/94

E-5

```
  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

PROF 1

RITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS



490 NH CARD USED
SECNO 10.000
720 CRITICAL DEPTH ASSUMED
   10.000       4.60   4014.60    4014.60    4014.61    4016.25       1.65       0.00       0.00    4032.00
   1605.0        0.0    1605.0        0.0        0.0      155.6        0.0        0.0        0.0    4037.00
     0.00       0.00     10.32       0.00      0.000      0.038      0.000      0.000    4010.00     153.29
 0.014959         0.        0.         0.          0          4          0       0.00      47.61     200.91

490 NH CARD USED
SECNO 9.000

302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.58

    9.000       5.20   4016.90    4016.12       0.00    4017.60       0.71       1.35       0.00    4040.00
   1605.0        0.0    1605.0        0.0        0.0      238.0        0.0        0.7        0.2    4040.00
     0.01       0.00      6.74       0.00      0.000      0.035      0.000      0.000    4011.70     122.42
 0.006000       150.      150.       150.          2          8          0       0.00      81.47     203.89

490 NH CARD USED
SECNO 8.000
    8.000       4.40   4017.80    4017.67       0.00    4018.91       1.10       1.30       0.00    4050.00
   1605.0        0.0    1605.0        0.0        0.0      190.5        0.0        1.5        0.5    4050.00
     0.01       0.00      8.43       0.00      0.000      0.035      0.000      0.000    4013.40     118.73
 0.011656       160.      160.       160.          3         15          0       0.00      76.39     195.12

490 NH CARD USED
SECNO 7.000
    7.000       4.49   4019.59    4019.13       0.00    4020.37       0.78       1.46       0.00    4050.00
   1605.0        0.0    1605.0        0.0        0.0      226.2        0.0        2.2        0.8    4047.00
     0.02       0.00      7.10       0.00      0.000      0.035      0.000      0.000    4015.10     113.29
 0.008277       150.      150.       150.          2         11          0       0.00      90.81     204.10

490 NH CARD USED
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  SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
  Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
  TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
  SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST


*SECNO 6.500
    6.500       4.28   4020.18   4019.82      0.00   4020.98      0.80      0.61      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     222.9       0.0       2.6       1.0   4048.00
     0.02       0.00      7.20      0.00     0.000     0.035     0.000     0.000   4015.90    113.67
 0.008784        72.       72.       72.         2        15         0      0.00     91.60    205.27

1490 NH CARD USED
*SECNO 6.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    6.000       4.87   4021.57   4021.57      0.00   4023.01      1.43      0.84      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     167.1       0.0       2.9       1.1   4050.00
     0.02       0.00      9.60      0.00     0.000     0.037     0.000     0.000   4016.70    108.41
 0.014736        75.       75.       75.         0         8         0      0.00     58.67    167.08

1490 NH CARD USED
*SECNO 5.200
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    5.200       5.69   4023.09   4023.09      0.00   4024.65      1.56      0.97      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     160.2       0.0       3.1       1.2   4058.00
     0.02       0.00     10.02      0.00     0.000     0.038     0.000     0.000   4017.40     90.80
 0.014697        66.       66.       66.         0         8         0      0.00     51.31    142.10

1490 NH CARD USED
*SECNO 5.100
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    5.100       6.00   4024.10   4024.10      0.00   4026.03      1.93      0.99      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     144.0       0.0       3.4       1.2   4058.00
     0.03       0.00     11.15      0.00     0.000     0.038     0.000     0.000   4018.10     77.12
 0.015295        66.       66.       66.         0         8         0      0.00     37.96    115.09

1490 NH CARD USED
*SECNO 5.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    5.000       7.47   4026.37   4026.37      0.00   4028.30      1.92      1.11      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     144.2       0.0       3.6       1.3   4058.00
     0.03       0.00     11.13      0.00     0.000     0.042     0.000     0.000   4018.90     64.58
 0.018746        66.       66.       66.         0        11         0      0.00     38.60    103.17
```

l-7

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  Run Date:  19MAY94    Run Time: 17:30:03    HMVersion: 6.50    Data File:   H:SWSUB45.IN                                    Page    5

    SECNO       DEPTH       CWSEL       CRIWS       WSELK       EG          HV          HL          OLOSS       L-BANK ELEV
    Q           QLOB        QCH         QROB        ALOB        ACH         AROB        VOL         TWA         R-BANK ELEV
    TIME        VLOB        VCH         VROB        XNL         XNCH        XNR         WTN         ELMIN       SSTA
    SLOPE       XLOBL       XLCH        XLOBR       ITRIAL      IDC         ICONT       CORAR       TOPWID      ENDST

490 NH CARD USED
SECNO 4.200

302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.44

     4.200        8.31    4028.51    4027.75       0.00    4029.81       1.30       1.51       0.00    4050.00
    1605.0         0.0     1605.0        0.0        0.0      175.2        0.0        4.0        1.4    4058.00
      0.03        0.00       9.16       0.00      0.000      0.038      0.000      0.000    4020.20      61.31
  0.009057        120.       120.       120.          3          5          0       0.00      42.20     103.52

490 NH CARD USED
SECNO 4.100
     4.100        8.43    4029.33    4028.10       0.00    4030.32       0.99       0.51       0.00    4050.00
    1605.0         0.0     1605.0        0.0        0.0      201.4        0.0        4.3        1.5    4058.00
      0.03        0.00       7.97       0.00      0.000      0.038      0.000      0.000    4020.90      60.37
  0.006593         66.        66.        66.          2         15          0       0.00      47.79     108.16

490 NH CARD USED
SECNO 4.000
     4.000        8.07    4029.67    4028.74       0.00    4030.79       1.13       0.48       0.00    4050.00
    1605.0         0.0     1605.0        0.0        0.0      188.5        0.0        4.6        1.5    4058.00
      0.04        0.00       8.51       0.00      0.000      0.038      0.000      0.000    4021.60      57.27
  0.007956         66.        66.        66.          3         15          0       0.00      46.74     104.01

490 NH CARD USED
SECNO 3.000
     3.000        7.01    4031.41    4030.17       0.00    4032.38       0.97       1.59       0.00    4050.00
    1605.0         0.0     1605.0        0.0        0.0      202.7        0.0        5.7        1.8    4058.00
      0.04        0.00       7.92       0.00      0.000      0.035      0.000      0.000    4024.40      50.82
  0.005203        250.       250.       250.          2         19          0       0.00      47.01      97.83

490 NH CARD USED
SECNO 2.000

302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  0.70

     2.000        5.69    4032.89    4032.66       0.00    4034.26       1.37       1.87       0.00    4050.00
    1605.0         0.0     1605.0        0.0        0.0      170.8        0.0        6.8        2.1    4060.00
      0.05        0.00       9.40       0.00      0.000      0.035      0.000      0.000    4027.20      48.79
  0.010645        260.       260.       260.          4         15          0       0.00      53.53     102.32
```

t. 8

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  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


1490 NH CARD USED
*SECNO 1.000
     1.000      5.49   4035.49   4034.78      0.00   4036.37      0.88      2.11      0.00   4050.00
    1605.0       0.0    1605.0       0.0       0.0     213.2       0.0       7.9       2.5   4060.00
      0.06      0.00      7.53      0.00     0.000     0.035     0.000     0.000   4030.00     43.53
  0.006876      250.      250.      250.         2        15         0      0.00     67.65    111.18
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PROFILE FOR STREAM   SUBCRITICAL RUN WITH WE


PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA


ELEVATION  4010.     4015.     4020.     4025.     4030.     4035.     4040.     4045.     4050.     4055.
    SECNO   CUMDIS

    10.00     0.  I        W.  E      .         .         .   L     .   R     .         .         .         .         .
             20.  I         W  E      .         .         .     L   .    R    .         .         .         .         .
             40.  .I        W  E      .         .         .       L .     R   .         .         .         .         .
             60.  .I        CW  E     .         .         .         L     R   .         .         .         .         .
             30.  . I       .CW E     .         .         .         .  L   R  .         .         .         .         .
             00.  . I       .CW E     .         .         .         .    L  R .         .         .         .         .
            120.  .  I      . CW E    .         .         .         .      L R.         .         .         .         .
            140.  .  I      . CW E    .         .         .         .        LR         .         .         .         .
     9.00   160.  .  I      . C WE    .         .         .         .         L         .         .         .         .
            180.  .   I     .  CW E   .         .         .         .         .  L      .         .         .         .
            200.  .   I     .  CW E   .         .         .         .         .    L    .         .         .         .
            220.  .    I    .  CW E   .         .         .         .         .       L .         .         .         .
            240.  .    I    .   CW E  .         .         .         .         .         L         .         .         .
            260.  .     I   .   CW E  .         .         .         .         .         .  L      .         .         .
            280.  .     I   .    W E  .         .         .         .         .         .    L    .         .         .
            300.  .     I   .    W E  .         .         .         .         .         .       L .         .         .
     8.00   320.  .      I  .    CW E .         .         .         .         .         .         L         .         .
            340.  .      I  .     W E .         .         .         .         .         .        RL         .         .
            360.  .       I .     CW E.         .         .         .         .         .       R L         .         .
            380.  .       I .      W E.         .         .         .         .         .       R L         .         .
            400.  .        I.      CWE.         .         .         .         .         .      R  L         .         .
            420.  .        I.      CW E         .         .         .         .         .     R   L         .         .
            440.  .         I       W E         .         .         .         .         .    R    L         .         .
     7.00   460.  .         I       CW.E        .         .         .         .         .   R     L         .         .
            480.  .         .I       CWE        .         .         .         .         .    R    L         .         .
            500.  .         .I       CWE        .         .         .         .         .    R    L         .         .
            520.  .         . I      CW E       .         .         .         .         .     R   L         .         .
     6.50   540.  .         . I       W E       .         .         .         .         .     R   L         .         .
            560.  .         . I       .W E      .         .         .         .         .      R  L         .         .
            580.  .         .  I      . W E     .         .         .         .         .       R L         .         .
            600.  .         .  I      . CW E    .         .         .         .         .        RL         .         .
     6.00   620.  .         .  I      .  W  E   .         .         .         .         .         L         .         .
            640.  .         .   I     .   W  E  .         .         .         .         .         L    R    .         .
            660.  .         .   I     .    W  E .         .         .         .         .         L         R         .
     5.20   680.  .         .    I    .     W  E.         .         .         .         .         L         .     R   .
            700.  .         .    I    .      W  E         .         .         .         .         L         .     R   .
            720.  .         .     I   .      W  .E        .         .         .         .         L         .     R   .
     5.10   740.  .         .     I   .       W . E       .         .         .         .         L         .     R   .
            760.  .         .      I  .         W  E      .         .         .         .         L         .     R   .
            780.  .         .      I  .         .W   E    .         .         .         .         L         .     R   .
            800.  .         .       I .         . W   E   .         .         .         .         L         .     R   .
     5.00   820.  .         .       I .         .  W   E  .         .         .         .         L         .     R   .
            840.  .         .       I .         .  W   E  .         .         .         .         L         .     R   .
            860.  .         .        I.         .   W   E .         .         .         .         L         .     R   .
            880.  .         .        I.         .   CW  E .         .         .         .         L         .     R   .
            900.  .         .         I         .    CW  E.         .         .         .         L         .     R   .
            920.  .         .         I         .    CW  E.         .         .         .         L         .     R   .
     4.20   940.  .         .         I         .     CW  E         .         .         .         L         .     R   .
            960.  .         .         .I        .     C W E         .         .         .         L         .     R   .
            980.  .         .         .I        .     C W E         .         .         .         L         .     R   .
     4.10  1000.  .         .         . I       .     C  W.E        .         .         .         L         .     R   .
           1020.  .         .         . I       .      C W.E        .         .         .         L         .     R   .
           1040.  .         .         .  I      .      C W.E        .         .         .         L         .     R   .
     4.00  1060.  .         .         .  I      .      C W. E       .         .         .         L         .     R   .
           1080.  .         .         .   I     .       C W E       .         .         .         L         .     R   .
           1100.  .         .         .   I     .       C W E       .         .         .         L         .     R   .
           1120.  .         .         .    I    .       C W E       .         .         .         L         .     R   .
           1140.  .         .         .    I    .       C W  E      .         .         .         L         .     R   .
           1160.  .         .         .    I    .        C.W E      .         .         .         L         .     R   .
           1180.  .         .         .     I   .        C.W E      .         .         .         L         .     R   .
           1200.  .         .         .     I   .        C.W E      .         .         .         L         .     R   .
           1220.  .         .         .      I  .        C. W E     .         .         .         L         .     R   .
           1240.  .         .         .      I  .         C W E     .         .         .         L         .     R   .
           1260.  .         .         .       I .         C W E     .         .         .         L         .     R   .
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      1280.  .         .         .       I .         C W E     .         .         .         L         .     R   .
      1300.  .         .         .        I.         C  W E    .         .         .         L         .     R   .
3.00  1320.  .         .         .        I.         C  W E    .         .         .         L         .     R   .
      1340.  .         .         .        I.         .C W E    .         .         .         L         .     R   .
      1360.  .         .         .         I         .C W E    .         .         .         L         .      R  .
      1380.  .         .         .         I         .C  W E   .         .         .         L         .      R  .
      1400.  .         .         .         .I        . C W E   .         .         .         L         .      R  .
      1420.  .         .         .         .I        . C W E   .         .         .         L         .       R .
      1440.  .         .         .         .I        .  CW E   .         .         .         L         .       R .
      1460.  .         .         .         . I       .  CW  E  .         .         .         L         .       R .
      1480.  .         .         .         . I       .  C W E  .         .         .         L         .       R .
      1500.  .         .         .         .  I      .   CW E  .         .         .         L         .        R.
      1520.  .         .         .         .  I      .   CW  E .         .         .         L         .        R.
      1540.  .         .         .         .   I     .    W  E .         .         .         L         .        R.
      1560.  .         .         .         .   I     .    CW E .         .         .         L         .         R
2.00  1580.  .         .         .         .   I     .    CW  E.         .         .         L         .         R
      1600.  .         .         .         .    I    .     W  E.         .         .         L         .         R
      1620.  .         .         .         .    I    .     CW E.         .         .         L         .         R
      1640.  .         .         .         .     I   .     CW  E         .         .         L         .         R
      1660.  .         .         .         .     I   .      W  E         .         .         L         .         R
      1680.  .         .         .         .      I  .      CW E         .         .         L         .         R
      1700.  .         .         .         .      I  .      CW .E        .         .         L                   R
      1720.  .         .         .         .       I .       CW.E        .         .         L         .         R
      1740.  .         .         .         .       I .       CW.E        .         .         L         .         R
      1760.  .         .         .         .       I .       C W E       .         .         L         .         R
      1780.  .         .         .         .        I.        CW E       .         .         L         .         R
      1800.  .         .         .         .        I.        CW E       .         .         L         .         R
1.00  1820.  .         .         .         .         I         CW E      .         .         L         .         R
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                                                                    THIS RUN EXECUTED 19MAY94    17:30:05
**************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
**************************************

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

 SUBCRITICAL RUN WITH WE

SUMMARY PRINTOUT TABLE  150

     SECNO      XLCH      ELTRD      ELLC     ELMIN        Q      CWSEL    CRIWS      EG       10*KS     VCH     AREA     .01K

*   10.000      0.00      0.00       0.00   4010.00  1605.00  4014.60  4014.60  4016.25    149.59    10.32   155.57   131.23
*    9.000    150.00      0.00       0.00   4011.70  1605.00  4016.90  4016.12  4017.60     60.00     6.74   238.02   207.21
     8.000    160.00      0.00       0.00   4013.40  1605.00  4017.80  4017.67  4018.91    116.56     8.43   190.50   148.66
     7.000    150.00      0.00       0.00   4015.10  1605.00  4019.59  4019.13  4020.37     82.77     7.10   226.16   176.42
     6.500     72.00      0.00       0.00   4015.90  1605.00  4020.18  4019.82  4020.98     87.84     7.20   222.94   171.24
*    6.000     75.00      0.00       0.00   4016.70  1605.00  4021.57  4021.57  4023.01    147.36     9.60   167.12   132.21
*    5.200     66.00      0.00       0.00   4017.40  1605.00  4023.09  4023.09  4024.65    146.97    10.02   160.23   132.39
*    5.100     66.00      0.00       0.00   4018.10  1605.00  4024.10  4024.10  4026.03    152.95    11.15   143.95   129.78
*    5.000     66.00      0.00       0.00   4018.90  1605.00  4026.37  4026.37  4028.30    187.46    11.13   144.19   117.23
*    4.200    120.00      0.00       0.00   4020.20  1605.00  4028.51  4027.75  4029.81     90.57     9.16   175.24   168.65
     4.100     66.00      0.00       0.00   4020.90  1605.00  4029.33  4028.10  4030.32     65.93     7.97   201.44   197.67
     4.000     66.00      0.00       0.00   4021.60  1605.00  4029.67  4028.74  4030.79     79.56     8.51   188.53   179.94
     3.000    250.00      0.00       0.00   4024.40  1605.00  4031.41  4030.17  4032.38     52.03     7.92   202.65   222.52
*    2.000    260.00      0.00       0.00   4027.20  1605.00  4032.89  4032.66  4034.26    106.45     9.40   170.83   155.56
     1.000    250.00      0.00       0.00   4030.00  1605.00  4035.49  4034.78  4036.37     68.76     7.53   213.17   193.55
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 SUBCRITICAL RUN WITH WE

SUMMARY PRINTOUT TABLE  150

      SECNO       Q        CWSEL    DIFWSP    DIFWSX    DIFKWS    TOPWID     XLCH

*    10.000    1605.00   4014.60      0.00      0.00     -0.01     47.61      0.00

*     9.000    1605.00   4016.90      0.00      2.30      0.00     81.47    150.00

      8.000    1605.00   4017.80      0.00      0.91      0.00     76.39    160.00

      7.000    1605.00   4019.59      0.00      1.78      0.00     90.81    150.00

      6.500    1605.00   4020.18      0.00      0.59      0.00     91.60     72.00

*     6.000    1605.00   4021.57      0.00      1.40      0.00     58.67     75.00

*     5.200    1605.00   4023.09      0.00      1.52      0.00     51.31     66.00

*     5.100    1605.00   4024.10      0.00      1.01      0.00     37.96     66.00

*     5.000    1605.00   4026.37      0.00      2.27      0.00     38.60     66.00

*     4.200    1605.00   4028.51      0.00      2.13      0.00     42.20    120.00

      4.100    1605.00   4029.33      0.00      0.82      0.00     47.79     66.00

      4.000    1605.00   4029.67      0.00      0.34      0.00     46.74     66.00

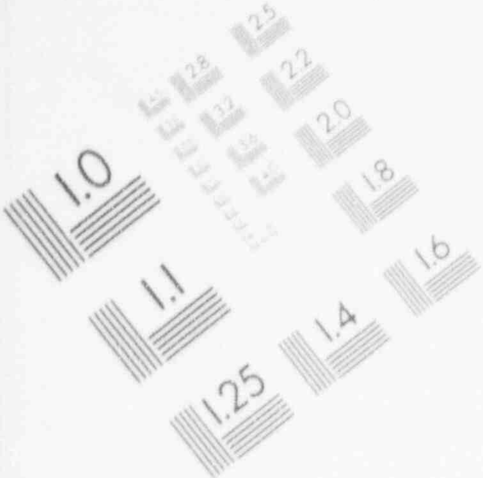
      3.000    1605.00   4031.41      0.00      1.74      0.00     47.01    250.00

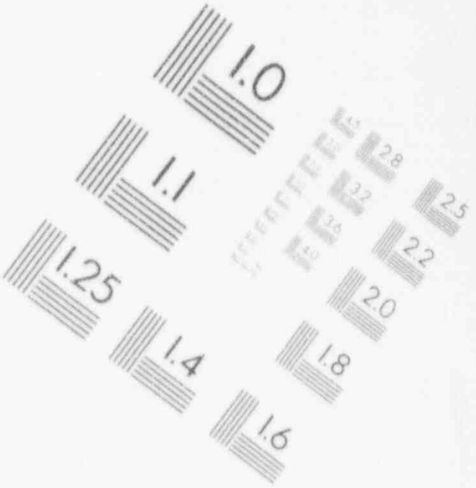
*     2.000    1605.00   4032.89      0.00      1.48      0.00     53.53    260.00

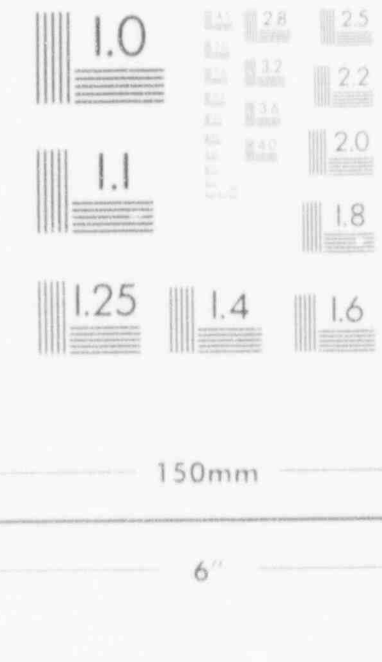
      1.000    1605.00   4035.49      0.00      2.60      0.00     67.65    250.00
```

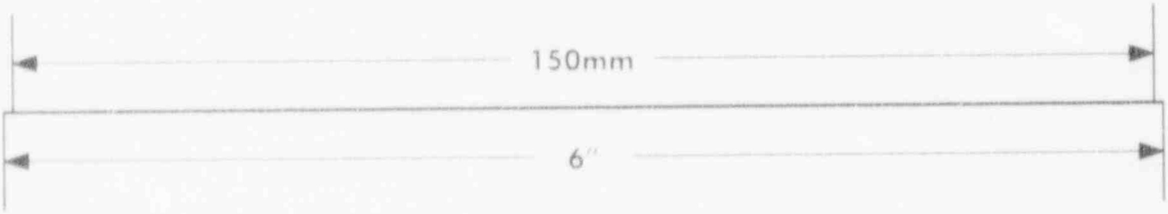
1

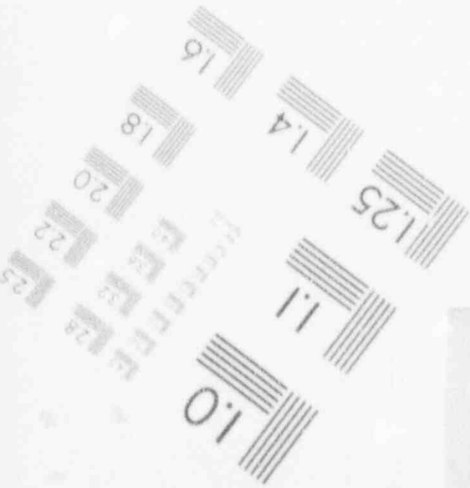
IMAGE EVALUATION
TEST TARGET (MT-3)

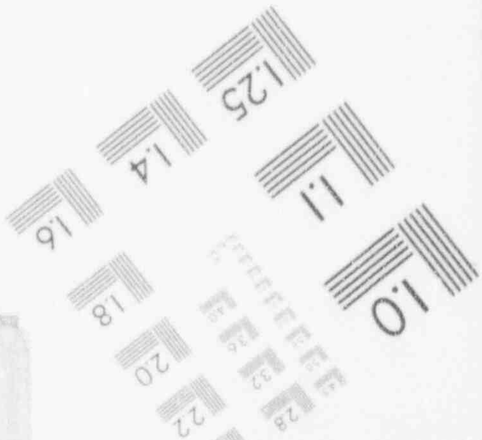






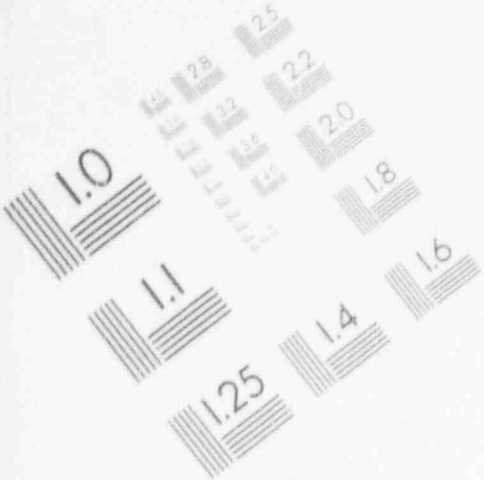


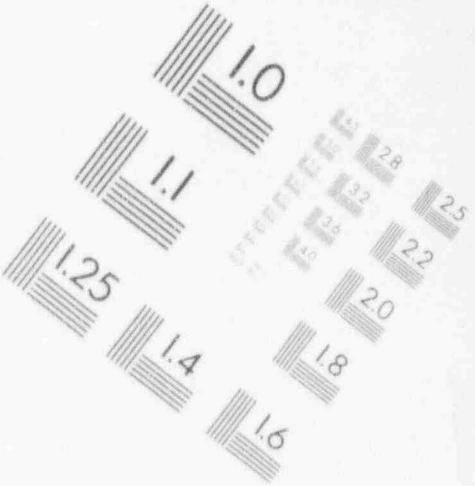


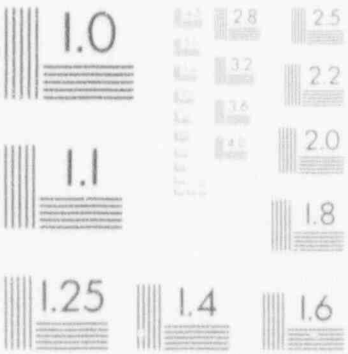


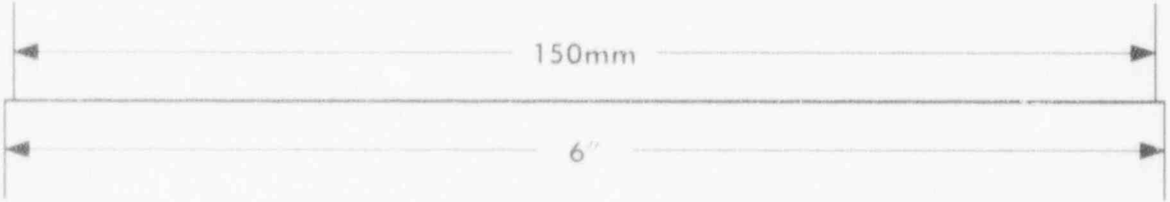
1

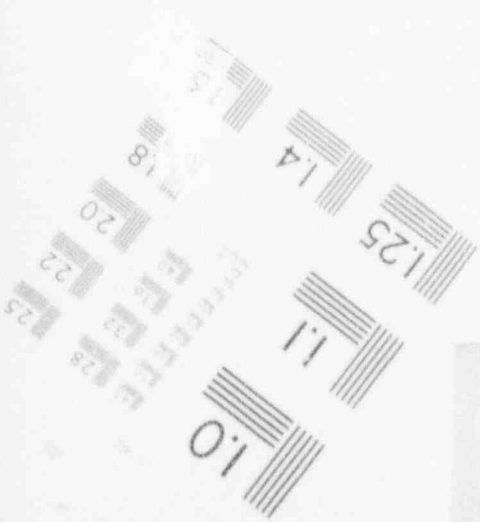
IMAGE EVALUATION
TEST TARGET (MT-3)

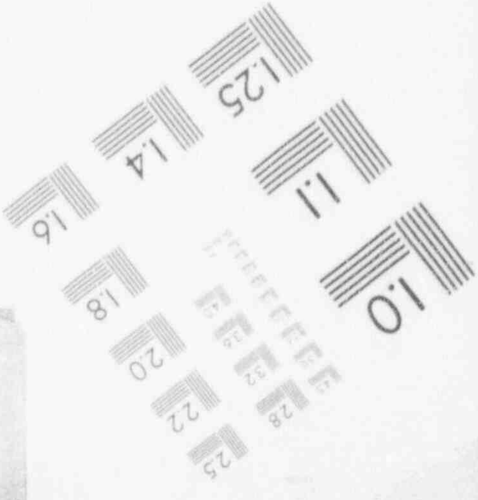






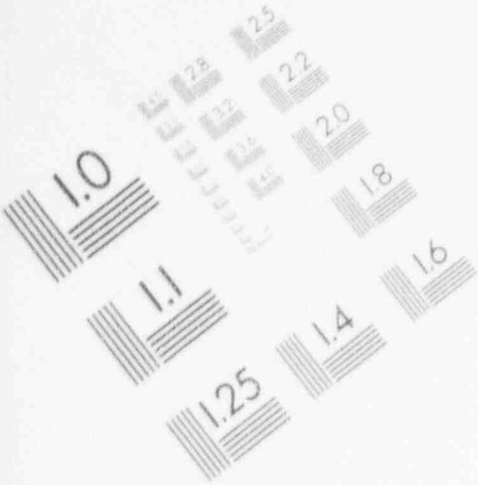


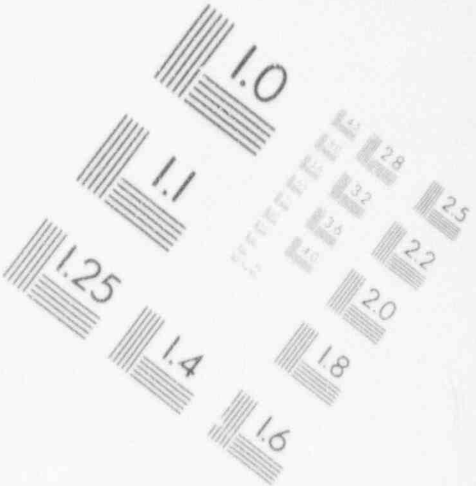


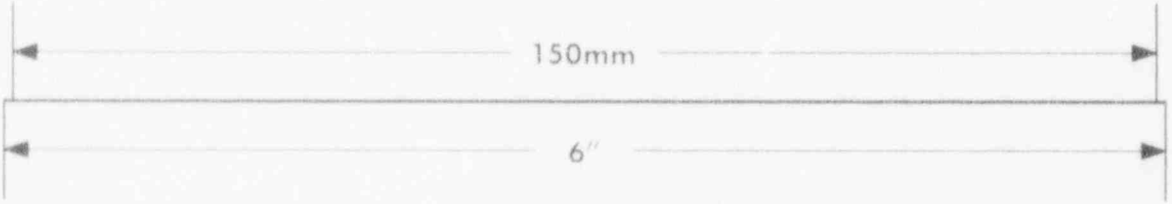


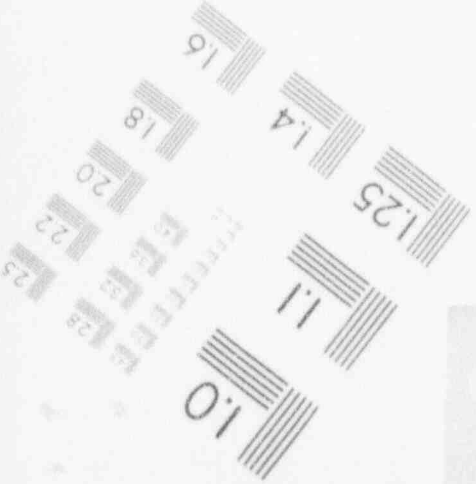
1

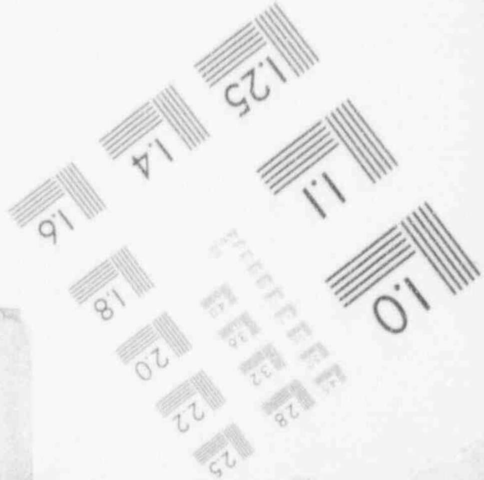
IMAGE EVALUATION
TEST TARGET (MT-3)











C-13

```
 SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO=     10.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

WARNING SECNO=      9.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=      6.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      6.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=      5.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.200  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=      5.100  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.100  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=      5.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=      4.200  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

WARNING SECNO=      2.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```

```
HEC2 S/N: 1916530006        HMVersion: 6.50    Data File: H:SWSUP45.IN
```

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```
**********************************************                        ****************************************
* HEC-2 WATER SURFACE PROFILES               *                        * U.S. ARMY CORPS OF ENGINEERS         *
*                                            *                        * HYDROLOGIC ENGINEERING CENTER        *
* Version   4.6.2;  May 1991                 *                        * 609 SECOND STREET, SUITE D           *
*                                            *                        * DAVIS, CALIFORNIA 95616-4687         *
* RUN DATE    19MAY94    TIME    17:29:47    *                        *        (916) 756-1104                *
**********************************************                        ****************************************


                     X     X  XXXXXXX   XXXXX           XXXXX
                     X     X  X        X     X         X     X
                     X     X  X        X                     X
                     XXXXXXX  XXXX     X         XXXXX   XXXXX
                     X     X  X        X               X
                     X     X  X        X     X         X
                     X     X  XXXXXXX   XXXXX          XXXXXXX
```

SIMULATION 4

```
                    :::::::::::::::::::::::::::::::::::::::::::::::
                    :::::::::::::::::::::::::::::::::::::::::::::::
                    :::                                         :::
                    :::     FULL MICRO-COMPUTER IMPLEMENTATION  :::
                    :::                                         :::
                    :::::::::::::::::::::::::::::::::::::::::::::::
                    :::::::::::::::::::::::::::::::::::::::::::::::


                               ============================
                               H A E S T A D   M E T H O D S
                               ============================

            37 Brookside Road  *  Waterbury, Connecticut  06708  *  (203) 755-1666
```

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```
Run Date:  19MAY94    Run Time: 17:29:47    HMVersion: 6.50    Data File:    H:SWSUF45.IN                        Page    1



                                                                                      THIS RUN EXECUTED 19MAY94     17:29:47
****************************************
HEC-2 WATER SURFACE PROFILES

Version   4.6.2;  May 1991
****************************************


FR
T1 SOUTHWEST CHANNEL
T2 ATLAS MINERALS 88-067 5/13/94
T3       SUPERCR:~ICAL RUN WITH WEDGE sec 4,4.1,4.2,5

J1  ICHECK     INQ        NINV      IDIR       STRT      METRIC     HVINS      Q         WSEL       FQ

      0.        0.         0.         1         -1.          0        1.0     1605.    4034.8        0.

NC     0.03      0.03       0.03
NH        2     0.034         60     0.035        220
X1      1.0       7.0        0.0     220.0      250.0      250.0      250.0       0.0       0.0       0.0
GR   4050.0       0.0     4030.0      60.0     4030.0       70.0     4040.0     145.0    4050.0     155.0
GR   4060.0     175.0     4060.0     220.0

NH        2     0.034         65     0.035        230
X1      2.0         8        0.0     230.0      260.0      260.0      260.0
GR   4050.0       0.0     4027.2      65.0     4027.2       75.0     4030.0      85.0    4040.0     145.0
GR   4050.0     175.0     4060.0     195.0     4060.0      230.0

NH        2     0.034         70     0.035        250
X1      3.0         7          0       250        250        250        250
GR   4050.0       0.0     4024.4      70.0     4024.4       80.0     4030.0      95.0    4040.0     115.0
GR   4050.0     140.0       4058       250

NH        2     0.038       105.     0.035        255
X1      4.0         6          0       255         66         66         66
GR   4050.0       0.0     4021.6      80.0     4030.0      105.0     4040.0     120.0    4050.0     140.0
GR   4058.0     255.0

NH        2     0.038        110     0.035        270
X1      4.1         6          0       270         66         66         66
GR   4050.0       0.0     4020.9      85.0     4030.0      110.0     4040.0     125.0    4050.0     135.0
GR   4058.0     270.0

NH        2     0.038        118     0.035        275
X1      4.2         6          0       275        120        120        120
GR   4050.0       0.0     4020.2      85.0     4035.0      118.0     4040.0     125.0    4050.0     155.0
GR   4058.0     275.0
```

5/20/94

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```
NH       2       0.042       112      0.035      275.0
X1     5.0           6         0        275         66         66         66
GR  4050.0         0.0    4018.9       85.0     4030.0      112.0     4040.0      150.0     4050.0      200.0
GR  4058.0       275.0

NH       2       0.042        95      0.035      280.0
X1     5.1           7         0        280         66         66         66
GR  4050.0         0.0    4018.1        95.     4018.1       105.     4030.0      125.0     4040.0      205.0
GR  4050.0       225.0    4058.0      280.0

NH       2       0.042       110      0.035      280.0
X1     5.2           7         0        280         66         66         66
GR  4050.0         0.0    4017.4      110.0     4017.4       115.     4030.0      175.0     4040.0      220.0
GR  4050.0       230.0    4058.0      280.0

NH       2       0.042       127      0.035      285.0
X1     6.0         8.0       0.0      285.0       75.0       75.0       75.0        0.0        0.0        0.0
GR  4050.0         0.0    4016.7      127.0     4016.7      133.0     4020.0      160.0     4030.0      205.0
GR  4040.0       230.0    4050.0      245.0     4050.0      285.0

NH       2       0.034       130      0.035      290.0
X1     6.5         8.0       0.0      290.0       72.0       72.0       72.0
GR  4050.0         0.0    4015.9      130.0     4015.9      140.0     4020.0      205.0     4030.0      220.0
GR  4040.0       240.0    4048.0      265.0     4048.0      290.0

NH       2       0.034       130      0.035        290
X1     7.0         7.0       0.0      290.0      150.0      150.0      150.0        0.0        0.0        0.0
GR  4050.0         0.0    4015.1      130.0     4015.1      140.0     4020.0      210.0     4030.0      225.0
GR  4040.0       240.0    4047.0      290.0

NH       2       0.034       135      0.035        310
X1     8.0         7.0       0.0      310.0      160.0      160.0      160.0        0.0        0.0        0.0
GR  4050.0         0.0    4013.4      135.0     4013.4      145.0     4020.0      220.0     4030.0      235.0
GR  4040.0       250.0    4050.0      310.0

NH       2       0.034       150      0.035      320.0
X1     9.0         7.0       0.0      320.0      150.0      150.0      150.0        0.0        0.0        0.0
GR  4040.0         0.0    4011.7      150.0     4011.7      160.0     4020.0      230.0     4030.0      255.0
GR  4040.0       270.0    4040.0      320.0

NH     2.0       0.034     204.2      0.035      325.0
X1    10.0         8.0       0.0      325.0        0.0        0.0        0.0
GR  4032.0         0.0    4015.7      150.0     4010.0      167.1     4010.0      187.1     4015.7      204.2
GR  4020.0       240.0    4030.0      270.0     4037.0      325.0
```

WXP 5/20/94

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```
   SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

PROF 1


490 NH CARD USED
SECNO 1.000
720 CRITICAL DEPTH ASSUMED
    1.000       4.78    4034.78    4034.78    4034.80    4036.20       1.42       0.00       0.00    4050.00
   1605.0        0.0     1605.0        0.0        0.0      167.8        0.0        0.0        0.0    4060.00
     0.00       0.00       9.56       0.00      0.000      0.035      0.000      0.000    4030.00      45.66
 0.013059         0.         0.         0.          0          4          0       0.00      60.20     105.86

490 NH CARD USED
SECNO 2.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    2.000       5.49    4032.69    4032.69       0.00    4034.24       1.55       3.20       1.60    4050.00
   1605.0        0.0     1605.0        0.0        0.0      160.4        0.0        0.9        0.3    4060.00
     0.01       0.00      10.00       0.00      0.000      0.035      0.000      0.000    4027.20      49.35
 0.012555       250.       250.       250.         20          8          0       0.00      51.79     101.14

490 NH CARD USED
SECNO 3.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    3.000       5.77    4030.17    4030.17       0.00    4032.00       1.83       3.25       1.61    4050.00
   1605.0        0.0     1605.0        0.0        0.0      147.8        0.0        1.9        0.6    4058.00
     0.01       0.00      10.86       0.00      0.000      0.035      0.000      0.000    4024.40      54.22
 0.012409       260.       260.       260.         20          8          0       0.00      41.12      95.34

490 NH CARD USED
SECNO 4.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    4.000       7.14    4028.74    4028.74       0.00    4030.57       1.84       3.44       1.63    4050.00
   1605.0        0.0     1605.0        0.0        0.0      147.5        0.0        2.7        0.8    4058.00
     0.02       0.00      10.88       0.00      0.000      0.038      0.000      0.000    4021.60      59.90
 0.015319       250.       250.       250.         20         11          0       0.00      41.33     101.24
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  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

1490 NH CARD USED
*SECNO 4.100
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     4.100      7.23   4028.13   4028.13       0.00   4029.95       1.82       1.00       0.12   4050.00
    1605.0       0.0    1605.0       0.0        0.0     148.3        0.0        2.9        0.9   4058.00
      0.02      0.00     10.82      0.00      0.000     0.038      0.000      0.000    4020.90     63.87
  0.014919       66.       66.       66.         20         5          0       0.00      41.00    104.87

1490 NH CARD USED
*SECNO 4.200
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     4.200      7.52   4027.72   4027.72       0.00   4029.66       1.94       1.00       0.09   4050.00
    1605.0       0.0    1605.0       0.0        0.0     143.7        0.0        3.2        1.0   4058.00
      0.02      0.00     11.17      0.00      0.000     0.038      0.000      0.000    4020.20     63.55
  0.015386       66.       66.       66.         20         8          0       0.00      38.21    101.77

1490 NH CARD USED
*SECNO 5.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
     5.000      7.47   4026.37   4026.37       0.00   4028.30       1.92       2.03       1.11   4050.00
    1605.0       0.0    1605.0       0.0        0.0     144.3        0.0        3.6        1.1   4058.00
      0.03      0.00     11.12      0.00      0.000     0.042      0.000      0.000    4018.90     64.57
  0.018707      120.      120.      120.         20         5          0       0.00      38.61    103.18

1490 NH CARD USED
*SECNO 5.100

1645 INT SEC ADDED BY RAISING SEC      5.10,   0.400 FT AND MULTIPLYING BY   1.009

3301 HV CHANGED MORE THAN HVINS
```

```
   SECNO      DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL        OLOSS     L-BANK ELEV
   Q          QLOB      QCH       QROB      ALOB       ACH       AROB      VOL       TWA       R-BANK ELEV
   TIME       VLOB      VCH       VROB      XNL        XNCH      XNR       WTN       ELMIN     SSTA
   SLOPE      XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR     TOPWID    ENDST


3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.54

    1.010       4.62   4023.12   4024.47      0.00   4027.39      4.27      0.91      0.00   4050.40
   1605.0        0.0    1605.0       0.0       0.0      96.8       0.0       3.6       1.1   4058.40
     0.03       0.00     16.58      0.00     0.000     0.038     0.000     0.000   4018.50     82.01
 0.044525        33.       33.       33.         6        15         0      0.00     31.81    113.83


1645 INT SEC ADDED BY RAISING SEC      1.01,  -0.400 FT AND MULTIPLYING BY   0.991

3301 HV CHANGED MORE THAN HVINS

    5.100       5.26   4023.36   4024.11      0.00   4026.27      2.91      1.11      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     117.2       0.0       3.7       1.1   4058.00
     0.03       0.00     13.69      0.00     0.000     0.038     0.000     0.000   4018.10     79.32
 0.026483        33.       33.       33.         5        11         0      0.00     34.53    113.85


1490 NH CARD USED
*SECNO 5.200
    5.200       5.29   4022.69   4023.06      0.00   4024.72      2.03      1.55      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     140.2       0.0       3.9       1.2   4058.00
     0.03       0.00     11.45      0.00     0.000     0.038     0.000     0.000   4017.40     92.16
 0.020971        66.       66.       66.         2         8         0      0.00     48.03    140.18


1490 NH CARD USED
*SECNO 6.000
    6.000       4.32   4021.02   4021.55      0.00   4023.18      2.16      1.54      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     136.0       0.0       4.1       1.3   4050.00
     0.03       0.00     11.80      0.00     0.000     0.037     0.000     0.000   4016.70    110.52
 0.026111        66.       66.       66.         5        11         0      0.00     54.08    164.60


1490 NH CARD USED
*SECNO 6.500
    6.500       3.38   4019.28   4019.82      0.00   4021.15      1.87      2.03      0.00   4050.00
   1605.0        0.0    1605.0       0.0       0.0     146.2       0.0       4.4       1.4   4048.00
     0.03       0.00     10.98      0.00     0.000     0.035     0.000     0.000   4015.90    117.11
 0.028161        75.       75.       75.         5        11         0      0.00     76.49    193.60
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  SECNO       DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q           QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME        VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE       XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

490 NH CARD USED
SECNO 7.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    7.000       4.03    4019.13    4019.13       0.00    4020.28       1.15       1.38       0.02    4050.00
   1605.0        0.0     1605.0        0.0        0.0      186.2        0.0        4.6        1.5    4047.00
     0.03       0.00       8.62       0.00      0.000      0.035      0.000      0.000    4015.10     115.00
 0.013926        72.        72.        72.         20         11          0       0.00      82.51     197.51

490 NH CARD USED
SECNO 8.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    8.000       4.27    4017.67    4017.67       0.00    4018.91       1.24       2.07       0.02    4050.00
   1605.0        0.0     1605.0        0.0        0.0      179.6        0.0        5.3        1.8    4050.00
     0.04       0.00       8.94       0.00      0.000      0.035      0.000      0.000    4013.40     119.27
 0.013649       150.       150.       150.         20          8          0       0.00      74.21     193.47

490 NH CARD USED
SECNO 9.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    9.000       4.40    4016.09    4016.09       0.00    4017.38       1.28       2.16       1.10    4040.00
   1605.0        0.0     1605.0        0.0        0.0      176.6        0.0        5.9        2.0    4040.00
     0.04       0.00       9.09       0.00      0.000      0.035      0.000      0.000    4011.70     126.70
 0.013348       160.       160.       160.         20          8          0       0.00      70.36     197.07

490 NH CARD USED
SECNO 10.000
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
   10.000       4.59    4014.59    4014.59       0.00    4016.25       1.66       1.90       0.87    4032.00
   1605.0        0.0     1605.0        0.0        0.0      155.2        0.0        6.5        2.2    4037.00
     0.05       0.00      10.34       0.00      0.000      0.034      0.000      0.000    4010.00     153.31
 0.012045       150.       150.       150.         20          8          0       0.00      47.57     200.89
```

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```
PROFILE FOR STREAM   SUPERCRITICAL RUN WITH


PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA


ELEVATION  4010.     4015.     4020.     4025.     4030.     4035.     4040.     4045.     4050.     4055.
    SECNO   CUMDIS

     1.00     0.  .         .         .         .         I         W E       .         .         L         .         R
             20.  .         .         .         .         I        W. E       .         .         L         .         R
             40.  .         .         .         .        I.        W. E       .         .         L         .         R
             60.  .         .         .         .        I.        W.E        .         .         L         .         R
             80.  .         .         .         .       I .       W  E        .         .         L         .         R
            100.  .         .         .         .       I .       W .E        .         .         L         .         R
            120.  .         .         .         .      I  .       W .E        .         .         L         .         R
            140.  .         .         .         .      I  .      W  E         .         .         L         .         R
            160.  .         .         .         .     I   .      W  E         .         .         L         .         R
            180.  .         .         .         .     I   .      W  E         .         .         L         .         R
            200.  .         .         .         .     I   .     W  E.         .         .         L         .         R
            220.  .         .         .         .    I    .     W  E.         .         .         L         .         R
            240.  .         .         .         .    I    .     W  E.         .         .         L         .         R
     2.00   260.  .         .         .         .   I     .    W  E .         .         .         L         .         R
            280.  .         .         .         .   I     .    W  E .         .         .         L         .         R
            300.  .         .         .         .   I     .    W  E .         .         .         L         .        R.
            320.  .         .         .         .  I      .   W  E  .         .         .         L         .        R.
            340.  .         .         .         .  I      .   W  E  .         .         .         L         .        R.
            360.  .         .         .         . I       .  W   E  .         .         .         L         .       R .
            380.  .         .         .         . I       .  W  E   .         .         .         L         .       R .
            400.  .         .         .         .I        .  W  E   .         .         .         L         .       R .
            420.  .         .         .         .I        . W   E   .         .         .         L         .       R .
            440.  .         .         .         .I        . W  E    .         .         .         L         .      R  .
            460.  .         .         .         I         . W  E    .         .         .         L         .      R  .
            480.  .         .         .         I         .W   E    .         .         .         L         .      R  .
            500.  .         .         .        I.         .W  E     .         .         .         L         .     R   .
     3.00   520.  .         .         .        I.         W   E     .         .         .         L         .     R   .
            540.  .         .         .       I .         W   E     .         .         .         L         .     R   .
            560.  .         .         .       I .         W   E     .         .         .         L         .     R   .
            580.  .         .         .      I  .         W  E      .         .         .         L         .     R   .
            600.  .         .         .      I  .        W.  E      .         .         .         L         .     R   .
            620.  .         .         .      I  .        W.  E      .         .         .         L         .     R   .
            640.  .         .         .     I   .        W.  E      .         .         .         L         .     R   .
            660.  .         .         .     I   .        W. E       .         .         .         L         .     R   .
            680.  .         .         .    I    .        W. E       .         .         .         L         .     R   .
            700.  .         .         .    I    .       W . E       .         .         .         L         .     R   .
            720.  .         .         .   I     .       W . E       .         .         .         L         .     R   .
            740.  .         .         .   I     .       W .E        .         .         .         L         .     R   .
     4.00   760.  .         .         .  I      .      W  .E        .         .         .         L         .     R   .
            780.  .         .         .  I      .      W  .E        .         .         .         L         .     R   .
            800.  .         .         . I       .      W  E         .         .         .         L         .     R   .
            820.  .         .         . I       .     W   E         .         .         .         L         .     R   .
     4.10   840.  .         .         . I       .     W   E         .         .         .         L         .     R   .
            860.  .         .         .I        .     W   E         .         .         .         L         .     R   .
            880.  .         .         .I        .     W   E         .         .         .         L         .     R   .
     4.20   900.  .         .         I         .    W   E.         .         .         .         L         .     R   .
            920.  .         .         I         .    W   E.         .         .         .         L         .     R   .
            940.  .         .         I         .    W  E .         .         .         .         L         .     R   .
            960.  .         .        I.         .   W   E .         .         .         .         L         .     R   .
            980.  .         .        I.         .   W   E .         .         .         .         L         .     R   .
           1000.  .         .       I .         .  W   E  .         .         .         .         L         .     R   .
     5.00  1020.  .         .       I .         .  W   E  .         .         .         .         L         .     R   .
           1040.  .         .      I  .        WC    E    .         .         .         .         L         .     R   .
     1.01  1060.  .         .      I  .     W  C.    E    .         .         .         .         .L        .      R  .
     5.10  1080.  .         .     I   .      WC .  E      .         .         .         .         L         .     R   .
           1100.  .         .     I   .     W C . E       .         .         .         .         L         .     R   .
           1120.  .         .    I    .     WC  .E        .         .         .         .         L         .     R   .
           1140.  .         .    I    .     W   E         .         .         .         .         L         .     R   .
     5.20  1160.  .         .    I    .    WC  E.         .         .         .         .         L         .     R   .
           1180.  .         .   I     .   WC   E.         .         .         .         .         L         .R        .
           1200.  .         .   I     .  WC   E .         .         .         .         .         L     R   .         .
     6.00  1220.  .         .  I      . WC  E   .         .         .         .         .         L         .         .
           1240.  .         .  I      .WC  E    .         .         .         .         .        RL         .         .
           1260.  .         .  .      WC  E     .         .         .         .         .       R L         .         .
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       1280.  .         . I      WC  E      .         .         .         .         .      R  L         .         .
 6.50  1300.  .         . I      WC E       .         .         .         .         .     R   L         .         .
       1320.  .         .I      WC. E       .         .         .         .         .    R    L         .         .
       1340.  .         .I      WC.E        .         .         .         .         .    R    L         .         .
 7.00  1360.  .         I       W .E        .         .         .         .         .   R     L         .         .
       1380.  .         I       W E         .         .         .         .         .    R    L         .         .
       1400.  .        I.      W  E         .         .         .         .         .     R   L         .         .
       1420.  .        I.      W E.         .         .         .         .         .     R   L         .         .
       1440.  .       I .      W E.         .         .         .         .         .      R  L         .         .
       1460.  .       I .     W  E.         .         .         .         .         .       R L         .         .
       1480.  .      I  .     W E .         .         .         .         .         .        RL         .         .
       1500.  .      I  .     W E .         .         .         .         .         .         L         .         .
 8.00  1520.  .      I  .    W  E .         .         .         .         .         .         L         .         .
       1540.  .     I   .    W E  .         .         .         .         .         .       L .         .         .
       1560.  .     I   .    W E  .         .         .         .         .         .    L    .         .         .
       1580.  .     I   .   W  E  .         .         .         .         .         .  L      .         .         .
       1600.  .    I    .   W E   .         .         .         .         .         L         .         .         .
       1620.  .    I    .  W  E   .         .         .         .         .       L .         .         .         .
       1640.  .   I     .  W  E   .         .         .         .         .    L    .         .         .         .
       1660.  .   I     .  W E    .         .         .         .         .  L      .         .         .         .
 9.00  1680.  .  I      . W  E    .         .         .         .         L         .         .         .         .
       1700.  .  I      . W E     .         .         .         .       LR.         .         .         .         .
       1720.  . I       .W  E     .         .         .         .     L R .         .         .         .         .
       1740.  . I       .W  E     .         .         .         .   L   R .         .         .         .         .
       1760.  . I       .W  E     .         .         .         .L     R  .         .         .         .         .
       1780.  .I        W  E      .         .         .        L.     R   .         .         .         .         .
       1800.  .I        W  E      .         .         .      L  .   P     .         .         .         .         .
10.00  1820.  I        W. E       .         .         .   L     .   R     .         .         .         .         .
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                                                                   THIS RUN EXECUTED 19MAY94    17:29:50
****************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
****************************************

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

 SUPERCRITICAL RUN WITH

SUMMARY PRINTOUT TABLE  150

     SECNO      XLCH      ELTRD      ELLC      ELMIN         Q      CWSEL     CRIWS        EG      10*KS       VCH      AREA      .01K
*    1.000      0.00       0.00      0.00    4030.00   1605.00   4034.78   4034.78   4036.20    130.59      9.56    167.83    140.45
*    2.000    250.00       0.00      0.00    4027.20   1605.00   4032.69   4032.69   4034.24    125.55     10.00    160.44    143.24
*    3.000    260.00       0.00      0.00    4024.40   1605.00   4030.17   4030.17   4032.00    124.09     10.86    147.79    144.08
*    4.000    250.00       0.00      0.00    4021.60   1605.00   4028.74   4028.74   4030.57    153.19     10.88    147.46    129.68
*    4.100     66.00       0.00      0.00    4020.90   1605.00   4028.13   4028.13   4029.95    149.19     10.82    148.30    131.40
*    4.200     66.00       0.00      0.00    4020.20   1605.00   4027.72   4027.72   4029.66    153.86     11.17    143.66    129.39
*    5.000    120.00       0.00      0.00    4018.90   1605.00   4026.37   4026.37   4028.30    187.07     11.12    144.30    117.35
*    5.100     66.00       0.00      0.00    4018.10   1605.00   4023.36   4024.11   4026.27    264.83     13.69    117.24     98.63
     5.200     66.00       0.00      0.00    4017.40   1605.00   4022.69   4023.06   4024.72    209.71     11.45    140.21    110.83
     6.000     66.00       0.00      0.00    4016.70   1605.00   4021.02   4021.55   4023.18    261.11     11.80    136.02     99.33
     6.500     75.00       0.00      0.00    4015.90   1605.00   4019.28   4019.82   4021.15    281.61     10.98    146.22     95.64
*    7.000     72.00       0.00      0.00    4015.10   1605.00   4019.13   4019.13   4020.28    139.26      8.62    186.20    136.01
*    8.000    150.00       0.00      0.00    4013.40   1605.00   4017.67   4017.67   4018.91    136.49      8.94    179.60    137.38
*    9.000    160.00       0.00      0.00    4011.70   1605.00   4016.09   4016.09   4017.38    133.48      9.09    176.59    138.92
*   10.000    150.00       0.00      0.00    4010.00   1605.00   4014.59   4014.59   4016.25    120.45     10.34    155.24    146.24
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 Run Date:  19MAY94    Run Time: 17:29:47    HMVersion: 6.50    Data File:   H:SWSUP45.IN                           Page    8

 SUPERCRITICAL RUN WITH

SUMMARY PRINTOUT TABLE  150

      SECNO         Q       CWSEL    DIFWSP    DIFWSX    DIFKWS    TOPWID      XLCH

      1.000   1605.00   4034.78      0.00      0.00     -0.02     60.20      0.00
      2.000   1605.00   4032.69      0.00     -2.09      0.00     51.79    250.00
      3.000   1605.00   4030.17      0.00     -2.52      0.00     41.12    260.00
      4.000   1605.00   4028.74      0.00     -1.43      0.00     41.33    250.00
      4.100   1605.00   4028.13      0.00     -0.60      0.00     41.00     66.00
      4.200   1605.00   4027.72      0.00     -0.41      0.00     38.21     66.00
      5.000   1605.00   4026.37      0.00     -1.34      0.00     38.61    120.00
      5.100   1605.00   4023.36      0.00      0.25      0.00     34.53     66.00
      5.200   1605.00   4022.69      0.00     -0.67      0.00     48.03     66.00
      6.000   1605.00   4021.02      0.00     -1.67      0.00     54.08     66.00
      6.500   1605.00   4019.28      0.00     -1.74      0.00     76.49     75.00
      7.000   1605.00   4019.13      0.00     -0.15      0.00     82.51     72.00
      8.000   1605.00   4017.67      0.00     -1.46      0.00     74.21    150.00
      9.000   1605.00   4016.09      0.00     -1.57      0.00     70.36    160.00
     10.000   1605.00   4014.59      0.00     -1.50      0.00     47.57    150.00
```

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 SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO=       1.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

CAUTION SECNO=       2.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       2.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       2.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       3.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       3.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       3.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       4.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       4.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       4.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       4.100  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       4.100  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       4.100  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       4.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       4.200  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       4.200  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       5.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       5.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       5.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       5.100  PROFILE=  1  INTERPOLATED X-SECTIONS USED

CAUTION SECNO=       7.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       7.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       7.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       8.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       8.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       8.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=       9.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       9.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=       9.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      10.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      10.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      10.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL
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HEC2 S/N: 1916530006        HMVersion: 6.50    Data File: H:SWSUB56.IN
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**********************************************                    ****************************************
*  HEC-2 WATER SURFACE PROFILES               *                    *  U.S. ARMY CORPS OF ENGINEERS        *
*                                             *                    *  HYDROLOGIC ENGINEERING CENTER       *
*  Version   4.6.2;  May 1991                 *                    *  609 SECOND STREET, SUITE D          *
*                                             *                    *  DAVIS, CALIFORNIA 95616-4687        *
*  RUN DATE    19MAY94    TIME   17:58:09     *                    *          (916) 756-1104              *
**********************************************                    ****************************************


                         X     X  XXXXXXX   XXXXX             XXXXX
                         X     X  X        X     X           X     X
                         X     X  X        X                       X
                         XXXXXXX  XXXX     X          XXXXX   XXXXX
                         X     X  X        X                 X
                         X     X  X        X     X           X
                         X     X  XXXXXXX   XXXXX            XXXXXXX
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SIMULATION 5

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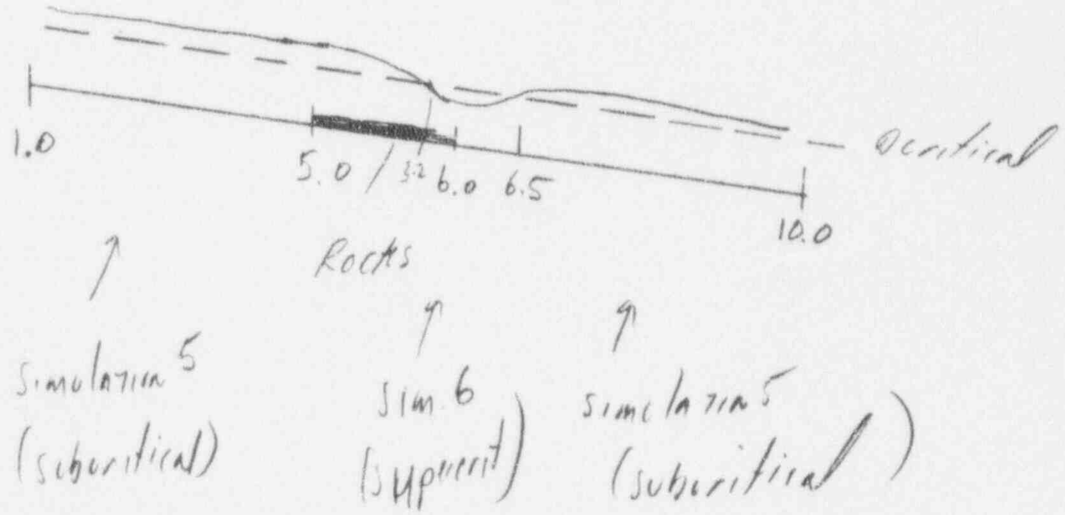
                        :::::::::::::::::::::::::::::::::::::::::::::::
                        :::::::::::::::::::::::::::::::::::::::::::::::
                        :::                                         :::
                        :::   FULL MICRO-COMPUTER IMPLEMENTATION    :::
                        :::                                         :::
                        :::::::::::::::::::::::::::::::::::::::::::::::
                        :::::::::::::::::::::::::::::::::::::::::::::::

                               ==============================
                               H A E S T A D   M E T H O D S
                               ==============================

           37 Brookside Road  *  Waterbury, Connecticut  06708  *  (203) 755-1666
```



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                                                                              THIS RUN EXECUTED 19MAY94     17:58:10

**************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
**************************************


FR
T1 SOUTHWEST CHANNEL
T2 ATLAS MINERALS 88-067 5/12/94
T3       SUBCRITICAL RUN WEDGE SEC 5, 5.1, 5.2, 6

J1  ICHECK      INQ       NINV      IDIR      STRT      METRIC     HVINS      Q        WSEL        FQ

     0.         0.         0.         0        -1.        0.        1.5     1605.   4014.61        0.

J2  NPROF      IPLOT     PRFVS     XSECV     XSECH       FN       ALLDC      IBW       CHNIM      ITRACE

    0.         0.         0.         0         0          0        -1


NC     0.03       0.03       0.03
NH        2      0.038      204.2      0.035        325       0.00          0          0          0          0
X1       10          8          0        325          0          0          0          0          0          0
GR     4032          0     4015.7        150       4010      167.1       4010      187.1     4015.7      204.2
GR     4020        240       4030        270       4037        325

NH        2      0.034        150      0.035        320          0          0          0          0          0
X1        9          7          0        320        150        150        150          0          0          0
GR     4040          0     4011.7      150.0     4011.7        160       4020        230       4030        255
GR     4040        270     4040.0      320.0

NH        2      0.034      135.0      0.035      310.0          0          0          0          0          0
X1        8          7        0.0      310.0      160.0        160        160          0          0          0
GR     4050          0     4013.4      135.0     4013.4        145       4020        220       4030        235
GR     4040        250     4050.0      310.0

NH        2      0.034      130.0      0.035      290.0          0          0          0          0          0
X1        7          7        0.0      290.0      150.0        150        150          0          0          0
GR     4050          0     4015.1      130.0     4015.1        140       4020        210       4030        225
GR     4040        240     4047.0      290.0

NH        2      0.034      130.0      0.035      290.0          0          0          0          0          0
X1      6.5          8        0.0      290.0       72.0         72         72
GR     4050          0     4015.9      130.0     4015.9       140.       4020        205       4030        220
GR     4040        240     4048.0      265.0     4048.0        290
```

WAP 5/20/94

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NH         2     0.042     160.0     0.035     285.0
X1         6         8       0.0     285.0      75.0        75        75
GR      4050         0    4016.7     127.0      4024       160    4023.0     160.1      4030       205
GR      4040       230    4050.0     245.0    4050.0       285

NH         2     0.042     140.0     0.035     280.0
X1       5.2         8       0.0     280.0      66.0        66        66
GR      4050         0    4017.4     110.0     4028.      140.    4024.5     140.1      4030       175
GR      4040       220      4050       230    4058.0     280.0

NH         2     0.042     125.0     0.035     280.0
X1       5.1         6       0.0     280.0      66.0        66        66
GR      4050         0    4018.1      95.0      4030       125      4040       205      4050       225
GR    4058.0     280.0

NH         2     0.042     112.0     0.035     275.0
X1         5         6       0.0     275.0      66.0        66        66
GR      4050         0    4018.9      85.0      4030       112      4040       150      4050       200
GR    4058.0     275.0

NH         2     0.038      85.0     0.035     275.0
X1       4.2         7       0.0     275.0     120.0       120       120
GR      4050         0    4020.2      85.0    4020.2        95      4030       110      4040       125
GR      4050       155    4058.0     275.0

NH         2     0.038      85.0     0.035     270.0
X1       4.1         7       0.0     270.0      66.0        66        66
GR      4050         0    4020.9      85.0    4020.9        95      4030       110      4040       125
GR      4050       135    4058.0     270.0

NH         2     0.038      80.0     0.035     255.0
X1         4         7       0.0     255.0      66.0        66        66
GR      4050         0    4021.6      80.0    4021.6        90      4030       105      4040       120
GR      4050       140    4058.0     255.0

NH         2     0.034      70.0     0.035     250.0         0         0         0         0         0
X1         3         7       0.0     250.0     250.0       250       250         0         0         0
GR      4050         0    4024.4      70.0    4024.4        80      4030        95      4040       115
GR      4050       140      4058       250

NH         2     0.034      65.0     0.035     230.0         0         0         0         0         0
X1         2         8       0.0     230.0     260.0       260       260         0         0         0
GR      4050         0    4027.2      65.0    4027.2        75      4030        85      4040       145
GR      4050       175    4060.0     195.0    4060.0       230

NH         2     0.034      60.0     0.035     220.0         0         0         0         0         0
X1         1         7       0.0     220.0     250.0       250       250         0         0         0
GR      4050         0    4030.0      60.0    4030.0        70      4040       145      4050       155
GR      4060       175    4060.0     220.0
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WRP 5/20/94

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    SECNO       DEPTH       CWSEL       CRIWS       WSELK       EG          HV          HL          OLOSS       L-BANK ELEV
    Q           QLOB        QCH         QROB        ALOB        ACH         AROB        VOL         TWA         R-BANK ELEV
    TIME        VLOB        VCH         VROB        XNL         XNCH        XNR         WTN         ELMIN       SSTA
    SLOPE       XLOBL       XLCH        XLOBR       ITRIAL      IDC         ICONT       CORAR       TOPWID      ENDST

*PROF 1

CRITICAL DEPTH TO BE CALCULATED AT ALL CROSS SECTIONS


1490 NH CARD USED
*SECNO 10.000
3720 CRITICAL DEPTH ASSUMED
    10.000        4.60    4014.60     4014.60     4014.61     4016.25        1.65        0.00        0.00    4032.00
    1605.0         0.0     1605.0         0.0         0.0       155.6         0.0         0.0         0.0    4037.00
      0.00        0.00      10.32        0.00       0.000       0.038       0.000       0.000     4010.00     153.29
  0.014959          0.         0.          0.           0           4           0        0.00       47.61     200.91

1490 NH CARD USED
*SECNO 9.000

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.58

     9.000        5.20    4016.90     4016.12        0.00     4017.60        0.71        1.35        0.00    4040.00
    1605.0         0.0     1605.0         0.0         0.0       238.0         0.0         0.7         0.2    4040.00
      0.01        0.00       6.74        0.00       0.000       0.035       0.000       0.000     4011.70     122.42
  0.006000        150.       150.        150.           2           8           0        0.00       81.47     203.89

1490 NH CARD USED
*SECNO 8.000
     8.000        4.40    4017.80     4017.67        0.00     4018.91        1.10        1.30        0.00    4050.00
    1605.0         0.0     1605.0         0.0         0.0       190.5         0.0         1.5         0.5    4050.00
      0.01        0.00       8.43        0.00       0.000       0.035       0.000       0.000     4013.40     118.73
  0.011656        160.       160.        160.           3          15           0        0.00       76.39     195.12

1490 NH CARD USED
*SECNO 7.000
     7.000        4.49    4019.59     4019.13        0.00     4020.37        0.78        1.46        0.00    4050.00
    1605.0         0.0     1605.0         0.0         0.0       226.2         0.0         2.2         0.8    4047.00
      0.02        0.00       7.10        0.00       0.000       0.035       0.000       0.000     4015.10     113.29
  0.008277        150.       150.        150.           2          11           0        0.00       90.81     204.10

1490 NH CARD USED
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  SECNO      DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL       OLOSS     L-BANK ELEV
  Q          QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA       R-BANK ELEV
  TIME       VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN     SSTA
  SLOPE      XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID    ENDST


*SECNO 6.500
   6.500      4.28   4020.18   4019.82      0.00   4020.98      0.80      0.61      0.00   4050.00
  1605.0       0.0    1605.0       0.0       0.0     222.9       0.0       2.6       1.0   4048.00
    0.02      0.00      7.20      0.00     0.000     0.035     0.000     0.000   4015.90    113.67
 0.008784      72.       72.       72.         2        15         0      0.00     91.60    205.27


1490 NH CARD USED
*SECNO 6.000
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
   6.000      6.16   4022.86   4022.86      0.00   4024.46      1.60      0.93      0.00   4050.00
  1605.0       0.0    1605.0       0.0       0.0     158.3       0.0       2.9       1.1   4050.00
    0.02      0.00     10.14      0.00     0.000     0.042     0.000     0.000   4016.70    103.49
 0.019009      75.       75.       75.         0        14         0      0.00     51.37    154.86


1490 NH CARD USED
*SECNO 5.200
7185 MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
   5.200      6.97   4024.37   4024.37      0.00   4026.13      1.76      1.23      0.00   4050.00
  1605.0       0.0    1605.0       0.0       0.0     150.6       0.0       3.1       1.1   4058.00
    0.02      0.00     10.65      0.00     0.000     0.042     0.000     0.000   4017.40     86.49
 0.018343      66.       66.       66.         0         8         0      0.00     43.24    129.72


1490 NH CARD USED
*SECNO 5.100
   5.100      7.48   4025.58   4025.39      0.00   4027.27      1.69      1.14      0.00   4050.00
  1605.0       0.0    1605.0       0.0       0.0     154.1       0.0       3.3       1.2   4058.00
    0.03      0.00     10.42      0.00     0.000     0.042     0.000     0.000   4018.10     72.71
 0.016216      66.       66.       66.         2         8         0      0.00     41.16    113.87


1490 NH CARD USED
*SECNO 5.000
   5.000      7.76   4026.66   4026.39      0.00   4028.31      1.65      1.04      0.00   4050.00
  1605.0       0.0    1605.0       0.0       0.0     155.7       0.0       3.6       1.3   4058.00
    0.03      0.00     10.31      0.00     0.000     0.042     0.000     0.000   4018.90     63.78
 0.015264      66.       66.       66.         2         5         0      0.00     40.11    103.89
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  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

1490 NH CARD USED
*SECNO 4.200

3302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  1.97

    4.200       8.17   4028.37    4026.29      0.00    4029.14      0.77       0.83       0.00    4050.00
   1605.0        0.0    1605.0        0.0       0.0      227.9       0.0        4.1        1.4    4058.00
     0.03       0.00      7.04       0.00     0.000      0.037     0.000      0.000    4020.20      61.70
 0.003922       120.      120.       120.         2         15         0       0.00      45.80     107.50

1490 NH CARD USED
*SECNO 4.100
    4.100       7.61   4028.51    4026.95      0.00    4029.43      0.92       0.29       0.00    4050.00
   1605.0        0.0    1605.0        0.0       0.0      208.3       0.0        4.4        1.5    4058.00
     0.03       0.00      7.71       0.00     0.000      0.036     0.000      0.000    4020.90      62.78
 0.005075        66.       66.        66.         3         15         0       0.00      44.76     107.54

1490 NH CARD USED
*SECNO 4.000
    4.000       7.05   4028.65    4027.62      0.00    4029.82      1.17       0.39       0.00    4050.00
   1605.0        0.0    1605.0        0.0       0.0      184.9       0.0        4.7        1.5    4058.00
     0.04       0.00      8.68       0.00     0.000      0.036     0.000      0.000    4021.60      60.14
 0.006973        66.       66.        66.         3         15         0       0.00      42.45     102.59

1490 NH CARD USED
*SECNO 3.000
    3.000       5.90   4030.30    4030.17      0.00    4032.00      1.70       2.18       0.00    4050.00
   1605.0        0.0    1605.0        0.0       0.0      153.3       0.0        5.7        1.8    4058.00
     0.04       0.00     10.47       0.00     0.000      0.035     0.000      0.000    4024.40      53.86
 0.011210       250.      250.       250.         3         15         0       0.00      41.75      95.61

1490 NH CARD USED
*SECNO 2.000
    2.000       6.11   4033.31    4032.66      0.00    4034.37      1.06       2.37       0.00    4050.00
   1605.0        0.0    1605.0        0.0       0.0      194.5       0.0        6.7        2.1    4060.00
     0.05       0.00      8.25       0.00     0.000      0.035     0.000      0.000    4027.20      47.57
 0.007569       260.      260.       260.         2         11         0       0.00      57.31     104.88
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   SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS     L-BANK ELEV
   Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA       R-BANK ELEV
   TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
   SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST


1490 NH CARD USED
*SECNO 1.000
     1.000      5.33   4035.33   4034.78      0.00   4036.30      0.97      1.93      0.00   4050.00
    1605.0       0.0    1605.0       0.0       0.0     202.8       0.0       7.9       2.4   4060.00
      0.06      0.00      7.92      0.00     0.000     0.035     0.000     0.000   4030.00     44.00
  0.007864      250.      250.      250.         2        15         0      0.00     66.01    110.01
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PROFILE FOR STREAM   SUBCRITICAL RUN WEDGE S


PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA


ELEVATION  4010.     4015.     4020.     4025.     4030.     4035.     4040.     4045.     4050.     4055.
    SECNO   CUMDIS

    10.00     0.  I        W.  E      .         .         .   L     .   R     .         .         .         .         .
             20.  I         W  E      .         .         .     L   .    R    .         .         .         .         .
             40.  .I        W  E      .         .         .       L .     R   .         .         .         .         .
             60.  .I        CW  E     .         .         .         L     R   .         .         .         .         .
             80.  . I       .CW E     .         .         .         .  L   R  .         .         .         .         .
            100.  . I       .CW E     .         .         .         .    L  R .         .         .         .         .
            120.  .  I      . CW E    .         .         .         .      L R.         .         .         .         .
            140.  .  I      . CW E    .         .         .         .        LR         .         .         .         .
     9.00   160.  .  I      . C WE    .         .         .         .         L         .         .         .         .
            180.  .   I     .  CW E   .         .         .         .         .  L      .         .         .         .
            200.  .   I     .  CW E   .         .         .         .         .    L    .         .         .         .
            220.  .    I    .  CW E   .         .         .         .         .       L .         .         .         .
            240.  .    I    .   CW E  .         .         .         .         .         L         .         .         .
            260.  .     I   .   CW E  .         .         .         .         .         .  L      .         .         .
            280.  .     I   .    W E  .         .         .         .         .         .    L    .         .         .
            300.  .     I   .    W E  .         .         .         .         .         .       L .         .         .
     8.00   320.  .      I  .    CW E .         .         .         .         .         .         L         .         .
            340.  .      I  .     W E .         .         .         .         .         .        RL         .         .
            360.  .       I .     CW E.         .         .         .         .         .       R L         .         .
            380.  .       I .      W E.         .         .         .         .         .       R L         .         .
            400.  .        I.      CWE.         .         .         .         .         .      R  L         .         .
            420.  .        I.      CW E         .         .         .         .         .     R   L         .         .
            440.  .         I       W E         .         .         .         .         .    R    L         .         .
     7.00   460.  .         I       CW.E        .         .         .         .         .   R     L         .         .
            480.  .         .I       CWE        .         .         .         .         .    R    L         .         .
            500.  .         .I       CWE        .         .         .         .         .    R    L         .         .
            520.  .         . I      CW E       .         .         .         .         .     R   L         .         .
     6.50   540.  .         . I       W E       .         .         .         .         .     R   L         .         .
            560.  .         . I       .CW E     .         .         .         .         .      R  L         .         .
            580.  .         .  I      .  W  E   .         .         .         .         .       R L         .         .
            600.  .         .  I      .    W  E .         .         .         .         .        RL         .         .
     6.00   620.  .         .  I      .     W  E.         .         .         .         .         L         .         .
            640.  .         .   I     .      W  E         .         .         .         .         L    R    .         .
            660.  .         .   I     .       W .E        .         .         .         .         L         R         .
     5.20   680.  .         .    I    .        W. E       .         .         .         .         L         .     R   .
            700.  .         .    I    .        W.  E      .         .         .         .         L         .     R   .
            720.  .         .     I   .         W   E     .         .         .         .         L         .     R   .
     5.10   740.  .         .     I   .         .W   E    .         .         .         .         L         .     R   .
            760.  .         .      I  .         .CW  E    .         .         .         .         L         .     R   .
            780.  .         .      I  .         . W   E   .         .         .         .         L         .     R   .
            800.  .         .       I .         .  W  E   .         .         .         .         L         .     R   .
     5.00   820.  .         .       I .         .  W   E  .         .         .         .         L         .     R   .
            840.  .         .       I .         .  CW  E  .         .         .         .         L         .     R   .
            860.  .         .        I.         .  CW  E  .         .         .         .         L         .     R   .
            880.  .         .        I.         .  C W E  .         .         .         .         L         .     R   .
            900.  .         .         I         .  C  W E .         .         .         .         L         .     R   .
            920.  .         .         I         .  C  W E .         .         .         .         L         .     R   .
     4.20   940.  .         .         I         .  C   WE .         .         .         .         L         .     R   .
            960.  .         .         .I        .  C   WE .         .         .         .         L         .     R   .
            980.  .         .         .I        .  C   W E.         .         .         .         L         .     R   .
     4.10  1000.  .         .         . I       .   C  W E.         .         .         .         L         .     R   .
           1020.  .         .         . I       .   C  W E.         .         .         .         L         .     R   .
           1040.  .         .         .  I      .    C W E.         .         .         .         L         .     R   .
     4.00  1060.  .         .         .  I      .    C W  E         .         .         .         L         .     R   .
           1080.  .         .         .   I     .     C W E         .         .         .         L         .     R   .
           1100.  .         .         .   I     .     C W E         .         .         .         L         .     R   .
           1120.  .         .         .    I    .     C W .E        .         .         .         L         .     R   .
           1140.  .         .         .    I    .      CW .E        .         .         .         L         .     R   .
           1160.  .         .         .    I    .      C W.E        .         .         .         L         .     R   .
           1180.  .         .         .     I   .       CW. E       .         .         .         L         .     R   .
           1200.  .         .         .     I   .       CW. E       .         .         .         L         .     R   .
           1220.  .         .         .      I  .        W. E       .         .         .         L         .     R   .
           1240.  .         .         .      I  .        CW  E      .         .         .         L         .     R   .
           1260.  .         .         .       I .        CW  E      .         .         .         L         .     R   .
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      1280.  .         .         .       I .         W  E      .         .         .         L         .     R   .
      1300.  .         .         .        I.         W   E     .         .         .         L         .     R   .
3.00  1320.  .         .         .        I.         CW  E     .         .         .         L         .     R   .
      1340.  .         .         .        I.         .W  E     .         .         .         L         .     R   .
      1360.  .         .         .         I         .CW  E    .         .         .         L         .      R  .
      1380.  .         .         .         I         .CW  E    .         .         .         L         .      R  .
      1400.  .         .         .         .I        . W  E    .         .         .         L         .      R  .
      1420.  .         .         .         .I        . CW  E   .         .         .         L         .       R .
      1440.  .         .         .         .I        .  W  E   .         .         .         L         .       R .
      1460.  .         .         .         . I       .  CW  E  .         .         .         L         .       R .
      1480.  .         .         .         . I       .  CW  E  .         .         .         L         .       R .
      1500.  .         .         .         .  I      .   CW E  .         .         .         L         .        R.
      1520.  .         .         .         .  I      .   CW  E .         .         .         L         .        R.
      1540.  .         .         .         .   I     .    CW E .         .         .         L         .        R.
      1560.  .         .         .         .   I     .    CW E .         .         .         L         .         R
2.00  1580.  .         .         .         .   I     .    C W E.         .         .         L         .         R
      1600.  .         .         .         .    I    .     CW E.         .         .         L         .         R
      1620.  .         .         .         .    I    .     CW E.         .         .         L         .         R
      1640.  .         .         .         .     I   .     C W E         .         .         L         .         R
      1660.  .         .         .         .     I   .      CW E         .         .         L         .         R
      1680.  .         .         .         .      I  .      CW E         .         .         L         .         R
      1700.  .         .         .         .      I  .      C W.E        .         .         L         .         R
      1720.  .         .         .         .       I .       CW.E        .         .         L         .         R
      1740.  .         .         .         .       I .       CW.E        .         .         L         .         R
      1760.  .         .         .         .       I .       C W E       .         .         L         .         R
      1780.  .         .         .         .        I.        CW E       .         .         L         .         R
      1800.  .         .         .         .        I.        CW E       .         .         L         .         R
1.00  1820.  .         .         .         .         I         CW E      .         .         L         .         R
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                                                                   THIS RUN EXECUTED 19MAY94    17:58:12
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 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

 SUBCRITICAL RUN WEDGE S

SUMMARY PRINTOUT TABLE  150

     SECNO     XLCH     ELTRD      ELLC     ELMIN        Q      CWSEL     CRIWS       EG      10*KS       VCH      AREA      .01K

*   10.000     0.00      0.00      0.00   4010.00  1605.00   4014.60   4014.60   4016.25    149.59     10.32    155.57    131.23
*    9.000   150.00      0.00      0.00   4011.70  1605.00   4016.90   4016.12   4017.60     60.00      6.74    238.02    207.21
     8.000   160.00      0.00      0.00   4013.40  1605.00   4017.80   4017.67   4018.91    116.56      8.43    190.50    148.66
     7.000   150.00      0.00      0.00   4015.10  1605.00   4019.59   4019.13   4020.37     82.77      7.10    226.16    176.42
     6.500    72.00      0.00      0.00   4015.90  1605.00   4020.18   4019.82   4020.98     87.84      7.20    222.94    171.24
*    6.000    75.00      0.00      0.00   4016.70  1605.00   4022.86   4022.86   4024.46    190.09     10.14    158.31    116.41
*    5.200    66.00      0.00      0.00   4017.40  1605.00   4024.37   4024.37   4026.13    183.43     10.65    150.64    118.50
     5.100    66.00      0.00      0.00   4018.10  1605.00   4025.58   4025.39   4027.27    162.16     10.42    154.06    126.04
     5.000    66.00      0.00      0.00   4018.90  1605.00   4026.66   4026.39   4028.31    152.64     10.31    155.73    129.91
*    4.200   120.00      0.00      0.00   4020.20  1605.00   4028.37   4026.29   4029.14     39.22      7.04    227.89    256.29
     4.100    66.00      0.00      0.00   4020.90  1605.00   4028.51   4026.95   4029.43     50.75      7.71    208.30    225.29
     4.000    66.00      0.00      0.00   4021.60  1605.00   4028.65   4027.62   4029.82     69.73      8.68    184.90    192.20
     3.000   250.00      0.00      0.00   4024.40  1605.00   4030.30   4030.17   4032.00    112.10     10.47    153.32    151.59
     2.000   260.00      0.00      0.00   4027.20  1605.00   4033.31   4032.66   4034.37     75.69      8.25    194.46    184.49
     1.000   250.00      0.00      0.00   4030.00  1605.00   4035.33   4034.78   4036.30     78.64      7.92    202.76    180.99
```

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 SUBCRITICAL RUN WEDGE S

SUMMARY PRINTOUT TABLE  150

       SECNO        Q       CWSEL     DIFWSP     DIFWSX     DIFKWS     TOPWID       XLCH

*     10.000   1605.00    4014.60       0.00       0.00      -0.01      47.61       0.00
*      9.000   1605.00    4016.90       0.00       2.30       0.00      81.47     150.00
       8.000   1605.00    4017.80       0.00       0.91       0.00      76.39     160.00
       7.000   1605.00    4019.59       0.00       1.78       0.00      90.81     150.00
       6.500   1605.00    4020.18       0.00       0.59       0.00      91.60      72.00
*      6.000   1605.00    4022.86       0.00       2.69       0.00      51.37      75.00
*      5.200   1605.00    4024.37       0.00       1.50       0.00      43.24      66.00
       5.100   1605.00    4025.58       0.00       1.21       0.00      41.16      66.00
       5.000   1605.00    4026.66       0.00       1.07       0.00      40.11      66.00
*      4.200   1605.00    4028.37       0.00       1.71       0.00      45.80     120.00
       4.100   1605.00    4028.51       0.00       0.14       0.00      44.76      66.00
       4.000   1605.00    4028.65       0.00       0.14       0.00      42.45      66.00
       3.000   1605.00    4030.30       0.00       1.65       0.00      41.75     250.00
       2.000   1605.00    4033.31       0.00       3.02       0.00      57.31     260.00
       1.000   1605.00    4035.33       0.00       2.01       0.00      66.01     250.00
```

```
 SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO=      10.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

WARNING SECNO=       9.000  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE

CAUTION SECNO=       6.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       6.000  PROFILE=  1  MINIMUM SPECIFIC ENERGY

CAUTION SECNO=       5.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=       5.200  PROFILE=  1  MINIMUM SPECIFIC ENERGY

WARNING SECNO=       4.200  PROFILE=  1  CONVEYANCE CHANGE OUTSIDE ACCEPTABLE RANGE
```

```
HEC2 S/N: 1916530006       HMVersion: 6.50    Data File: H:SWSUP56.IN
```

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```
**********************************************                                  ****************************************
*  HEC-2 WATER SURFACE PROFILES              *                                  *  U.S. ARMY CORPS OF ENGINEERS        *
*                                            *                                  *  HYDROLOGIC ENGINEERING CENTER       *
*  Version  4.6.2;  May 1991                 *                                  *  609 SECOND STREET, SUITE D          *
*                                            *                                  *  DAVIS, CALIFORNIA 95616-4687        *
*  RUN DATE    19MAY94    TIME    17:57:52   *                                  *        (916) 756-1104                *
**********************************************                                  ****************************************


                    X     X  XXXXXXX   XXXXX              XXXXX
                    X     X  X        X     X            X     X
                    X     X  X        X                        X
                    XXXXXXX  XXXX     X          XXXXX    XXXXX
                    X     X  X        X                  X
                    X     X  X        X     X            X
                    X     X  XXXXXXX   XXXXX             XXXXXXX
```

SIMULATION 6

```
                  :::::::::::::::::::::::::::::::::::::::::::::::::::::
                  :::::::::::::::::::::::::::::::::::::::::::::::::::::
                  :::                                               :::
                  :::     FULL MICRO-COMPUTER IMPLEMENTATION        :::
                  :::                                               :::
                  :::::::::::::::::::::::::::::::::::::::::::::::::::::
                  :::::::::::::::::::::::::::::::::::::::::::::::::::::


                           ==============================
                           H A E S T A D   M E T H O D S
                           ==============================

          37 Brookside Road  *  Waterbury, Connecticut  06708  *  (203) 755-1666
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                                                                                THIS RUN EXECUTED 19MAY94     17:57:52

*****************************************
 HEC-2 WATER SURFACE PROFILES

 Version    4.6.2;  May 1991
*****************************************


FR
T1 SOUTHWEST CHANNEL
T2 ATLAS MINERALS 88-067 5/12/94
T3        SUPERCRITICAL RUN WITH WEDGE SEC 5, 5.1, 5.2, 6

J1  ICHECK     INQ        NINV       IDIR       STRT      METRIC      HVINS      Q          WSEL       FQ

      0.        0.         0.          1         -1.          0        1.0      1605.    4034.8         0.

NC     0.03       0.03       0.03
NH        2      0.034         60      0.035        220
X1      1.0        7.0        0.0      220.0      250.0      250.0      250.0        0.0        0.0        0.0
GR   4050.0        0.0     4030.0       60.0     4030.0       70.0     4040.0      145.0     4050.0      155.0
GR   4060.0      175.0     4060.0      220.0

NH        2      0.034         65      0.035        230
X1      2.0          8        0.0      230.0      260.0      260.0      260.0
GR   4050.0        0.0     4027.2       65.0     4027.2       75.0     4030.0       85.0     4040.0      145.0
GR   4050.0      175.0     4060.0      195.0     4060.0      230.0

NH        2      0.034         70      0.035        250
X1      3.0          7          0        250        250        250        250
GR   4050.0        0.0     4024.4       70.0     4024.4       80.0     4030.0       95.0     4040.0      115.0
GR   4050.0      140.0       4058        250

NH        2      0.038         80      0.035        255
X1      4.0          7          0        255         66         66         66
GR   4050.0        0.0     4021.6       80.0     4021.6       90.0     4030.0      105.0     4040.0      120.0
GR   4050.0      140.0     4058.0      255.0

NH        2      0.038         85      0.035        270
X1      4.1          7          0        270         66         66         66
GR   4050.0        0.0     4020.9       85.0     4020.9       95.0     4030.0      110.0     4040.0      125.0
GR   4050.0      135.0     4058.0      270.0

NH        2      0.038         85      0.035        275
X1      4.2          7          0        275        120        120        120
GR   4050.0        0.0     4020.2       85.0     4020.2       95.0     4030.0      110.0     4040.0      125.0
GR   4050.0      155.0     4058.0      275.0
```

UMP 5/20/94

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NH         2     0.042       112     0.035     275.0
X1       5.0         6         0       275        66        66        66
GR    4050.0       0.0    4018.9      85.0    4030.0     112.0    4040.0     150.0    4050.0     200.0
GR    4058.0     275.0

NH         2     0.042       125     0.035     280.0
X1       5.1         6         0       280        66        66        66
GR    4050.0       0.0    4018.1      95.0    4030.0     125.0    4040.0     205.0    4050.0     225.0
GR    4058.0     280.0

NH         2     0.042       140     0.035     280.0
X1       5.2         8         0       280        66        66        66
GR    4050.0       0.0    4017.4     110.0     4028.      140.    4024.5     140.1    4030.0     175.0
GR    4040.0     220.0    4050.0     230.0    4058.0     280.0

NH         2     0.042       160     0.035     285.0
X1       6.0       8.0       0.0     285.0      75.0      75.0      75.0       0.0       0.0       0.0
GR    4050.0       0.0    4016.7     127.0     4024.       160    4023.0     160.1    4030.0     205.0
GR    4040.0     230.0    4050.0     245.0    4050.0     285.0

NH         2     0.034       130     0.035     290.0
X1       6.5       8.0       0.0     290.0      72.0      72.0      72.0
GR    4050.0       0.0    4015.9     130.0    4015.9      140.    4020.0     205.0    4030.0     220.0
GR    4040.0     240.0    4048.0     265.0    4048.0     290.0

 H         2     0.034       130     0.035       290
 1       7.0       7.0       0.0     290.0     150.0     150.0     150.0       0.0       0.0       0.0
 R    4050.0       0.0    4015.1     130.0    4015.1     140.0    4020.0     210.0    4030.0     225.0
 R    4040.0     240.0    4047.0     290.0

 H         2     0.034       135     0.035       310
 1       8.0       7.0       0.0     310.0     160.0     160.0     160.0       0.0       0.0       0.0
 R    4050.0       0.0    4013.4     135.0    4013.4     145.0    4020.0     220.0    4030.0     235.0
 R    4040.0     250.0    4050.0     310.0

 H         2     0.034       150     0.035     320.0
 1       9.0       7.0       0.0     320.0     150.0     150.0     150.0       0.0       0.0       0.0
 R    4040.0       0.0    4011.7     150.0    4011.7     160.0    4020.0     230.0    4030.0     255.0
 R    4040.0     270.0    4040.0     320.0

 H       2.0     0.038     204.2     0.035     325.0
 1      10.0       8.0       0.0     325.0       0.0       0.0       0.0
 R    4032.0       0.0    4015.7     150.0    4010.0     167.1    4010.0     187.1    4015.7     204.2
 R    4020.0     240.0    4030.0     270.0    4037.0     325.0
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WBP
5/20/94

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  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


*PROF 1



1490 NH CARD USED
*SECNO 1.000
3720 CRITICAL DEPTH ASSUMED
    1.000       4.78   4034.78    4034.78    4034.80    4036.20       1.42       0.00       0.00    4050.00
   1605.0        0.0    1605.0        0.0        0.0      167.8        0.0        0.0        0.0    4060.00
     0.00       0.00      9.56       0.00      0.000      0.035      0.000      0.000    4030.00      45.66
 0.013059         0.        0.         0.          0          4          0       0.00      60.20     105.86


1490 NH CARD USED
*SECNO 2.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    2.000       5.49   4032.69    4032.69       0.00    4034.24       1.55       3.20       1.60    4050.00
   1605.0        0.0    1605.0        0.0        0.0      160.4        0.0        0.9        0.3    4060.00
     0.01       0.00     10.00       0.00      0.000      0.035      0.000      0.000    4027.20      49.35
 0.012555       250.      250.       250.         20          8          0       0.00      51.79     101.14


1490 NH CARD USED
*SECNO 3.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    3.000       5.77   4030.17    4030.17       0.00    4032.00       1.83       3.25       1.61    4050.00
   1605.0        0.0    1605.0        0.0        0.0      147.8        0.0        1.9        0.6    4058.00
     0.01       0.00     10.86       0.00      0.000      0.035      0.000      0.000    4024.40      54.22
 0.012409       260.      260.       260.         20          8          0       0.00      41.12      95.34


1490 NH CARD USED
*SECNO 4.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    4.000       6.02   4027.62    4027.62       0.00    4029.56       1.94       3.26       0.03    4050.00
   1605.0        0.0    1605.0        0.0        0.0      143.5        0.0        2.7        0.8    4058.00
     0.02       0.00     11.18       0.00      0.000      0.036      0.000      0.000    4021.60      63.05
 0.013759       250.      250.       250.         20          8          0       0.00      37.70     100.75
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  SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
  Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
  TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
  SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST

1490 NH CARD USED
*SECNO 4.100
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    4.100       6.05    4026.95    4026.95       0.00    4028.88       1.93       0.91       0.08    4050.00
   1605.0        0.0     1605.0        0.0        0.0      143.9        0.0        2.9        0.9    4058.00
     0.02       0.00      11.15       0.00      0.000      0.036      0.000      0.000    4020.90      67.34
 0.013673        66.        66.        66.         20          5          0       0.00      37.62     104.96

1490 NH CARD USED
*SECNO 4.200
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    4.200       6.11    4026.31    4026.31       0.00    4028.27       1.95       0.90       0.38    4050.00
   1605.0        0.0     1605.0        0.0        0.0      143.1        0.0        3.1        0.9    4058.00
     0.02       0.00      11.22       0.00      0.000      0.036      0.000      0.000    4020.20      67.56
 0.013659        66.        66.        66.         20          5          0       0.00      36.80     104.36

1490 NH CARD USED
*SECNO 5.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    5.000       7.47    4026.37    4026.37       0.00    4028.30       1.92       1.91       0.93    4050.00
   1605.0        0.0     1605.0        0.0        0.0      144.2        0.0        3.5        1.0    4058.00
     0.03       0.00      11.13       0.00      0.000      0.042      0.000      0.000    4018.90      64.58
 0.018746       120.       120.       120.         20         11          0       0.00      38.60     103.17

1490 NH CARD USED
*SECNO 5.100
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    5.100       7.32    4025.42    4025.42       0.00    4027.26       1.84       1.22       0.01    4050.00
   1605.0        0.0     1605.0        0.0        0.0      147.3        0.0        3.7        1.1    4058.00
     0.03       0.00      10.89       0.00      0.000      0.042      0.000      0.000    4018.10      73.20
 0.018270        66.        66.        66.         20          8          0       0.00      40.25     113.45
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   SECNO      DEPTH      CWSEL      CRIWS      WSELK       EG          HV          HL         OLOSS      L-BANK ELEV
   Q          QLOB       QCH        QROB       ALOB        ACH         AROB        VOL        TWA        R-BANK ELEV
   TIME       VLOB       VCH        VROB       XNL         XNCH        XNR         WTN        ELMIN      SSTA
   SLOPE      XLOBL      XLCH       XLOBR      ITRIAL      IDC         ICONT       CORAR      TOPWID     ENDST

490 NH CARD USED
SECNO 5.200
685 20 TRIALS ATTEMPTED WSEL,CWSEL
693 PROBABLE MINIMUM SPECIFIC ENERGY
720 CRITICAL DEPTH ASSUMED
    5.200       6.99   4024.39    4024.39       0.00    4026.13        1.74       1.20        0.52    4050.00
   1605.0        0.0    1605.0        0.0        0.0      151.6         0.0        4.0         1.2    4058.00
     0.03       0.00     10.59       0.00      0.000      0.042       0.000      0.000     4017.40      86.41
 0.018028        66.       66.        66.         20          8           0       0.00       43.38     129.79

490 NH CARD USED
SECNO 6.000
    6.000       5.66   4022.36    4022.87       0.00    4024.62        2.26       1.51        0.00    4050.00
   1605.0        0.0    1605.0        0.0        0.0      133.1         0.0        4.2         1.2    4050.00
     0.03       0.00     12.06       0.00      0.000      0.042       0.000      0.000     4016.70     105.44
 0.030179        66.       66.        66.          4         11           0       0.00       47.10     152.55

490 NH CARD USED
SECNO 6.500
    6.500       3.00   4018.90    4019.82       0.00    4021.76        2.86       2.86        0.00    4050.00
   1605.0        0.0    1605.0        0.0        0.0      118.3         0.0        4.4         1.3    4048.00
     0.03       0.00     13.57       0.00      0.000      0.035       0.000      0.000     4015.90     118.57
 0.049689        75.       75.        75.          6         19           0       0.00       68.94     187.51

490 NH CARD USED
SECNO 7.000

645 INT SEC ADDED BY RAISING SEC      7.00,   0.400 FT AND MULTIPLYING BY   1.033

301 HV CHANGED MORE THAN HVINS

302 WARNING:  CONVEYANCE CHANGE OUTSIDE OF ACCEPTABLE RANGE,  KRATIO =  0.64

    1.010       3.66   4019.16    4019.47       0.00    4020.67        1.50       1.09        0.00    4050.40
   1605.0        0.0    1605.0        0.0        0.0      163.0         0.0        4.5         1.4    4047.40
     0.03       0.00      9.84       0.00      0.000      0.035       0.000      0.000     4015.50     120.18
 0.020302        36.       36.        36.          6         11           0       0.00       78.57     198.76
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    SECNO      DEPTH      CWSEL      CRIWS      WSELK      EG         HV         HL         OLOSS      L-BANK ELEV
    Q          QLOB       QCH        QROB       ALOB       ACH        AROB       VOL        TWA        R-BANK ELEV
    TIME       VLOB       VCH        VROB       XNL        XNCH       XNR        WTN        ELMIN      SSTA
    SLOPE      XLOBL      XLCH       XLOBR      ITRIAL     IDC        ICONT      CORAR      TOPWID     ENDST


1645 INT SEC ADDED BY RAISING SEC       1.01,  -0.400 FT AND MULTIPLYING BY   0.968

3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    7.000       4.03    4019.13    4019.13       0.00    4020.28       1.15       0.60       0.30    4050.00
   1605.0        0.0     1605.0        0.0        0.0      186.9        0.0        4.7        1.5    4047.00
     0.03       0.00       8.59       0.00      0.000      0.035      0.000      0.000    4015.10     114.97
 0.013790        36.        36.        36.         20          8          0       0.00      82.65     197.63

1490 NH CARD USED
*SECNO 8.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    8.000       4.27    4017.67    4017.67       0.00    4018.91       1.24       2.05       0.03    4050.00
   1605.0        0.0     1605.0        0.0        0.0      179.9        0.0        5.3        1.7    4050.00
     0.04       0.00       8.92       0.00      0.000      0.035      0.000      0.000    4013.40     119.25
 0.013590       150.       150.       150.         20          8          0       0.00      74.26     193.52

1490 NH CARD USED
*SECNO 9.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
    9.000       4.40    4016.10    4016.10       0.00    4017.38       1.28       2.15       1.09    4040.00
   1605.0        0.0     1605.0        0.0        0.0      176.6        0.0        6.0        2.0    4040.00
     0.04       0.00       9.09       0.00      0.000      0.035      0.000      0.000    4011.70     126.70
 0.013344       160.       160.       160.         20          8          0       0.00      70.36     197.07

1490 NH CARD USED
*SECNO 10.000
3685 20 TRIALS ATTEMPTED WSEL,CWSEL
3693 PROBABLE MINIMUM SPECIFIC ENERGY
3720 CRITICAL DEPTH ASSUMED
   10.000       4.60    4014.60    4014.60       0.00    4016.25       1.66       2.12       0.90    4032.00
   1605.0        0.0     1605.0        0.0        0.0      155.4        0.0        6.5        2.2    4037.00
     0.05       0.00      10.33       0.00      0.000      0.038      0.000      0.000    4010.00     153.31
 0.015005       150.       150.       150.         20          8          0       0.00      47.59     200.89
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PROFILE FOR STREAM   SUPERCRITICAL RUN WITH

PLOTTED POINTS (BY PRIORITY) E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

ELEVATION 4010.     4015.     4020.     4025.     4030.     4035.     4040.     4045.     4050.     4055.
    SECNO   CUMDIS

     1.00    0.   .         .         .         .         I         W E       .         .         L         .         R
            20.   .         .         .         .         I        W. E       .         .         L         .         R
            40.   .         .         .         .        I.        W. E       .         .         L         .         R
            60.   .         .         .         .        I.        W.E        .         .         L         .         R
            80.   .         .         .         .       I .       W .E        .         .         L         .         R
           100.   .         .         .         .       I .       W .E        .         .         L         .         R
           120.   .         .         .         .      I  .       W .E        .         .         L         .         R
           140.   .         .         .         .      I  .      W  E         .         .         L         .         R
           160.   .         .         .         .     I   .      W  E         .         .         L         .         R
           180.   .         .         .         .     I   .      W  E         .         .         L         .         R
           200.   .         .         .         .     I   .     W  E.         .         .         L         .         R
           220.   .         .         .         .    I    .     W  E.         .         .         L         .         R
           240.   .         .         .         .    I    .     W  E.         .         .         L         .         R
     2.00  260.   .         .         .         .   I     .    W  E .         .         .         L         .         R
           280.   .         .         .         .   I     .    W  E .         .         .         L         .         R
           300.   .         .         .         .   I     .    W  E .         .         .         L         .        R.
           320.   .         .         .         .  I      .   W  E  .         .         .         L         .        R.
           340.   .         .         .         .  I      .   W  E  .         .         .         L         .        R.
           360.   .         .         .         . I       .  W   E  .         .         .         L         .       R .
           380.   .         .         .         . I       .  W  E   .         .         .         L         .       R .
           400.   .         .         .         .I        .  W  E   .         .         .         L         .       R .
           420.   .         .         .         .I        . W   E   .         .         .         L         .       R .
           440.   .         .         .         .I        . W  E    .         .         .         L         .      R  .
           460.   .         .         .         I         . W  E    .         .         .         L         .      R  .
           480.   .         .         .         I         .W   E    .         .         .         L         .      R  .
           500.   .         .         .        I.         .W  E     .         .         .         L         .     R   .
     3.00  520.   .         .         .        I.         W   E     .         .         .         L         .     R   .
           540.   .         .         .       I .         W   E     .         .         .         L         .     R   .
           560.   .         .         .       I .         W  E      .         .         .         L         .     R   .
           580.   .         .         .      I  .        W.  E      .         .         .         L         .     R   .
           600.   .         .         .      I  .        W. E       .         .         .         L         .     R   .
           620.   .         .         .      I  .       W . E       .         .         .         L         .     R   .
           640.   .         .         .     I   .       W . E       .         .         .         L         .     R   .
           660.   .         .         .     I   .      W  .E        .         .         .         L               R   .
           680.   .         .         .    I    .      W  .E        .         .         .         L         .     R   .
           700.   .         .         .    I    .      W  E         .         .         .         L               R   .
           720.   .         .         .   I     .     W   E         .         .         .         L         .     R   .
           740.   .         .         .   I     .     W   E         .         .         .         L         .     R   .
     4.00  760.   .         .         .  I      .    W   E.         .         .         .         L         .     R   .
           780.   .         .         .  I      .    W   E.         .         .         .         L         .     R   .
           800.   .         .         . I       .   W   E .         .         .         .         L         .     R   .
           820.   .         .         . I       .   W   E .         .         .         .         L         .     R   .
     4.10  840.   .         .         . I       .   W   E .         .         .         .         L         .     R   .
           860.   .         .         .I        .   W  E  .         .         .         .         L         .     R   .
           880.   .         .         .I        .  W   E  .         .         .         .         L         .     R   .
     4.20  900.   .         .         I         .  W   E  .         .         .         .         L         .     R   .
           920.   .         .         I         .  W   E  .         .         .         .         L         .     R   .
           940.   .         .         I         .  W   E  .         .         .         .         L         .     R   .
           960.   .         .        I.         .  W   E  .         .         .         .         L         .     R   .
           980.   .         .        I.         .  W   E  .         .         .         .         L         .     R   .
          1000.   .         .       I .         .  W   E  .         .         .         .         L         .     R   .
     5.00 1020.   .         .       I .         .  W   E  .         .         .         .         L         .     R   .
          1040.   .         .      I  .         . W   E   .         .         .         .         L         .     R   .
          1060.   .         .      I  .         . W  E    .         .         .         .         L         .     R   .
     5.10 1080.   .         .     I   .         .W   E    .         .         .         .         L         .     R   .
          1100.   .         .     I   .         W   E     .         .         .         .         L         .     R   .
          1120.   .         .    I    .         W  E      .         .         .         .         L         .     R   .
          1140.   .         .    I    .        W. E       .         .         .         .         L         .     R   .
     5.20 1160.   .         .    I    .        W. E       .         .         .         .         L         .     R   .
          1180.   .         .   I     .       W .E        .         .         .         .         L         .R        .
          1200.   .         .   I     .     WC  E         .         .         .         .         L     R   .         .
     6.00 1220.   .         .  I      .    WC  E.         .         .         .         .         L         .         .
          1240.   .         .  I      .  WC   E .         .         .         .        RL         .         .
          1260.   .         .  I      .WC   E   .         .         .         .       R L         .         .
```

```
       1280.  .         . I     W.C    E    .         .         .         .         .      R  L         .         .
 6.50  1300.  .         . I     W C   E     .         .         .         .         .     R   L         .         .
       1320.  .         .I      WC. E       .         .         .         .         .    R    L         .         .
 1.01  1340.  .         .I      WC.E        .         .         .         .         .    R    .L        .         .
 7.00  1360.  .         I       W .E        .         .         .         .         .   R     L         .         .
       1380.  .         I       W E         .         .         .         .         .    R    L         .         .
       1400.  .        I.      W  E         .         .         .         .         .     R   L         .         .
       1420.  .        I.      W E.         .         .         .         .         .     R   L         .         .
       1440.  .       I .      W E.         .         .         .         .         .      R  L         .         .
       1460.  .       I .     W  E.         .         .         .         .         .       R L         .         .
       1480.  .      I  .     W E .         .         .         .         .         .        RL         .         .
       1500.  .      I  .     W E .         .         .         .         .         .         L         .         .
 8.00  1520.  .      I  .    W  E .         .         .         .         .         .         L         .         .
       1540.  .     I   .    W E  .         .         .         .         .         .       L .         .         .
       1560.  .     I   .    W E  .         .         .         .         .         .    L    .         .         .
       1580.  .     I   .   W  E  .         .         .         .         .         .  L      .         .         .
       1600.  .    I    .   W E   .         .         .         .         .         L         .         .         .
       1620.  .    I    .  W  E   .         .         .         .         .       L .         .         .         .
       1640.  .   I     .  W  E   .         .         .         .         .    L    .         .         .         .
       1660.  .   I     .  W E    .         .         .         .         .  L      .         .         .         .
 9.00  1680.  .  I      . W  E    .         .         .         .         L         .         .         .         .
       1700.  .  I      . W E     .         .         .         .       LR.         .         .         .         .
       1720.  . I       .W  E     .         .         .         .     L R .         .         .         .         .
       1740.  . I       .W  E     .         .         .         .   L   R .         .         .         .         .
       1760.  . I       .W  E     .         .         .         .L     R  .         .         .         .         .
       1780.  .I        W  E      .         .         .        L.     R   .         .         .         .         .
       1800.  .I        W  E      .         .         .      L  .    R    .         .         .         .         .
10.00  1820.  I        W.  E      .         .         .   L     .   R     .         .         .         .         .
```

```
                                                                        THIS RUN EXECUTED 19MAY94     17:57:55
****************************************
 HEC-2 WATER SURFACE PROFILES

 Version   4.6.2;  May 1991
****************************************

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

 SUPERCRITICAL RUN WITH

SUMMARY PRINTOUT TABLE  150

      SECNO      XLCH      ELTRD      ELLC      ELMIN        Q       CWSEL      CRIWS       EG       10*KS       VCH       AREA      .01K
*     1.000      0.00       0.00      0.00    4030.00   1605.00   4034.78   4034.78   4036.20     130.59      9.56     167.83    140.45
*     2.000    250.00       0.00      0.00    4027.20   1605.00   4032.69   4032.69   4034.24     125.55     10.00     160.44    143.24
*     3.000    260.00       0.00      0.00    4024.40   1605.00   4030.17   4030.17   4032.00     124.09     10.86     147.79    144.08
*     4.000    250.00       0.00      0.00    4021.60   1605.00   4027.62   4027.62   4029.56     137.59     11.18     143.54    136.83
*     4.100     66.00       0.00      0.00    4020.90   1605.00   4026.95   4026.95   4028.88     136.73     11.15     143.94    137.26
*     4.200     66.00       0.00      0.00    4020.20   1605.00   4026.31   4026.31   4028.27     136.59     11.22     143.06    137.33
*     5.000    120.00       0.00      0.00    4018.90   1605.00   4026.37   4026.37   4028.30     187.46     11.13     144.19    117.23
*     5.100     66.00       0.00      0.00    4018.10   1605.00   4025.42   4025.42   4027.26     182.70     10.89     147.32    118.74
*     5.200     66.00       0.00      0.00    4017.40   1605.00   4024.39   4024.39   4026.13     180.28     10.59     151.63    119.54
      6.000     66.00       0.00      0.00    4016.70   1605.00   4022.36   4022.87   4024.62     301.79     12.06     133.11     92.39
      6.500     75.00       0.00      0.00    4015.90   1605.00   4018.90   4019.82   4021.76     496.89     13.57     118.29     72.00
*     7.000     72.00       0.00      0.00    4015.10   1605.00   4019.13   4019.13   4020.28     137.90      8.59     186.88    136.68
*     8.000    150.00       0.00      0.00    4013.40   1605.00   4017.67   4017.67   4018.91     135.90      8.92     179.89    137.68
*     9.000    160.00       0.00      0.00    4011.70   1605.00   4016.10   4016.10   4017.38     133.44      9.09     176.61    138.94
*    10.000    150.00       0.00      0.00    4010.00   1605.00   4014.60   4014.60   4016.25     150.05     10.33     155.39    131.03
```

```
 SUPERCRITICAL RUN WITH

SUMMARY PRINTOUT TABLE  150

     SECNO        Q        CWSEL     DIFWSP    DIFWSX    DIFKWS    TOPWID      XLCH
*      1.000   1605.00   4034.78      0.00      0.00     -0.02     60.20      0.00
*      2.000   1605.00   4032.69      0.00     -2.09      0.00     51.79    250.00
*      3.000   1605.00   4030.17      0.00     -2.52      0.00     41.12    260.00
*      4.000   1605.00   4027.62      0.00     -2.55      0.00     37.70    250.00
*      4.100   1605.00   4026.95      0.00     -0.67      0.00     37.62     66.00
*      4.200   1605.00   4026.31      0.00     -0.63      0.00     36.80     66.00
*      5.000   1605.00   4026.37      0.00      0.06      0.00     38.60    120.00
*      5.100   1605.00   4025.42      0.00     -0.95      0.00     40.25     66.00
*      5.200   1605.00   4024.39      0.00     -1.03      0.00     43.38     66.00
       6.000   1605.00   4022.36      0.00     -2.03      0.00     47.10     66.00
       6.500   1605.00   4018.90      0.00     -3.46      0.00     68.94     75.00
*      7.000   1605.00   4019.13      0.00     -0.03      0.00     82.65     72.00
*      8.000   1605.00   4017.67      0.00     -1.46      0.00     74.26    150.00
*      9.000   1605.00   4016.10      0.00     -1.57      0.00     70.36    160.00
*     10.000   1605.00   4014.60      0.00     -1.50      0.00     47.59    150.00
```

```
SUMMARY OF ERRORS AND SPECIAL NOTES

CAUTION SECNO=      1.000  PROFILE=  1  CRITICAL DEPTH ASSUMED

CAUTION SECNO=      2.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      2.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      2.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      3.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      3.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      3.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      4.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      4.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      4.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      4.100  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      4.100  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      4.100  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      4.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      4.200  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      4.200  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      5.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      5.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      5.100  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.100  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      5.100  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      5.200  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      5.200  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      5.200  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      7.000  PROFILE=  1  INTERPOLATED X-SECTIONS USED

CAUTION SECNO=      8.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      8.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      8.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=      9.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=      9.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=      9.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL

CAUTION SECNO=     10.000  PROFILE=  1  CRITICAL DEPTH ASSUMED
CAUTION SECNO=     10.000  PROFILE=  1  PROBABLE MINIMUM SPECIFIC ENERGY
CAUTION SECNO=     10.000  PROFILE=  1  20 TRIALS ATTEMPTED TO BALANCE WSEL
```

Canonie Environmental
By JWS Date 5/10/94 Subject Riprap Size Design Natural Sheet F-1 of F-15
Chkd By Date 5/20/94 Southwest Channel - Atlas Proj No 88-067-12

ATTACHMENT F

COE RIPRAP SIZING METHOD CALCULATIONS

CanonieEnvironmental

F-2

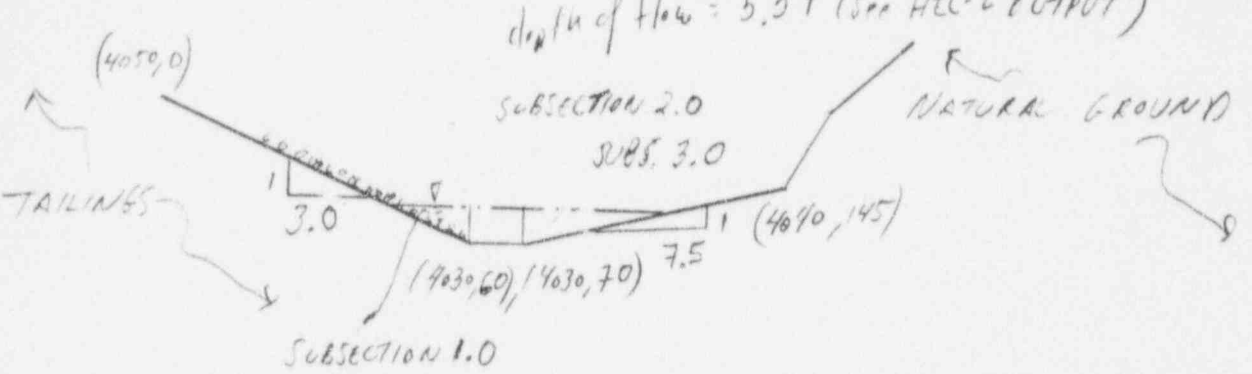
By JWI Date 5/18/94 Subject COE METHOD Example Calc Sheet No. 1 of 4

Chkd. By VRV Date 5/20/94 Project No. 88-067-12

1/4" X 1/4"

COE RIPRAP SIZING METHOD EXAMPLE
CALCULATION FOR HEC-2 CROSS SECTION 1.0

PROFILE OF CROSS SECTION 1.0:



STEP 1 - SELECT D_{50}. - Try D_{50} of 4.9"

STEP 2. COMPUTE LOCAL BOUNDARY SHEAR AT SUBSECTION 1.0

$$\tau = \frac{\gamma \bar{V}^2}{\left[32.6 \log\left(\frac{12.2R}{K}\right)\right]^2}$$

NOTE: Only need τ at subsection 1.0 because this is tailings embankment side.

• FIND $\bar{V}$ - AVG. LOCAL VELOCITY IN SUBSECTION 1.0

$$\bar{V} = \frac{Q_T (CR^{1/2})_m}{\Sigma\left[(CR^{1/2})_i A_i\right]}$$

C in SUBSECTION 1.0 = $32.6 \log(12.2R/k)$

use $C = 1.486 R^{1/6}/n$ to estimate C in subsection 2 and 3

By JWL Date 5/18/94 Subject COE METHOD EXAMPLE CALC Sheet No. 2 of 4
Chkd. By VAP Date 5/20/94 Project No. 88-067-12

1/4" X 1/4"

$R = A/P$

Depth of Flow in X-SEC. 1.0 = 4.78 FT (from HEC-2)

SUMMARIZE A, P, R

	SUBSECTION			
	1	2	3	
A	43.26	53.7	108.14	ft²
P	16.98	10	40.63	ft
R	2.55	5.37	2.66	ft

COMPUTE C FOR EACH SUBSECTION

$$C_1 = 32.6 \log(12.2(2.55/4.9/12)) = 61.35$$

$$C_2 = 1.486 (5.37)^{1/6}/0.035 = 56.18$$

$$C_3 = 1.486 (2.66)^{1/6}/0.035 = 49.98$$

COMPUTE $\bar{V}$ FOR SUBSEC. 1.

$$\bar{V}_1 = \frac{(1605)(61.35)(2.55)^{1/2}}{(61.35)(2.55)^{1/2} 43.26 + (56.18)(5.37)^{1/2}(53.7) + 49.98(2.66)^{1/2}(108.14)}$$

$$= 7.84 \text{ fps}$$

By JW Date 5/18/94 Subject COE METHOD CHANNEL CALC. Sheet No. 3 of 4 x-4
Chkd. By VAD Date 5/20/94 Project No. 88-067-12

1/4" X 1/4"

COMPUTE τ_1

$$\tau_1 = \frac{62.4(7.84)^2}{(61.35)^2}$$

$$\boxed{\tau_1 = 1.02 \text{ psf}}$$: LOCAL BOUNDARY SHEAR SUBSECTION 1.0

STEP 3.0

COMPUTE RIPRAP DESIGN SHEAR

$$\tau' = \tau\left(1 - \frac{\sin^2\phi}{\sin^2\theta}\right)^{0.5}$$

where

$$\tau = a(\gamma_s - \gamma)D_{50}$$

$$= 0.04(154.2 - 62.4)\ 4.9/12$$

$$= 1.50 \text{ psf}$$

ϕ: SIDE SLOPE ANGLE IN SUBSECTION 1.0
$= \tan^{-1}(1/3.0) = 18.4°$

θ: Repose ∡ of Riprap = 42°

$$\therefore \tau' = 1.50\left(1 - \frac{\sin^2(18.4)}{\sin^2 42}\right)^{1/2}$$

$$\boxed{\tau = 1.32 \text{ psf}}$$: SIDE SLOPE DESIGN SHEAR (ALLOWABLE)

CanonieEnvironmental

By JWS Date 5/18/94 Subject COE EXAMPLE CALC. Sheet No. 4 of 4

Chkd. By VHP Date 5/20/94 Project No. 88-057-12

1/4" X 1/4"

STEP 4.

COMPARE LOCAL BOUNDARY SHEAR TO DESIGN SHEAR:

$\tau_{LOCAL} = 1.02$ psf

$\tau_{design} = 1.32$ psf

$\tau_{LOCAL} < \tau_{design}$ — therefore selected D_{50} of 4.9" is adequate

STEP 5. Select D_{50} of 4.02" AND repeat steps 1 through 4. - SEE ATTACHED TABLE FOR THESE CALCULATIONS USING $D_{50} = 4.02$" FOR X-SEC 1.0.

N corresponding to following Tables:

1) Sec. No. refers to HEC-2 cross section number. See Figure 1 for location of HEC-2 sections.

2) See Figure 2 for subsection detail

3) Depth of flow is from HEC-2 simulations. See Table 5 for summary.

4) Station refers to distance on channel cross section profile measured from the tailings embankment.

5) Sta. Elevation refers to elevation of point on channel profile corresponding to station (see note 3).
see Attachment B for channel profiles and HEC-2 "GR" card in Attachments C and E for stations and elevations.

6) Zn is channel subsection side slope (ZH:1V). Values in ( ) denote bottom width of channel subsection.

7) An is channel subsection area.

8) Pn is channel subsection wetted perimeter.

9) Rn is hydraulic radius of Channel Subsection

10) See Main Text of Calc. for discussion of Manning's n.

11) k is roughness dimension of channel subsection. k is defined as raw (not oversized) D50 for subsection 1
and only previously deigned riprap gradations (see Table 1 for listing) are considered. Minimum D50 has been determined for subsection 1.0

12) C is Chezy's coefficient = 32.6 log (12.2 R/k) for subsection 1 and C = 1.486 R^(1/6)/n for other subsections.

ee Main text of Calc. and Attachment A for definition of average local velocity, local boundary shear, Allow bottom shear, and allowable side shear.

F-7

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	INITIAL CONDITIONS WITH NO "ROCKS" IN CHANNEL
Riprap Unit Wt., lb/ft³	154.1	Depth of Flow from HEC-2 Simulations 1 and 2 - see Attachment C.
Riprap Angle of Repose,Deg.	42	

CHANNEL GEOMETRY PROPERTIES									CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Lcl. Velocity, fps	Lcl. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
			0	4050													
1.0	1		60	4030	3.00	43.26	16.98	2.55	0.034	4.02	64.14	102.36	8.12	1.00	1.23	1.08	YES
0	2		70	4030	(10.00)	53.70	10.00	5.37	0.035	14.86	56.18	130.20					
1.0	3		145	4040	7.50	108.14	40.63	2.66	0.035	11.42	49.98	81.54					
Totals		5.37				205.09							7.83				
			0	4050													
2.0	1		65	4027.2	2.85	51.14	18.10	2.83	0.034	4.9	62.81	105.58	9.06	1.30	1.50	1.30	YES
2.0	2		75	4027.2	(10.00)	59.90	10.00	5.99	0.035	15.41	57.22	140.03					
2.0	3		85	4030	3.57	45.90	22.22	2.07	0.035	10.25	47.92	68.87					
2.0	4		145	4040	6.00	30.53	19.40	1.57	0.035	9.07	45.79	57.43					
Totals		5.99				187.47							8.56				
			0	4050													
3.0	1		70	4024.4	2.73	51.71	17.91	2.89	0.034	8.8	54.82	93.16	8.23	1.41	2.69	2.31	YES
3.0	2		80	4024.4	(10.00)	61.50	10.00	6.15	0.035	15.54	57.47	142.52					
3.0	3		95	4030	2.68	50.25	16.01	3.14	0.035	12.20	51.37	91.01					
3.0	4		115	4040	2.00	0.30	1.23	0.25	0.035	3.35	33.61	16.67					
Totals		6.15				163.76							9.80				
			0	4050													
4.0	1		80	4021.6	2.82	58.78	19.31	3.04	0.038	8.8	55.57	96.95	8.47	1.45	2.69	2.33	YES
4.0	2		90	4021.6	(10.00)	64.60	10.00	6.46	0.035	15.79	57.94	147.27					
4.0	3		105	4030	1.79	37.26	13.22	2.82	0.035	11.69	50.46	84.71					
Totals		6.46				160.64							9.99				
			0	4050													
4.1	1		85	4020.9	2.92	64.59	20.53	3.15	0.038	4.9	64.32	114.08	8.95	1.21	1.50	1.31	YES
4.1	2		95	4020.9	(10.00)	66.50	10.00	6.65	0.035	15.94	58.22	150.14					
4.1	3		110	4030	1.65	36.45	12.82	2.84	0.035	11.73	50.53	85.20					
Totals		6.65				167.53							9.58				

#5

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	INITIAL CONDITIONS WITH NO "ROCKS" IN CHANNEL
Riprap Unit Wt., lb/ft³	154.1	Depth of Flow from HEC-2 Simulations 1 and 2 - see Attachment C.
Riprap Angle of Repose,Deg.	42	

CHANNEL GEOMETRY PROPERTIES									CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Lcl. Velocity, fps	Lcl. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
			0	4050													
4.2	1		85	4020.2	2.85	64.21	20.28	3.17	0.038	4.9	64.41	114.61	9.01	1.22	1.50	1.30	YES
2	2		95	4020.2	(10.00)	67.10	10.00	6.71	0.035	15.98	58.31	151.04					
4.2	3		110	4030	1.53	34.46	12.27	2.81	0.035	11.67	50.43	84.52					
Totals		6.71				165.77							9.68				
			0	4050													
5.0	1		85	4018.9	2.73	51.52	17.87	2.88	0.038	8.8	54.80	93.04	9.43	1.85	2.69	2.31	YES
5.0	2		95	4018.9	(10.00)	61.40	10.00	6.14	0.035	15.54	57.45	142.36					
5.0	3		112	4030	1.53	28.87	11.23	2.57	0.035	11.25	49.69	79.67					
Totals		6.14				141.79							11.32				
			0	4050													
5.1	1		95	4018.1	2.98	51.48	18.47	2.79	0.038	8.8	54.32	90.68	9.65	1.97	2.69	2.37	YES
5.1	2		105	4018.1	(10.00)	58.80	10.00	5.88	0.035	15.32	57.04	138.31					
5.1	3		125	4030	1.68	29.05	11.50	2.53	0.035	11.17	49.55	78.76					
Totals		5.88				139.34							11.52				
			0	4050													
5.2	1		110	4017.4	3.37	45.80	18.34	2.50	0.038	17.04	43.41	68.60	9.50	2.99	5.21	4.72	YES
5.2	2		115	4017.4	(5.00)	26.05	5.00	5.21	0.035	14.71	55.90	127.60					
5.2	3		175	4030	4.76	64.63	25.35	2.55	0.035	11.21	49.62	79.23					
Totals		5.21				136.47							11.76				
			0	4050													
6.0	1		127	4016.7	3.81	35.75	17.07	2.09	0.042	17.04	40.92	59.21	8.63	2.78	5.21	4.82	YES
6.0	2		133	4016.7	(6.00)	25.98	6.00	4.33	0.035	13.78	54.20	112.79					
6.0	3		160	4020	8.18	72.36	27.20	2.66	0.035	11.41	49.98	81.51					
6.0	4		205	4030	4.50	2.39	4.75	0.50	0.035	5.08	37.86	26.84					
Totals		4.33				136.48							11.76				

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605
Riprap Unit Wt., lb/ft³	154.1
Riprap Angle of Repose,Deg.	42

INITIAL CONDITIONS WITH NO "ROCKS" IN CHANNEL

Depth of Flow from HEC-2 Simulations 1 and 2 - see Attachment C.

CHANNEL GEOMETRY PROPERTIES									CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Lcl. Velocity, fps	Lcl. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
			0	4050													
6.5	1		130	4015.9	3.81	34.92	16.87	2.07	0.042	4.02	61.20	88.05	7.70	0.99	1.23	1.14	YES
.5	2		140	4015.9	(10.00)	42.80	10.00	4.28	0.035	13.72	54.10	111.92					
6.5	3		205	4020	15.85	144.95	65.13	2.23	0.035	10.59	48.51	72.37					
6.5	4		220	4030	1.50	0.02	0.32	0.07	0.035	1.56	27.56	7.54					
Totals		4.28				222.69							7.21				
			0	4050													
7.0	1		130	4015..	3.72	37.55	17.32	2.17	0.033	4.02	61.86	91.08	7.66	0.96	1.23	1.13	YES
7.0	2		140	4015.1	(10.00)	44.90	10.00	4.49	0.035	13.96	54.53	115.55					
7.0	3		210	4020	14.29	144.00	64.30	2.24	0.035	10.62	48.56	72.68					
Totals		4.49				226.45							7.09				
			0	4050													
8.0	1		135	4013.4	3.69	35.70	16.82	2.12	0.033	4.9	58.76	85.62	8.61	1.34	1.50	1.38	YES
8.0	2		145	4013.4	(10.00)	44.00	10.00	4.40	0.035	13.86	54.35	114.00					
8.0	3		220	4020	11.36	110.00	50.19	2.19	0.035	10.52	48.39	71.63					
Totals		4.4				189.70							8.46				
			0	4040													
9.0	1		150	4011.7	5.30	71.66	28.05	2.55	0.033	4.02	64.18	102.59	7.13	0.77	1.23	1.18	YES
9.0	2		160	4011.7	(10.00)	52.00	10.00	5.20	0.035	14.70	55.88	127.43					
9.0	3		230	4020	8.43	114.02	44.16	2.58	0.035	11.27	49.73	79.91					
Totals		5.2				237.68							6.75				
			150	4015.7													
10.0	1		167.1	4010	3.00	31.74	14.55	2.18	0.038	8.8	50.85	75.12	7.80	1.47	2.69	2.37	YES
10.0	2		187.1	4010	(20.00)	92.00	20.00	4.60	0.035	14.08	54.75	117.43					
10.0	3		204.2	4015.7	3.00	31.74	14.55	2.18	0.035	10.50	48.35	71.42					
Totals		4.6				155.48							10.32				

F-10

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	FUTURE CONDITIONS WITH "ROCKS" IN CHANNEL SEC NO. 4, 4.1, 4.2, AND 5.0
Riprap Unit Wt., lb/ft^3	154.1	APP. 545 CY OF ROCK/SEDIMENT
Riprap Angle of Repose,Deg.	42	Depth of Flow from HEC-2 Simulations 3 and 4 - see Attachment E.

		CHANNEL GEOMETRY PROPERTIES							CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft^2	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Velocity, fps	Avg. Bnd. Shear, psf	Allow. Bot Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
1.0	1		60	4030	3.00	45.21	17.36	2.60	0.033	4.02	64.45	104.00	7.83	0.92	1.23	1.08	YES
0	2		70	4030	(10.00)	54.90	10.00	5.49	0.035	14.97	56.39	132.13					
.0	3		145	4040	7.50	113.03	41.54	2.72	0.035	11.52	50.17	82.75					
Totals		5.49				213.14							7.53				
			0	4050													
2.0	1		65	4027.2	2.85	46.15	17.19	2.68	0.038	8.8	53.79	88.13	8.82	1.68	2.69	2.34	YES
2.0	2		75	4027.2	(10.00)	56.90	10.00	5.69	0.035	15.15	56.73	135.32					
2.0	3		85	4030	3.57	42.90	21.10	2.03	0.035	10.18	47.79	68.13					
2.0	4		145	4040	6.00	25.06	17.58	1.43	0.035	8.67	45.04	53.77					
Totals		5.69				171.01							9.39				
			0	4050													
3.0	1		70	4024.4	2.73	67.18	20.41	3.29	0.033	4.02	67.77	122.95	7.61	0.79	1.23	1.05	YES
3.0	2		80	4024.4	(10.00)	70.10	10.00	7.01	0.035	16.20	58.74	155.51					
3.0	3		95	4030	2.68	63.15	16.01	3.94	0.035	13.32	53.37	105.99					
3.0	4		115	4040	2.00	1.99	3.15	0.63	0.035	5.74	39.32	31.22					
Totals		7.01				202.42							7.93				
			0	4050													
4.0	1		80	4021.6	2.82	91.73	24.12	3.80	0.034	4.9	67.01	130.66	9.51	1.26	1.50	1.30	YES
4.0	2		105	4030	2.98	96.91	25.34	3.82	0.035	13.17	53.09	103.84					
T		8.07				188.64							8.51				
			0	4050													
4.1	1		85	4020.9	2.92	103.79	26.03	3.99	0.033	4.02	70.48	140.75	9.04	1.03	1.23	1.08	YES
4.1	2		110	4030	2.75	97.62	24.65	3.96	0.035	13.34	53.40	106.28					
Totals		8.43				201.41							7.97				
			0	4050													
4.2	1		85	4020.2	2.85	98.49	25.12	3.92	0.038	8.8	59.15	117.13	9.65	1.66	2.69	2.34	YES
4.2	2		118	4035	2.23	76.99	20.31	3.79	0.035	13.12	53.02	103.23					
Totals		8.31				175.47							9.15				
			0	4050													
5.0	1		85	4018.9	2.73	76.26	21.74	3.51	0.042	17.04	48.22	90.31	10.76	3.11	5.21	4.47	YES
5.0	2		112	4030	2.43	67.87	19.65	3.45	0.035	12.67	52.20	97.02					
Totals		7.47				144.12							11.14				

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	FUTURE CONDITIONS WITH "ROCKS" IN CHANNEL SEC NO. 4, 4.1, 4.2, AND 5.0
Riprap Unit Wt., lb/ft²	154.1	APP. 545 CY OF ROCK/SEDIMENT
Riprap Angle of Repose,Deg.	42	Depth of Flow from HEC-2 Simulations 3 and 4 - see Attachment E.

		CHANNEL GEOMETRY PROPERTIES							CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Velocity, fps	Avg. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
			0	4050													
.1	1		95	4018.1	2.98	41.20	16.52	2.49	0.042	17.04	43.38	68.50	9.75	3.15	5.21	4.58	YES
5.1	2		105	4018.1	(10.00)	52.60	10.00	5.26	0.035	14.76	55.99	128.41					
5.1	3		125	4030	1.68	23.25	10.29	2.26	0.035	10.66	48.64	73.12					
Totals		5.26				117.05							13.71				
			0	4050													
5.2	1		110	4017.4	3.37	47.21	18.62	2.54	0.042	17.04	43.63	69.47	9.27	2.82	5.21	4.72	YES
5.2	2		115	4017.4	(5.00)	26.45	5.00	5.29	0.035	14.79	56.04	128.90					
5.2	3		175	4030	4.76	66.63	25.74	2.59	0.035	11.29	49.75	80.04					
Totals		5.29				140.29							11.44				
			0	4050													
6.0	1		127	4016.7	3.81	35.59	17.03	2.09	0.042	17.04	40.88	59.10	8.66	2.80	5.21	4.82	YES
6.0	2		133	4016.7	(6.00)	25.92	6.00	4.32	0.035	13.77	54.18	112.62					
6.0	3		160	4020	8.18	72.09	27.20	2.65	0.035	11.40	49.95	81.31					
6.0	4		205	4030	4.50	2.34	4.70	0.50	0.035	5.05	37.80	26.67					
Totals		4.32				135.94							11.81				
			0	4050													
ˆ.5	1		130	4015.9	3.81	34.92	16.87	2.07	0.033	4.02	61.20	88.05	7.70	0.99	1.23	1.14	YES
.5	2		140	4015.9	(10.00)	42.80	10.00	4.28	0.035	13.72	54.10	111.92					
6.5	3		205	4020	15.85	144.95	65.13	2.23	0.035	10.59	48.51	72.37					
6.5	4		220	4030	1.50	0.02	0.32	0.07	0.035	1.56	27.56	7.54					
Totals		4.28				222.69							7.21				
			0	4050													
7.0	1		130	4015.1	3.72	37.55	17.32	2.17	0.033	4.02	61.26	91.08	7.66	0.96	1.23	1.13	YES
7.0	2		140	4015.1	(10.00)	44.90	10.00	4.49	0.035	13.96	54.53	115.55					
7.0	3		210	4020	14.29	144.00	64.30	2.24	0.035	10.62	48.56	72.68					
Totals		4.49				226.45							7.09				
			0	4050													
8.0	1		135	4013.4	3.69	35.70	16.82	2.12	0.034	4.9	58.76	85.62	8.61	1.34	1.50	1.38	YES
8.0	2		145	4013.4	(10.00)	44.00	10.00	4.40	0.035	13.86	54.35	114.00					
8.0	3		220	4020	11.36	110.00	50.19	2.19	0.035	10.52	48.39	71.63					
Totals		4.4				189.70							8.46				

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	FUTURE CONDITIONS WITH "ROCKS" IN CHANNEL SEC NO. 4, 4.1, 4.2, AND 5.0
Riprap Unit Wt., lb/ft³	154.1	APP. 545 CY OF ROCK/SEDIMENT
Riprap Angle of Repose,Deg.	42	Depth of Flow from HEC-2 Simulations 3 and 4 - see Attachment E.

		CHANNEL GEOMETRY PROPERTIES							CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft³	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Velocity, fps	Avg. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg
			0	4040													
.0	1		150	4011.7	5.30	71.66	28.05	2.55	0.033	4.02	64.18	102.59	7.13	0.77	1.23	1.18	YES
9.0	2		160	4011.7	(10.00)	52.00	10.00	5.20	0.035	14.70	55.88	127.43					
9.0	3		230	4020	8.43	114.02	44.16	2.58	0.035	11.27	49.73	79.91					
Totals		5.2				237.68							6.75				
			150	4015.7													
10.0	1		167.1	4010	3.00	31.74	14.55	2.18	0.038	8.8	50.85	75.12	7.80	1.47	2.69	2.37	YES
10.0	2		187.1	4010	(20.00)	92.00	20.00	4.60	0.035	14.08	54.75	117.43					
10.0	3		204.2	4015.7	3.00	31.74	14.55	2.18	0.035	10.50	48.35	71.42					
Totals		4.6				155.48							10.32				

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	FUTURE CONDITIONS WITH "ROCKS" IN CHANNEL IN SECTIONS 5, 51. 5.2, AND 6
Riprap Unit Wt., lb/ft³	154.1	APP. 447 CY. OF ROCK/SEDIMENT
Riprap Angle of Repose,Deg.	42	Depth of Flow from HEC-2 Simulations 5 and 6 - see Attachment E.

			CHANNEL GEOMETRY PROPERTIES						CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Velocity, fps	Avg. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
1.0	1		60	4030	3.00	42.61	16.85	2.53	0.033	4.02	64.03	101.81	8.22	1.03	1.23	1.08	YES
`.0	2		70	4030	(10.00)	53.30	10.00	5.33	0.035	14.82	56.11	129.55					
.0	3		145	4040	7.50	106.53	40.33	2.64	0.035	11.38	49.92	81.13					
Totals		5.33				202.45							7.93				
			0	4050													
2.0	1		65	4027.2	2.85	53.21	18.46	2.88	0.034	4.9	63.09	107.11	8.73	1.21	1.50	1.30	YES
2.0	2		75	4027.2	(10.00)	61.10	10.00	6.11	0.035	15.51	57.41	141.90					
2.0	3		85	4030	3.57	47.10	22.66	2.08	0.035	10.28	47.96	69.15					
2.0	4		145	4040	6.00	32.87	20.13	1.63	0.035	9.23	46.07	58.86					
Totals		6.11				194.28							8.26				
			0	4050													
3.0	1		70	4024.4	2.73	47.59	17.18	2.77	0.038	8.8	54.23	90.27	8.78	1.64	2.69	2.31	YES
3.0	2		80	4024.4	(10.00)	59.00	10.00	5.90	0.035	15.34	57.07	138.63					
3.0	3		95	4030	2.68	46.50	16.01	2.90	0.035	11.83	50.71	86.42					
3.0	4		115	4040	2.00	0.09	0.67	0.13	0.035	2.30	30.38	11.13					
Totals		5.9				153.18							10.48				
			0	4050													
4.0	1		80	4021.6	2.82	70.00	21.07	3.32	0.033	4.02	67.90	123.75	8.40	0.95	1.23	1.06	YES
4.0	2		90	4021.6	(10.00)	70.50	10.00	7.05	0.035	16.23	58.79	156.10					
.0	3		105	4030	1.79	44.38	14.43	3.08	0.035	12.10	51.20	89.79					
Totals		7.05				184.88							8.68				
			0	4050													
4.1	1		85	4020.9	2.92	84.58	23.50	3.60	0.033	4.02	69.03	130.98	7.50	0.74	1.23	1.08	YES
4.1	2		95	4020.9	(10.00)	76.10	10.00	7.61	0.035	16.61	59.55	164.26					
4.1	3		110	4030	1.65	47.73	14.67	3.25	0.035	12.37	51.68	93.22					
Totals		7.61				208.41							7.70				
			0	4050													
4.2	1		85	4020.2	2.85	95.20	24.69	3.85	0.033	4.02	70.00	137.44	6.88	0.60	1.23	1.07	YES
4.2	2		95	4020.2	(10.00)	81.70	10.00	8.17	0.035	16.96	60.25	172.23					
4.2	3		110	4030	1.53	51.08	14.94	3.42	0.035	12.62	52.11	96.37					
Totals		8.17				227.98							7.04				

RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	FUTURE CONDITIONS WITH "ROCKS" IN CHANNEL IN SECTIONS 5, 51. 5.2, AND 6
Riprap Unit Wt., lb/ft³	154.1	APP. 447 CY. OF ROCK/SEDIMENT
Riprap Angle of Repose,Deg.	42	Depth of Flow from HEC-2 Simulations 5 and 6 - see Attachment E.

			CHANNEL GEOMETRY PROPERTIES						CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Velocity, fps	Avg. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
			0	4050													
5.0	1		85	4018.9	2.73	82.29	22.58	3.64	0.038	8.8	58.11	110.93	10.85	2.17	2.69	2.31	YES
.0	2		112	4030	2.43	73.24	20.41	3.59	0.035	12.85	52.53	99.52					
Totals		7.76				155.53							10.32				
			0	4050													
5.1	1		95	4018.1	2.98	83.31	23.50	3.55	0.038	8.8	57.73	108.69	10.95	2.25	2.69	2.37	YES
5.1	2		125	4030	2.52	70.53	20.29	3.48	0.035	12.70	52.26	97.43					
Totals		7.48				153.84							10.43				
			0	4050													
5.2	1		110	4017.4	3.37	81.96	24.53	3.34	0.038	8.8	56.89	103.98	11.15	2.40	2.69	2.44	YES
5.2	2		140	4028	2.83	68.75	20.92	3.29	0.035	12.42	51.77	93.84					
Totals		6.97				150.71							10.65				
			0	4050													
6.0	1		127	4016.7	3.81	61.09	22.32	2.74	0.042	17.04	44.71	73.97	11.23	3.94	5.21	4.82	YES
6.0	2		160	4024	4.52	72.41	26.20	2.76	0.035	11.59	50.29	83.60					
Totals		5.66				133.50							12.02				
			0	4050													
6.5	1		130	4015.9	3.81	34.92	16.87	2.07	0.033	4.02	61.20	88.05	7.70	0.99	1.23	1.14	YES
.5	2		140	4015.9	(10.00)	42.80	10.00	4.28	0.035	13.72	54.10	111.92					
6.5	3		205	4020	15.85	144.95	65.13	2.23	0.035	10.59	48.51	72.37					
Totals		4.28				222.67							7.21				
			0	4050													
7.0	1		130	4015.1	3.72	37.55	17.32	2.17	0.033	4.02	61.86	91.08	7.66	0.96	1.23	1.13	YES
7.0	2		140	4015.1	(10.00)	44.90	10.00	4.49	0.035	13.96	54.53	115.55					
7.0	3		210	4020	14.29	144.00	64.30	2.24	0.035	10.62	48.56	72.68					
Totals		4.49				226.45							7.09				
			0	4050													
8.0	1		135	4013.4	3.69	35.70	16.82	2.12	0.034	4.9	58.76	85.62	8.61	1.34	1.50	1.38	YES
8.0	2		145	4013.4	(10.00)	44.00	10.00	4.40	0.035	13.86	54.35	114.00					
8.0	3		220	4020	11.36	110.00	50.19	2.19	0.035	10.52	48.39	71.63					
Totals		4.4				189.70							8.46				

4.5

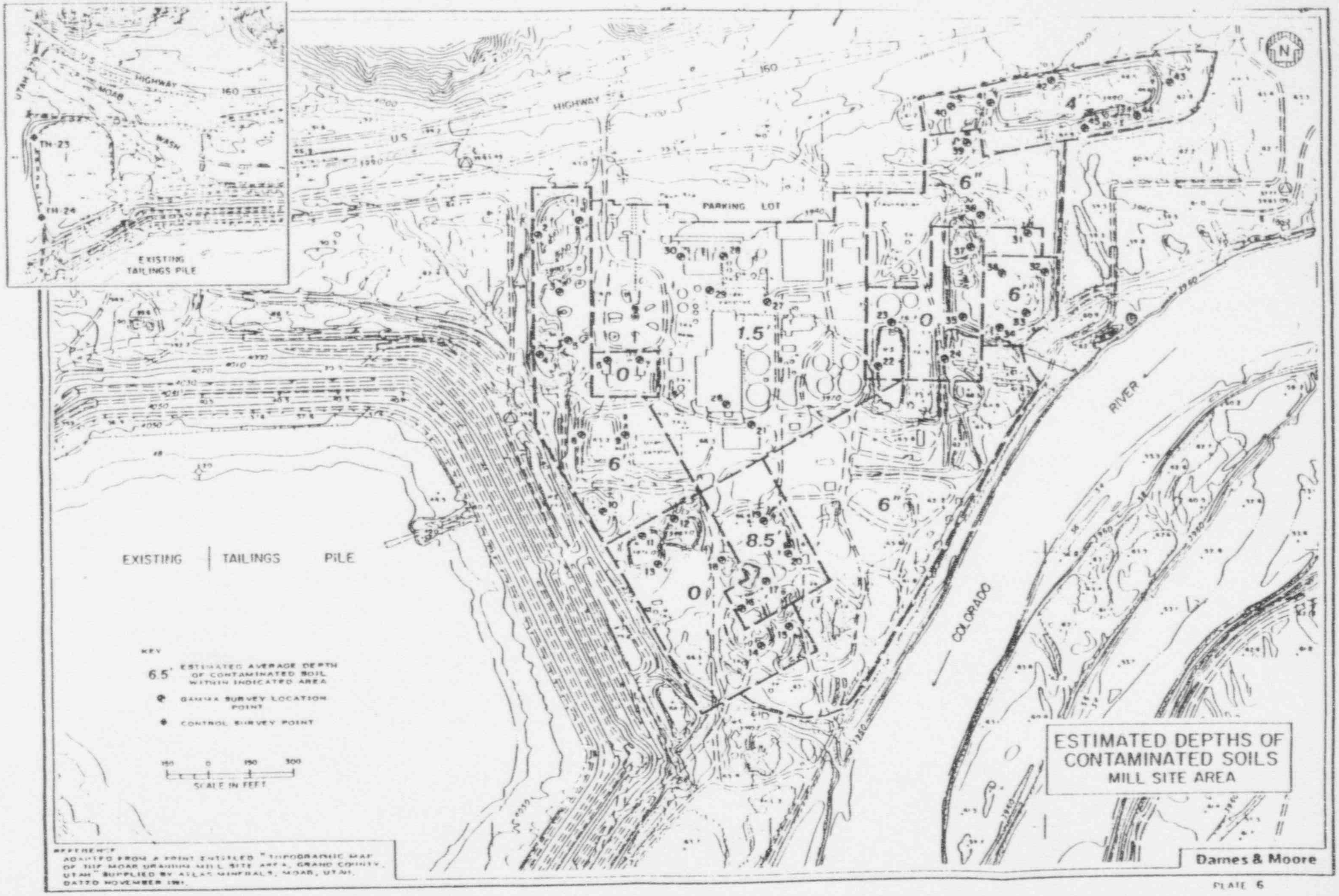
RIPRAP SIZING ANALYSIS FOR NATURAL SOUTHWEST RUNOFF DRAINAGE CHANNEL USING ARMY CORP OF ENGINEER METHOD

Qtotal, cfs	1605	FUTURE CONDITIONS WITH "ROCKS" IN CHANNEL IN SECTIONS 5, 51. 5.2, AND 6
Riprap Unit Wt., lb/ft³	154.1	APP. 447 CY. OF ROCK/SEDIMENT
Riprap Angle of Repose,Deg.	42	Depth of Flow from HEC-2 Simulations 5 and 6 - see Attachment E.

			CHANNEL GEOMETRY PROPERTIES						CHANNEL ROUGHNESS				AVERAGE LOCAL VELOCITY AND SHEAR STRESS CALCULATIONS FOR SUBSECTION 1				
SEC No.	Sub section	Depth of Flow, ft	Station, ft	Sta. Elevation, ft	Zn	An, ft²	Pn,ft	Rn,ft	Manning's n	kn,in	C	CR^(1/2)n	Avg. Velocity, fps	Avg. Bnd. Shear, psf	Allow. Bot. Shear, psf	Allow Side Shear, psf	Shear Allow > Shear Avg.
			0	4040													
.0	1		150	4011.7	5.30	71.66	28.05	2.55	0.033	4.02	64.18	102.59	7.13	0.77	1.23	1.18	YES
.0	2		160	4011.7	(10.00)	52.00	10.00	5.20	0.035	14.70	55.88	127.43					
9.0	3		230	4020	8.43	114.02	44.16	2.58	0.035	11.27	49.73	79.91					
Totals		5.2				237.68							6.75				
			150	4015.7													
10.0	1		167.1	4010	3.00	31.74	14.55	2.18	0.038	8.8	50.85	75.12	7.80	1.47	2.69	2.37	YES
10.0	2		187.1	4010	(20.00)	92.00	20.00	4.60	0.035	14.08	54.75	117.43					
10.0	3		204.2	4015.7	3.00	31.74	14.55	2.18	0.035	10.50	48.35	71.42					
Totals		4.6				155.48							10.32				

APPENDIX C

GAMMA LOGS FROM ATLAS MILL SITE



ESTIMATED DEPTHS OF CONTAMINATED SOILS
MILL SITE AREA

KEY

6.5' ESTIMATED AVERAGE DEPTH OF CONTAMINATED SOIL WITHIN INDICATED AREA

● GAMMA SURVEY LOCATION POINT

● CONTROL SURVEY POINT

150 0 150 300

SCALE IN FEET

REFERENCE
ADAPTED FROM A PRINT ENTITLED "TOPOGRAPHIC MAP OF THE MOAB URANIUM MILL SITE AREA, GRAND COUNTY, UTAH" SUPPLIED BY ATLAS MINERALS, MOAB, UTAH, DATED NOVEMBER 1981.

Dames & Moore

PLATE 6

FILE 05461-040-021 BY ______ DATE ______ CHECKED BY ______ DATE ______

4765 INDEPENDENCE STREET
WHEAT RIDGE (DENVER), CO 80033
(303) 422-5478

NUCLEAR LOGGING SERVICE, INC.

BOX 670
NUCLA, CO 81424
(303) 864-2213

COMPANY: Dames & Moore
PROJECT AREA: ATLAS Mill Site
HOLE NO: 1 THRU 20
DATE: 22 July 1987
COUNTY: GRAND
STATE: UTAH
SECTION: TWN: RNG:
ELEVATION:

—CALIBRATION—

CHART SCALE: 1.0" = 5.0 FT
.8 FT. K FACTOR (AIR)
WATER FACTOR CASING FACTOR
DEAD TIME: u SEC.
PROBE NO. 771
PROBE DIAMETER: 1 1/4 IN.
5" – FULL SCALE

—HOLE DATA—

DRILLING CONTRACTOR:
DRILL NO:
DEPTH DRILLED: FT.
HOLE DIAMETER: 4.0 UNCASED IN.
DRILLING FLUID: AUGER
FLUID LEVEL: FT.
DEPTH LOGGED: FT.
TOTAL FOOTAGE LOGGED: FT.

INITIAL RUN

GAMMA—FULL SCALE 200 CPS
TIME CONSTANT 2 SEC.
LOGGING SPEED: 20 FT./MIN.
RESISTANCE OHMS/DIV.
SELF POTENTIAL: MV/DIV.

GAMMA RERUNS

SCALE: CPS.	SCALE: CPS.	SCALE: CPS.
TIME CONSTANT SEC.	TIME CONSTANT SEC.	TIME CONSTANT SEC.
LOGGING SPEED: 5 FT./MIN.	LOGGING SPEED: 5 FT./MIN.	LOGGING SPEED: FT./MIN.
FROM: FT.	FROM: FT.	FROM: FT.
TO: FT.	TO: FT.	TO: FT.
TOTAL: FT.	TOTAL: FT.	TOTAL: FT.

(Third column: DENSITY)

TOTAL DEPTH FT.

UNIT NO: 15
OPERATOR: Freeman
DRIVE 4.0 HRS.
STANDBY: 1.0 HRS. TIME IN:
LOGGING: 4.0 HRS. TIME OUT:
TOTAL: 9.0 HRS.
ROUND TRIP MILEAGE: 175 MILES

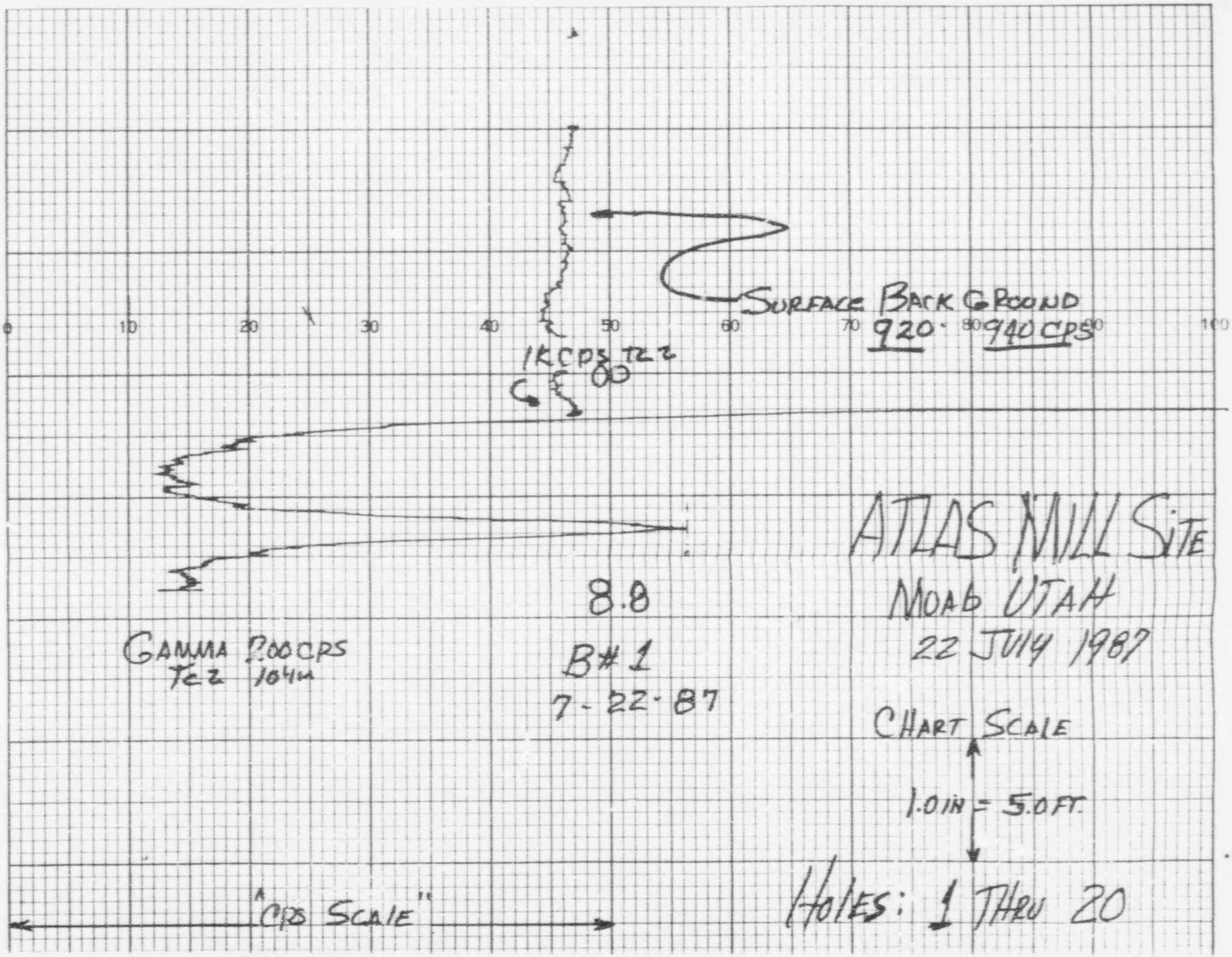
GAMMA RERUNS

SCALE: CPS.	SCALE: CPS.	SCALE: CPS.
TIME CONSTANT SEC.	TIME CONSTANT SEC.	TIME CONSTANT SEC.
LOGGING SPEED: 5 FT./MIN.	LOGGING SPEED: 5 FT./MIN	LOGGING SPEED: FT./MIN.
FROM: FT.	FROM: FT.	FROM: FT.
TO: FT.	TO: FT.	TO: FT.
TOTAL: FT.	TOTAL: FT.	TOTAL: FT.

(Third column: NEUTRON—NEUTRON)

REMARKS:
SURFACE BACKGROUND RECORDED @ EACH Hole.

GAMMA RAY CPS SELF POTENTIAL MILLIVOLTS RESISTANCE OHMS



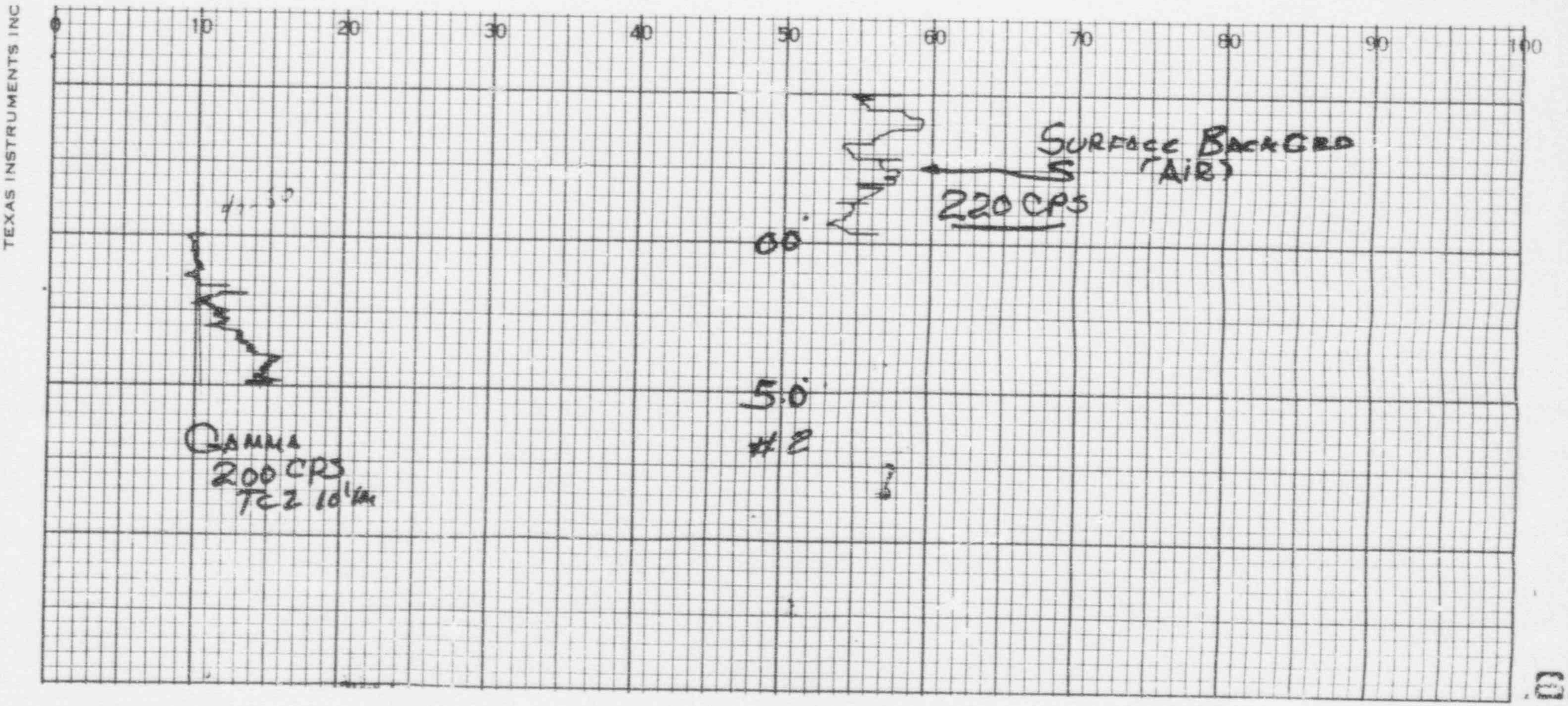
SURFACE BACK GROUND
920 - 940 CPS

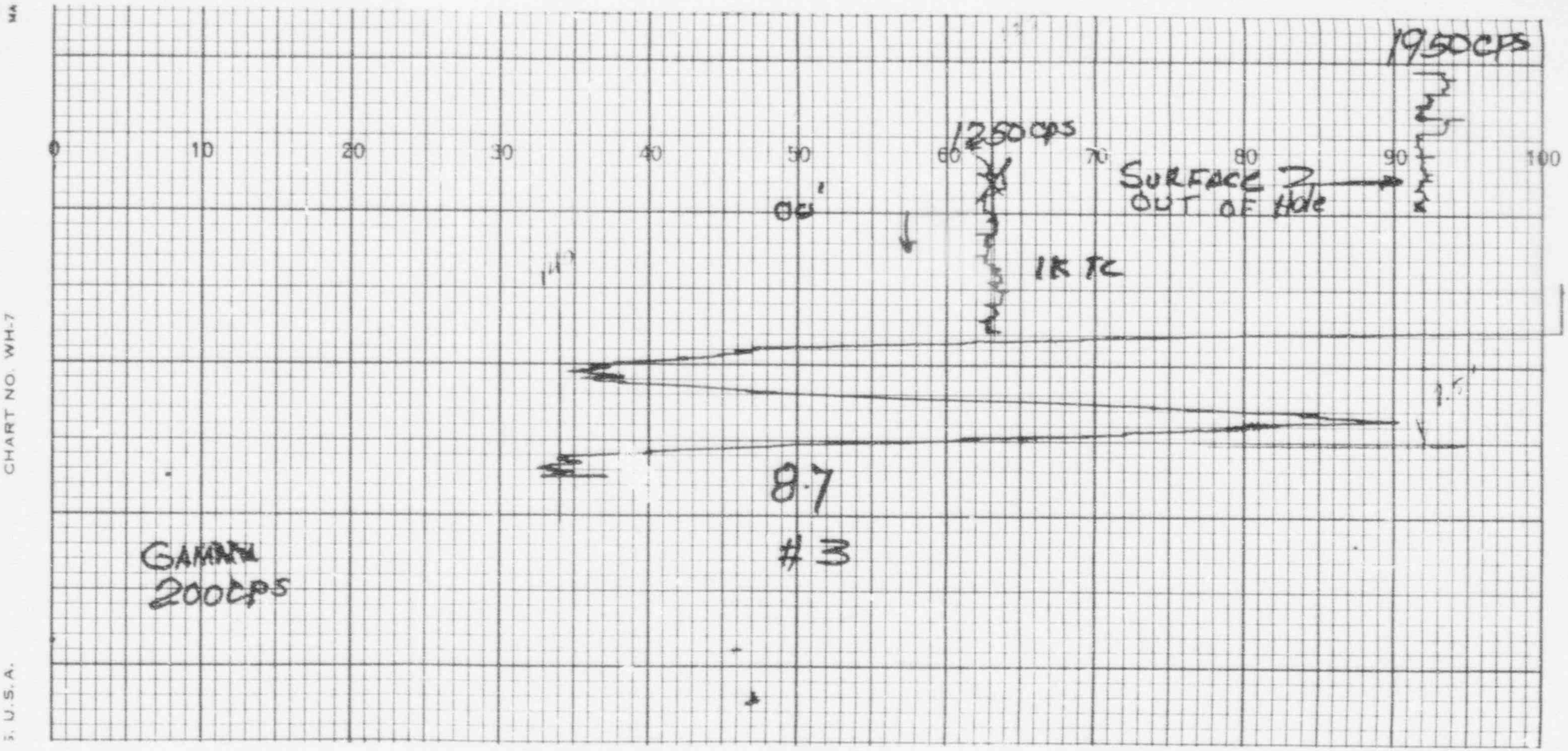
ATLAS MILL SITE
MOAB UTAH
22 JULY 1987

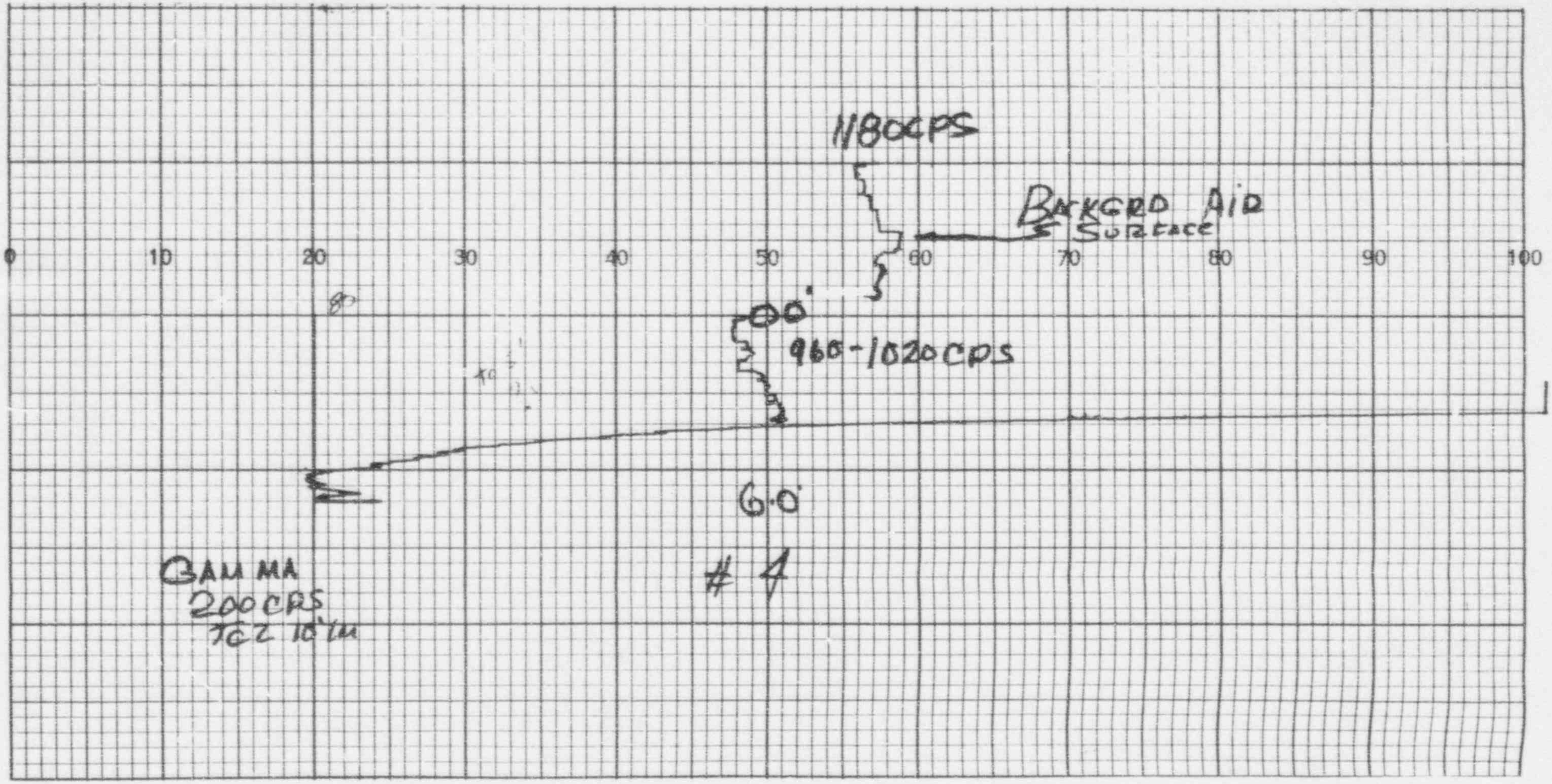
8.8
B#1
7-22-87

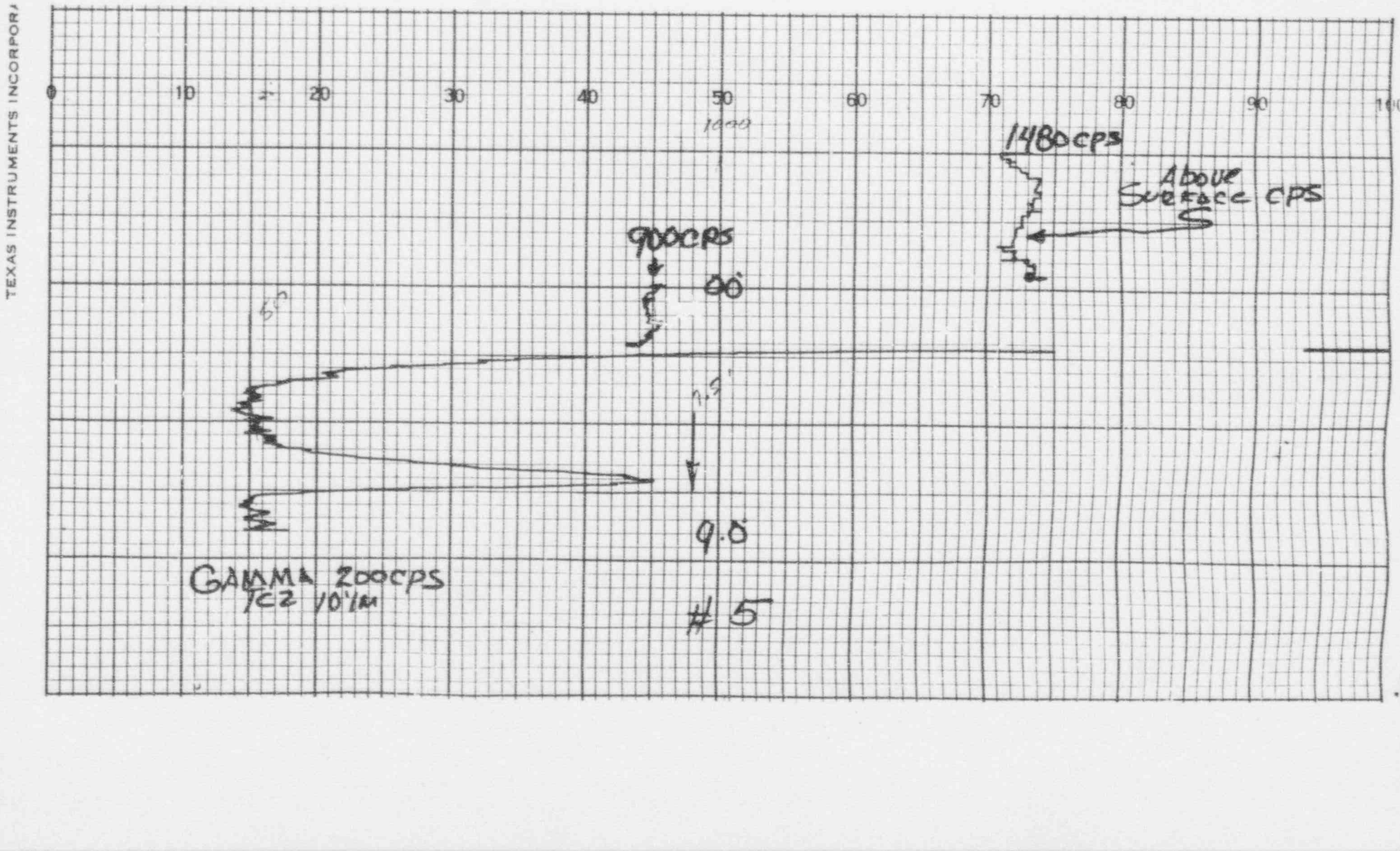
CHART SCALE
1.0IN = 5.0FT.

HOLES: 1 THRU 20


TEXAS INSTRUMENTS INC
0
10
20
30
40
50
60
70
80
90
100
SURFACE BACKGRD
(AIR)
220 CPS
60'
50'
#2
GAMMA
200 CPS
TC2 10¹/M

0
10
20
30
40
50
60
70
80
90
100
1950CPS
1250 CPS
SURFACE OUT OF Hole
85'
1K TC
87
#3
GAMMA 200CPS
CHART NO. WH-7
U.S.A.


0
10
20
30
40
50
60
70
80
90
100
1180CPS
BAKGRD AIR
SURFACE
0.0'
960-1020CPS
6.0'
4
GAMMA
200CPS
TC2 10'M
80
40


TEXAS INSTRUMENTS INCORPOR
0
10
20
30
40
50
60
70
80
90
100
1000
1480CPS
Above
Surface CPS
900CPS
0.0'
6.0
7.5'
9.0
#5
GAMMA 200CPS
TC2 10'/M

.E2

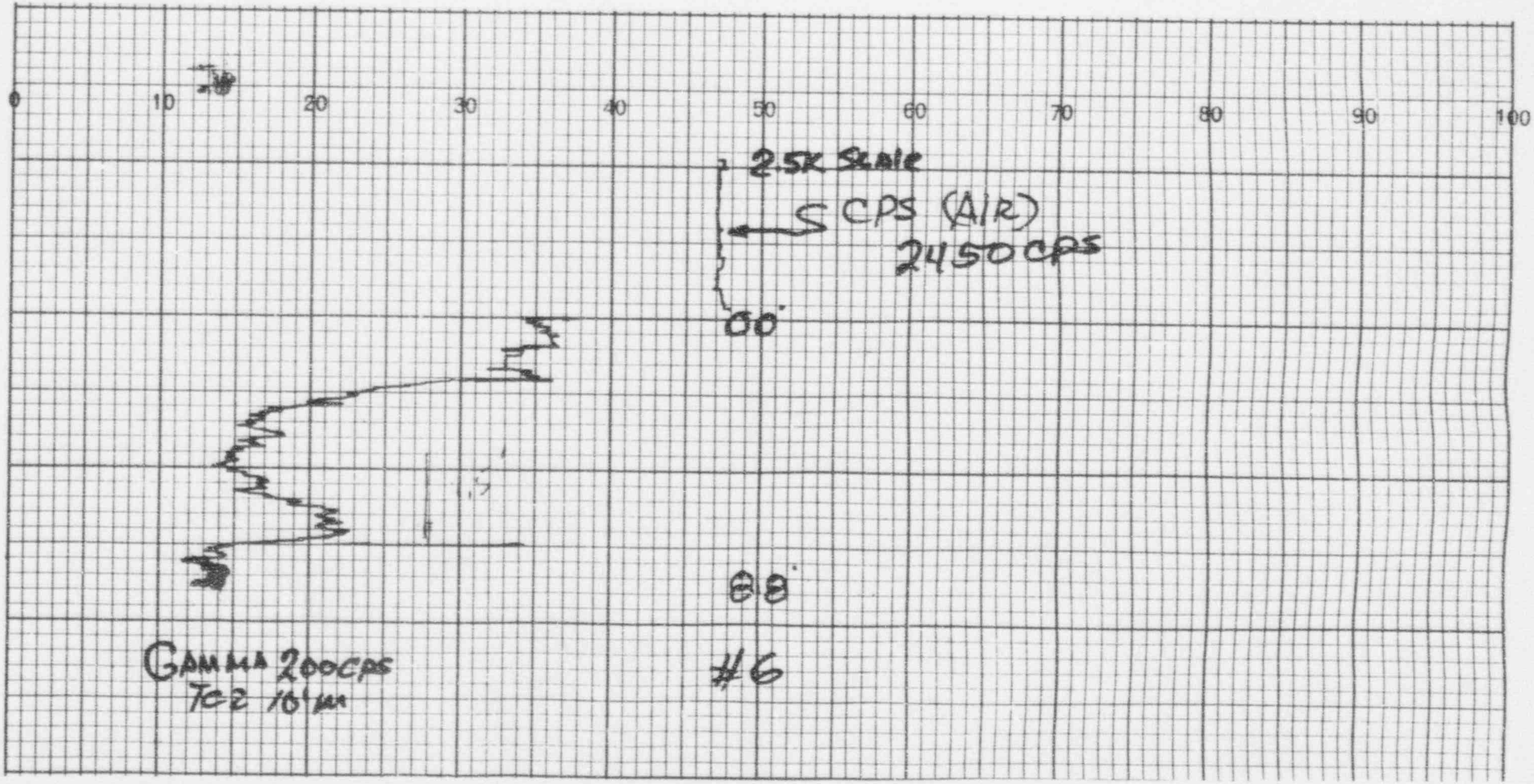
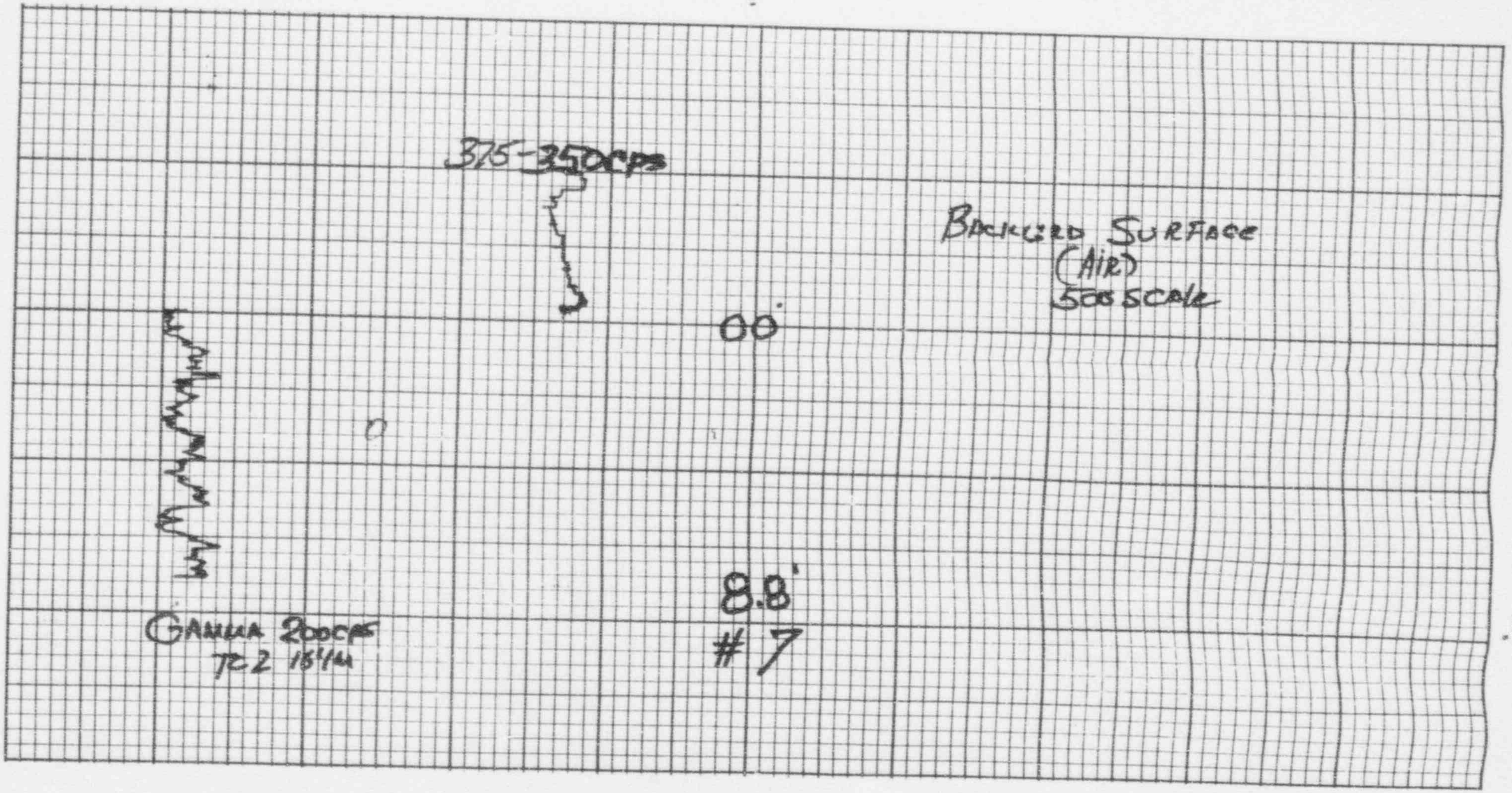


CHART NO. WH-7

N, TEXAS, U.S.A.

TEXAS INSTRUME



.80

MADE IN U.S.A.

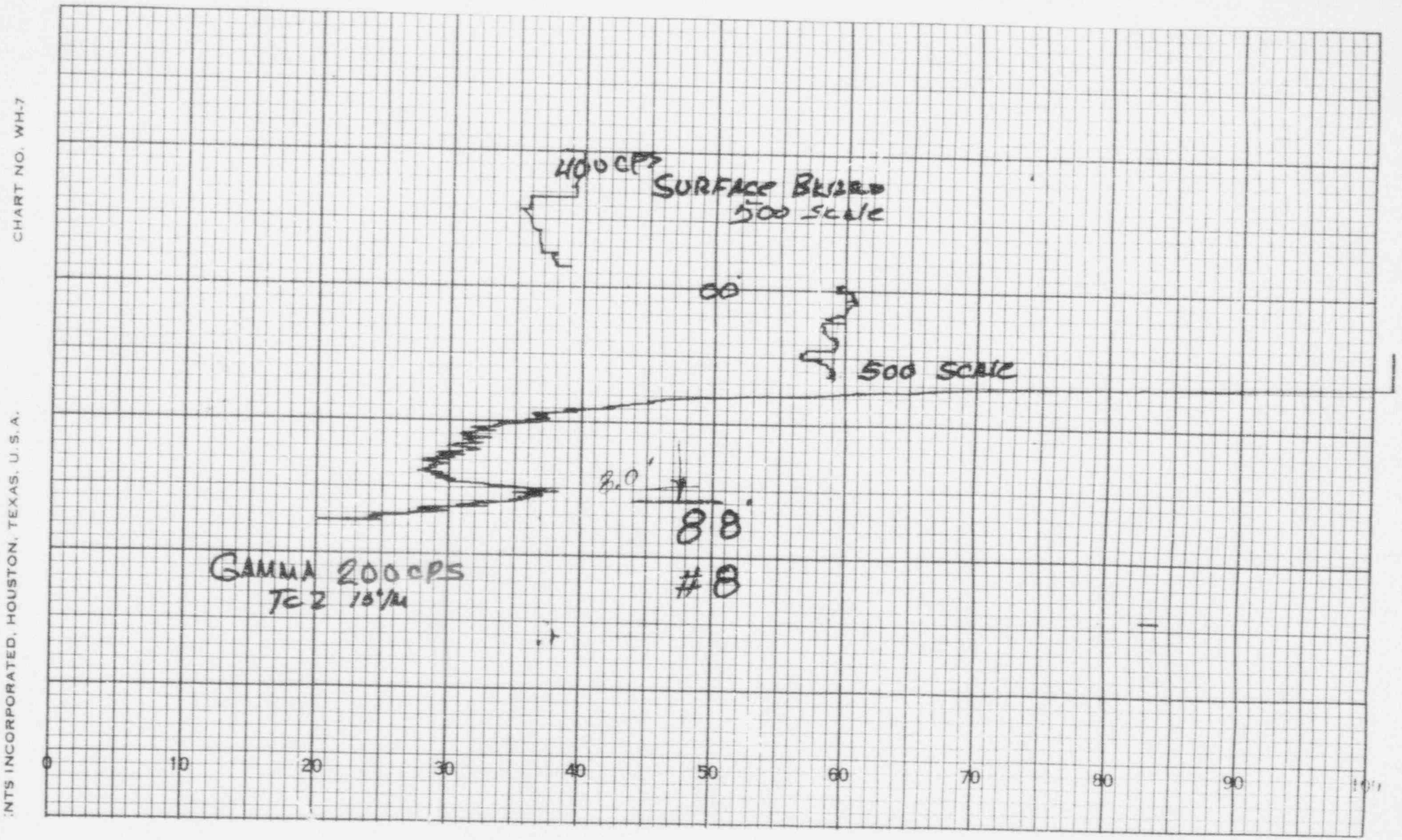
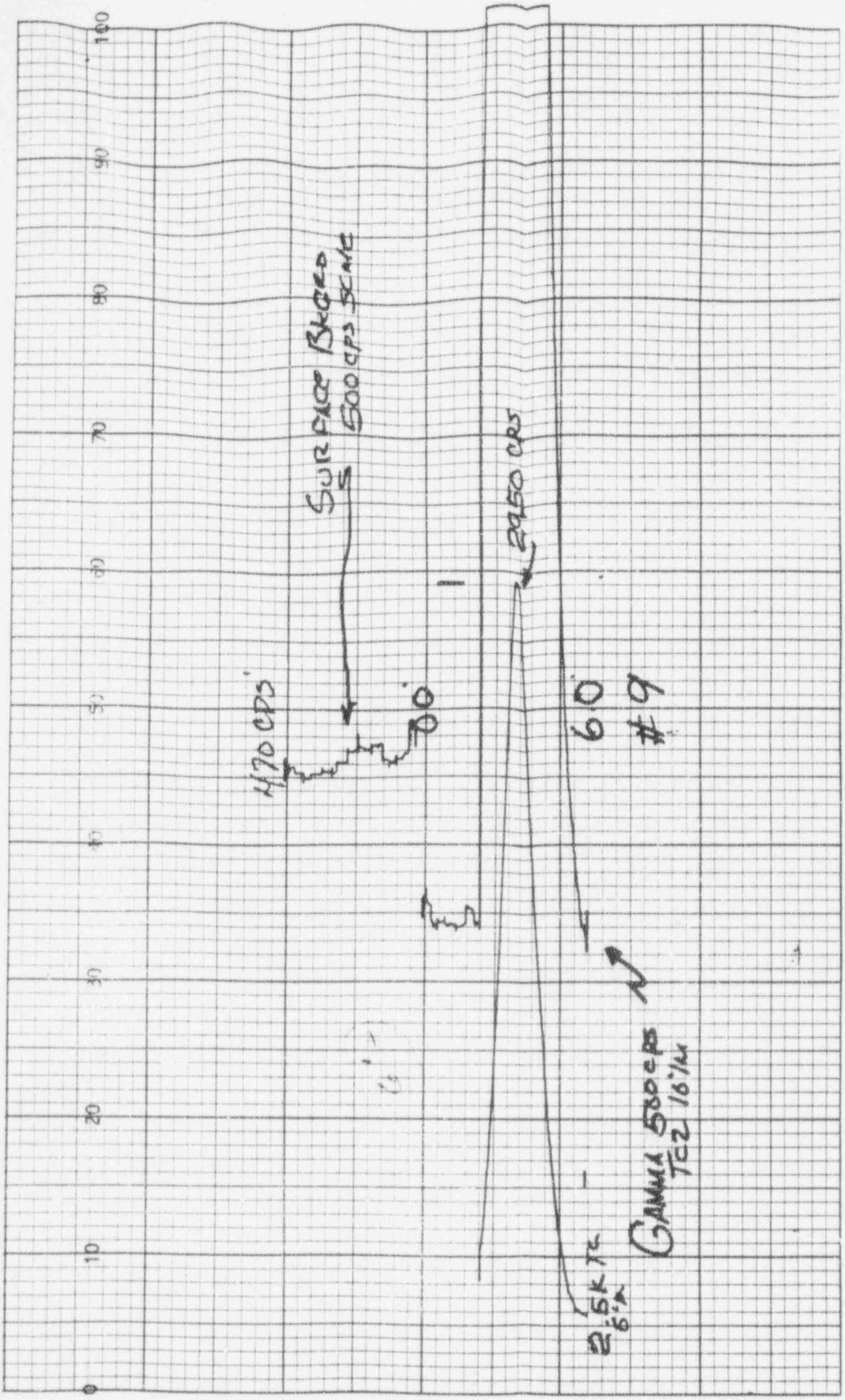
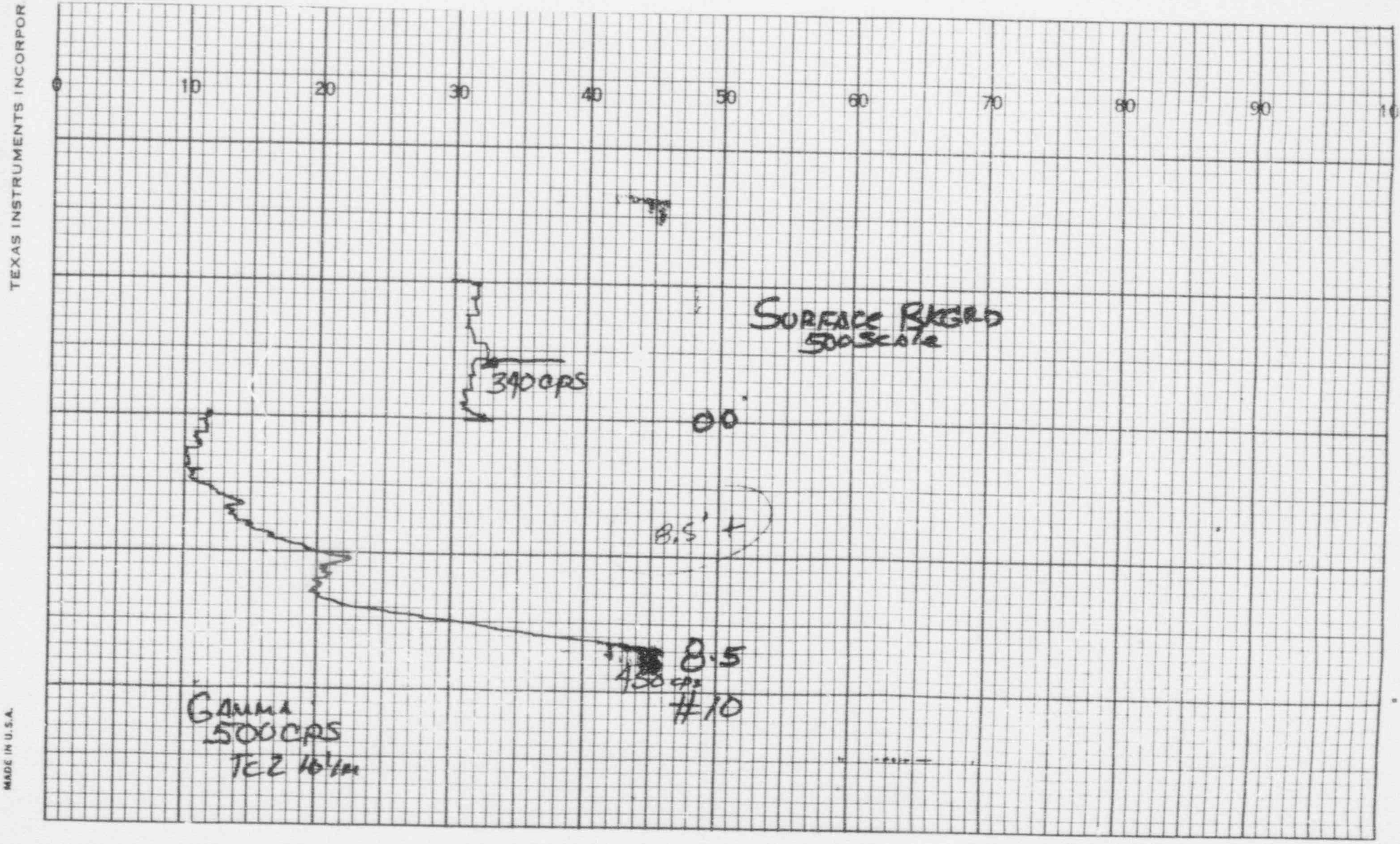
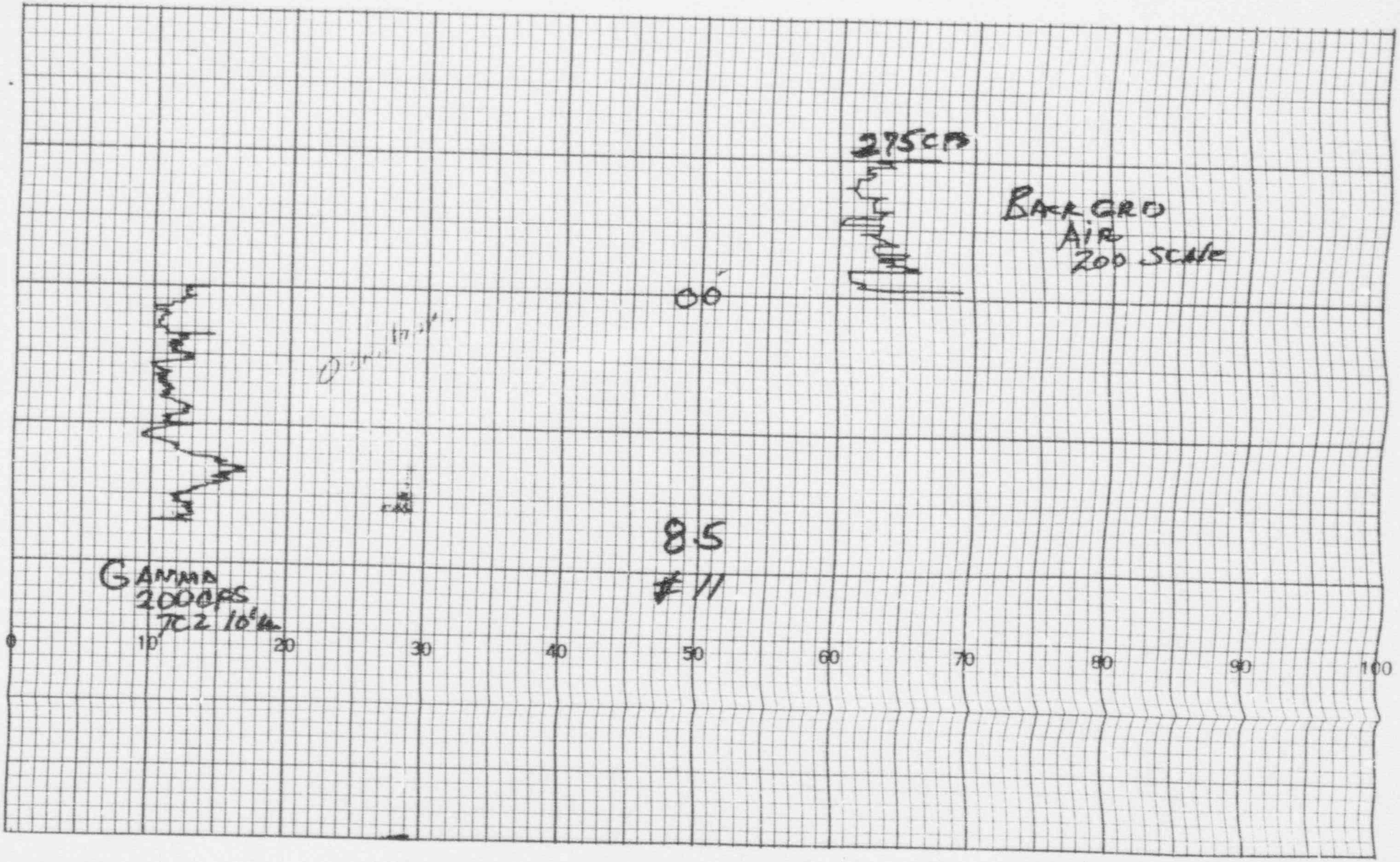


CHART NO. WH-7
NTS INCORPORATED, HOUSTON, TEXAS, U.S.A.
400 CPS
SURFACE BKGRD
500 scale
88'
500 SCALE
8.0'
88'
#8
GAMMA 200 CPS
TC 2 18'/M
0
10
20
30
40
50
60
70
80
90
100


0
10
20
30
40
50
60
70
80
90
100
470 CPS
SURFACE BKGRD
500 CPS SCALE
50
2950 CPS
60
#9
2.5K TC
6'/m
GAMMA 500 CPS
TC2 10"/M
CHART NO. WH-7
ATED, HOUSTON, TEXAS, U.S.A.

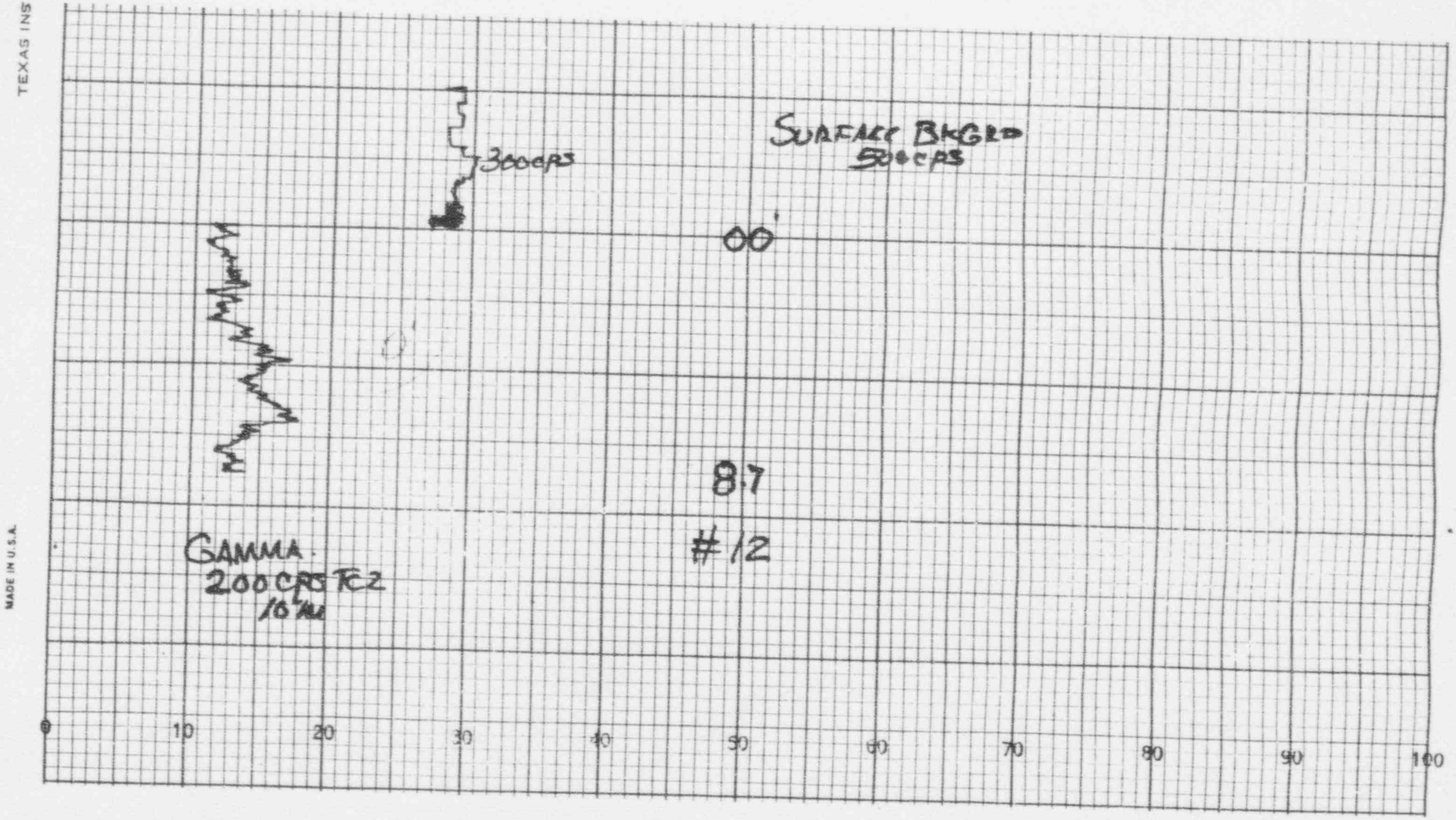

TEXAS INSTRUMENTS INCORPOR
MADE IN U.S.A.
0
10
20
30
40
50
60
70
80
90
100
SURFACE BKGRD
500 scale
340 CPS
00
8.5' +
8.5
450 cps
#10
GAMMA
500 CPS
TC2 10'/m

.79



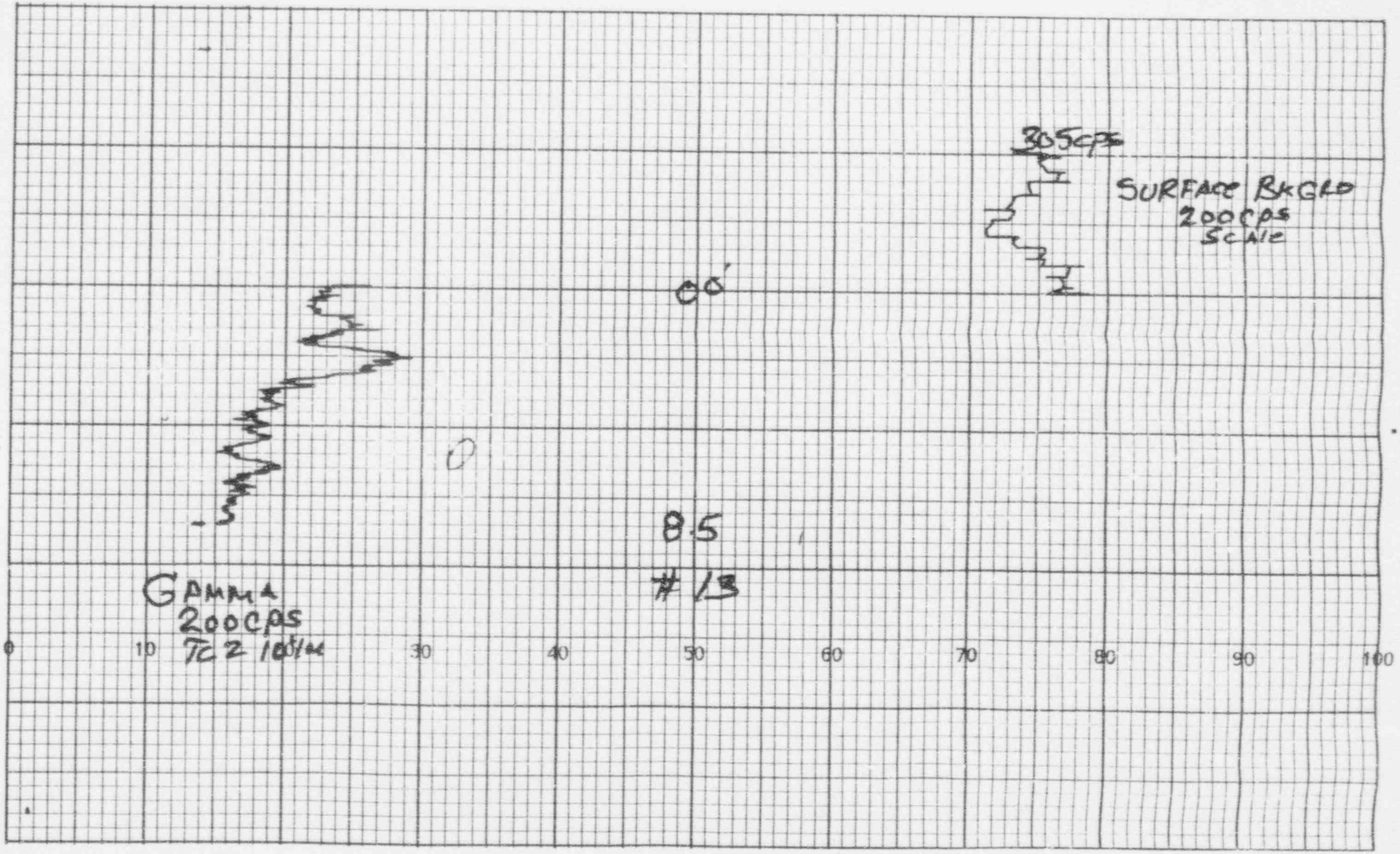
EXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.

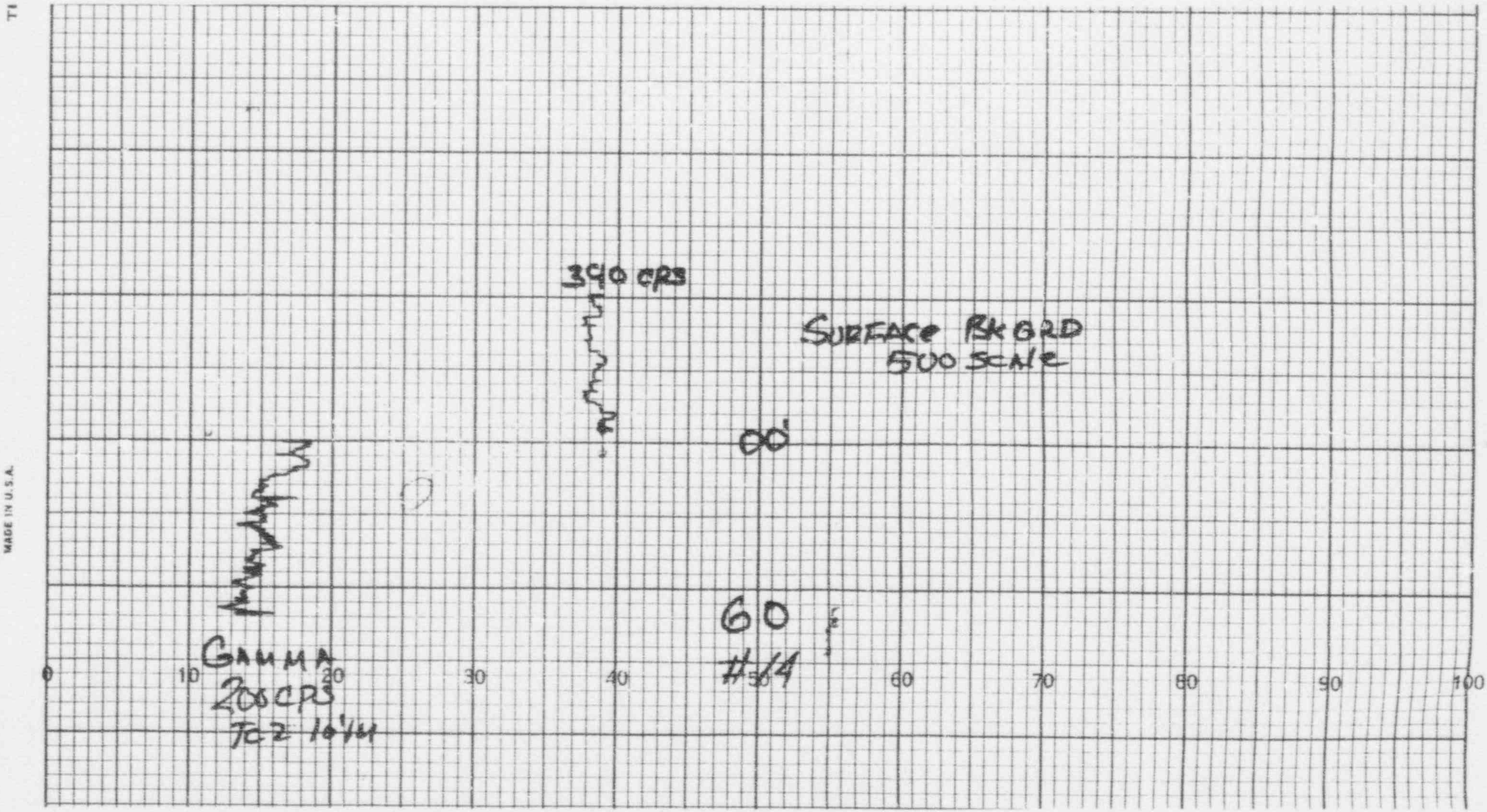
CHART NO.


TEXAS INS
MADE IN U.S.A.
SURFACE BKGRD
500cps
300cps
00
8.7
#12
GAMMA
200CPS TC2
10"/M
0
10
20
30
40
50
60
70
80
90
100

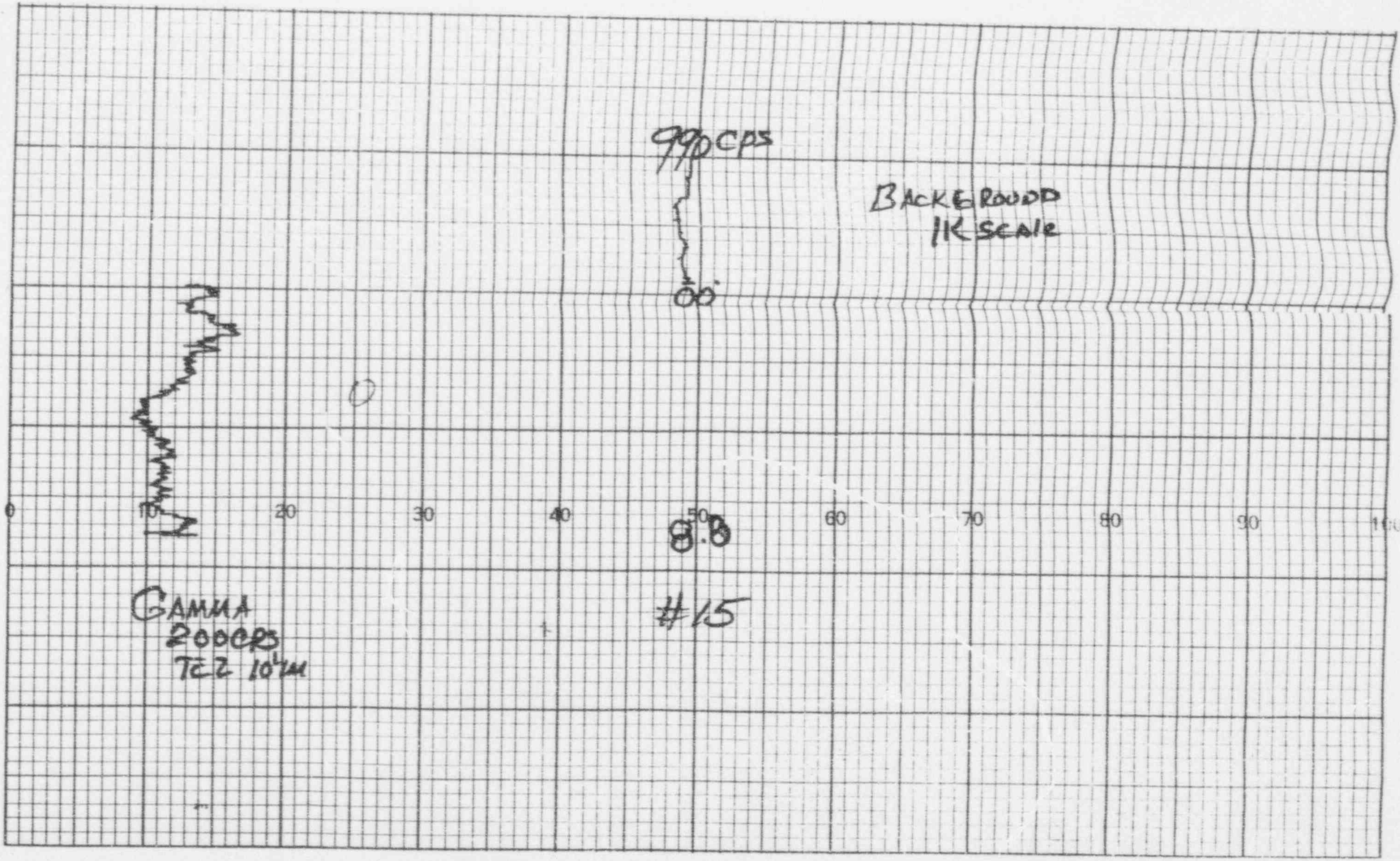
.7E

.77

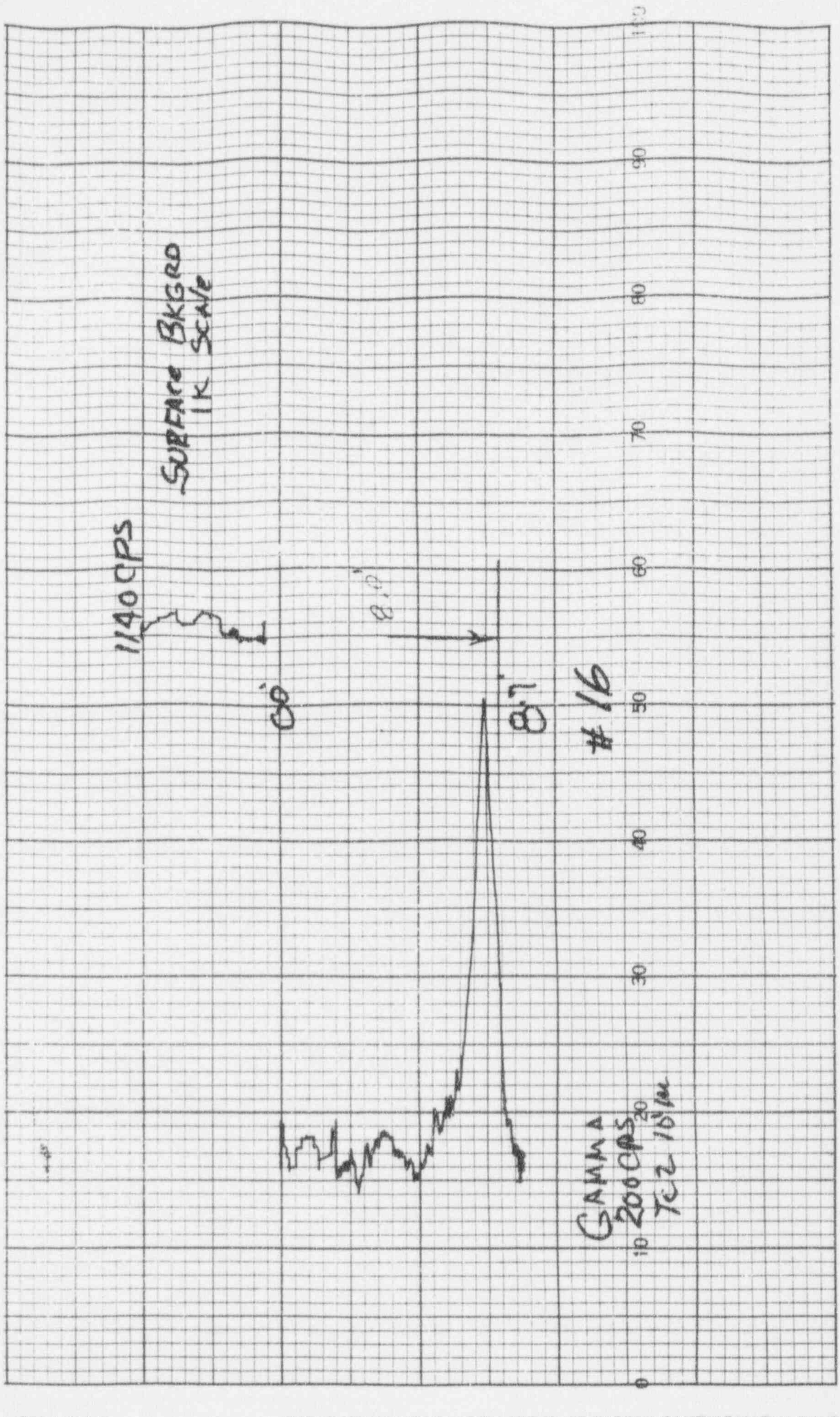

305cps
SURFACE BKGRD
200cps
Scale
00'
0
8.5
#13
GAMMA
200cps
TC 2 10ft/in
0
10
30
40
50
60
70
80
90
100
TE
MADE IN U.S.A.
WH-7

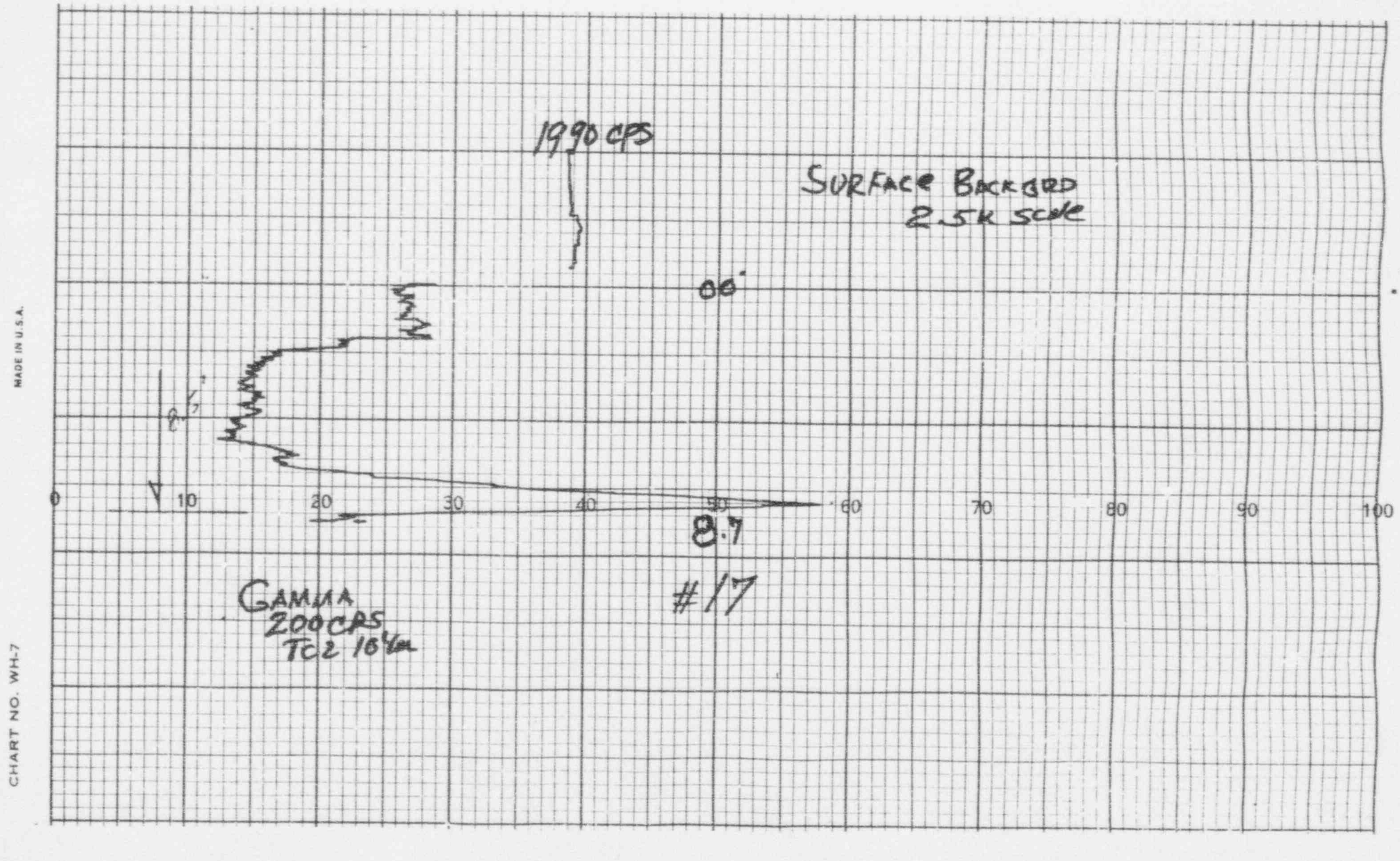

T1
MADE IN U.S.A.
0
10
20
30
40
50
60
70
80
90
100
390 CPS
SURFACE BKGRD
500 SCALE
00'
60
#14
GAMMA
208CPS
TC2 10'/M

.7E

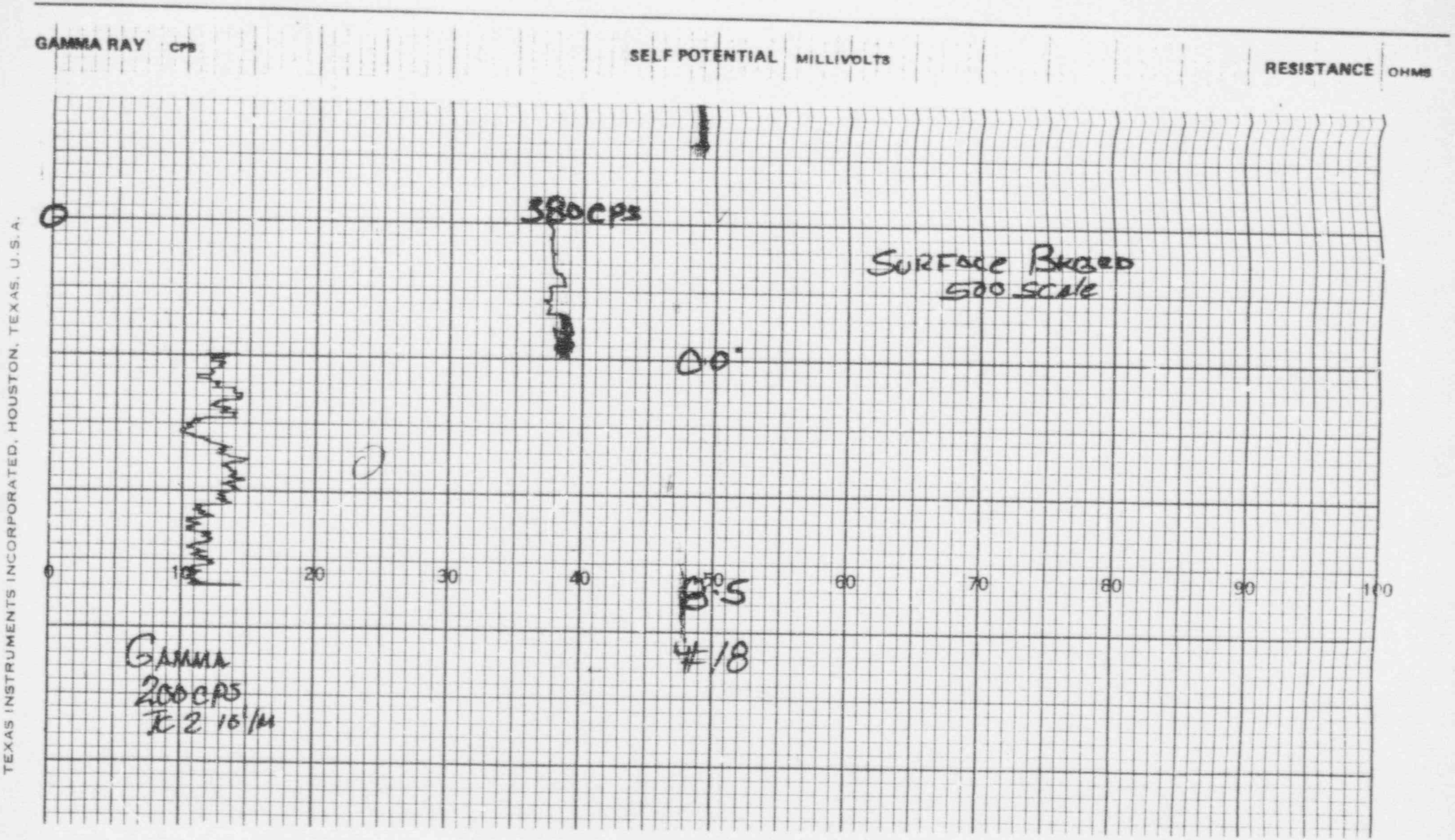


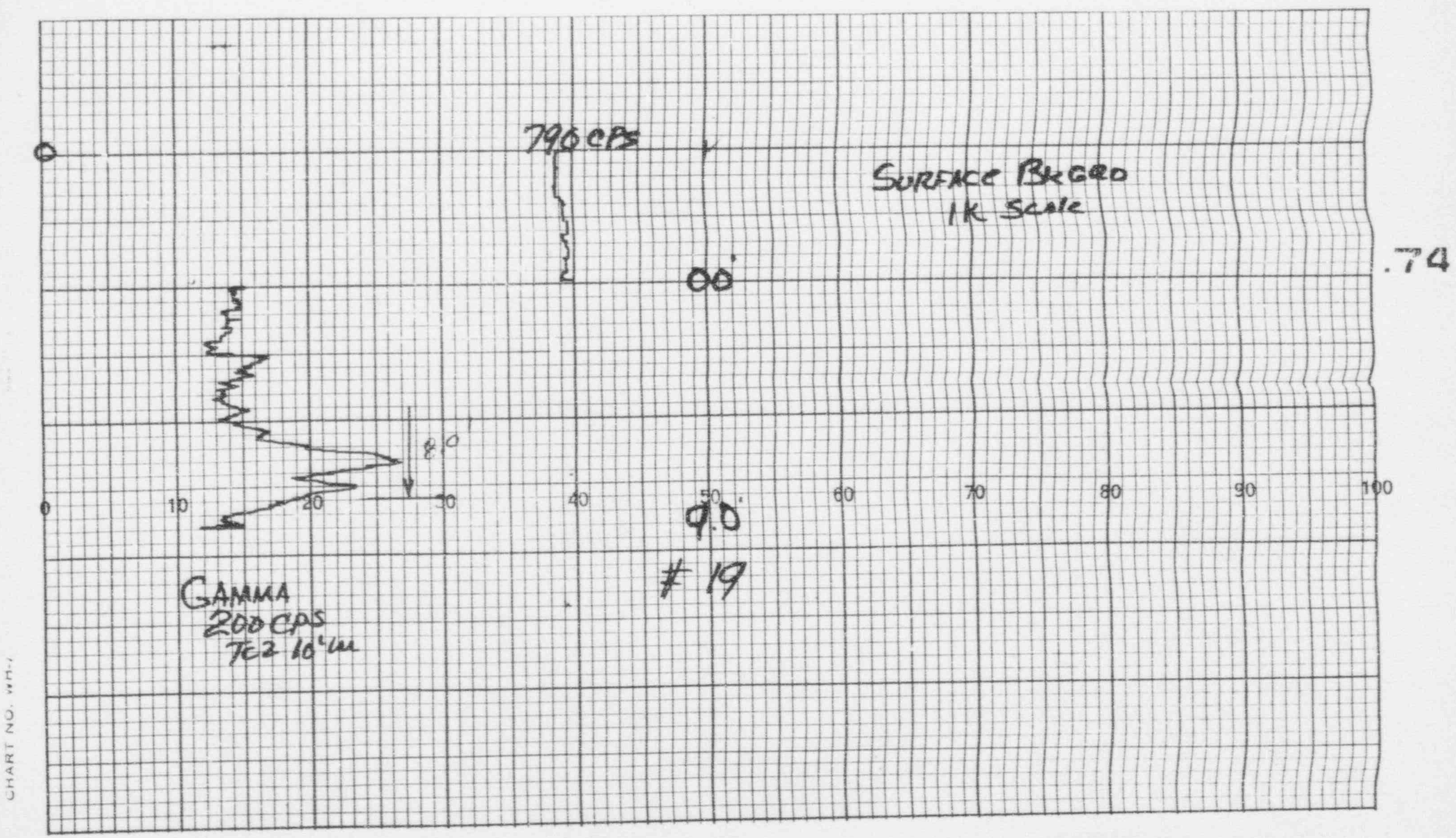
TEXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.


1140 CPS
SURFACE BKGRD
1K SCALE
0.0'
8.0'
8.7'
#16
GAMMA
200 CPS
TC2 10'/m
0
10
20
30
40
50
60
70
80
90
100
EXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.
CHART NO.

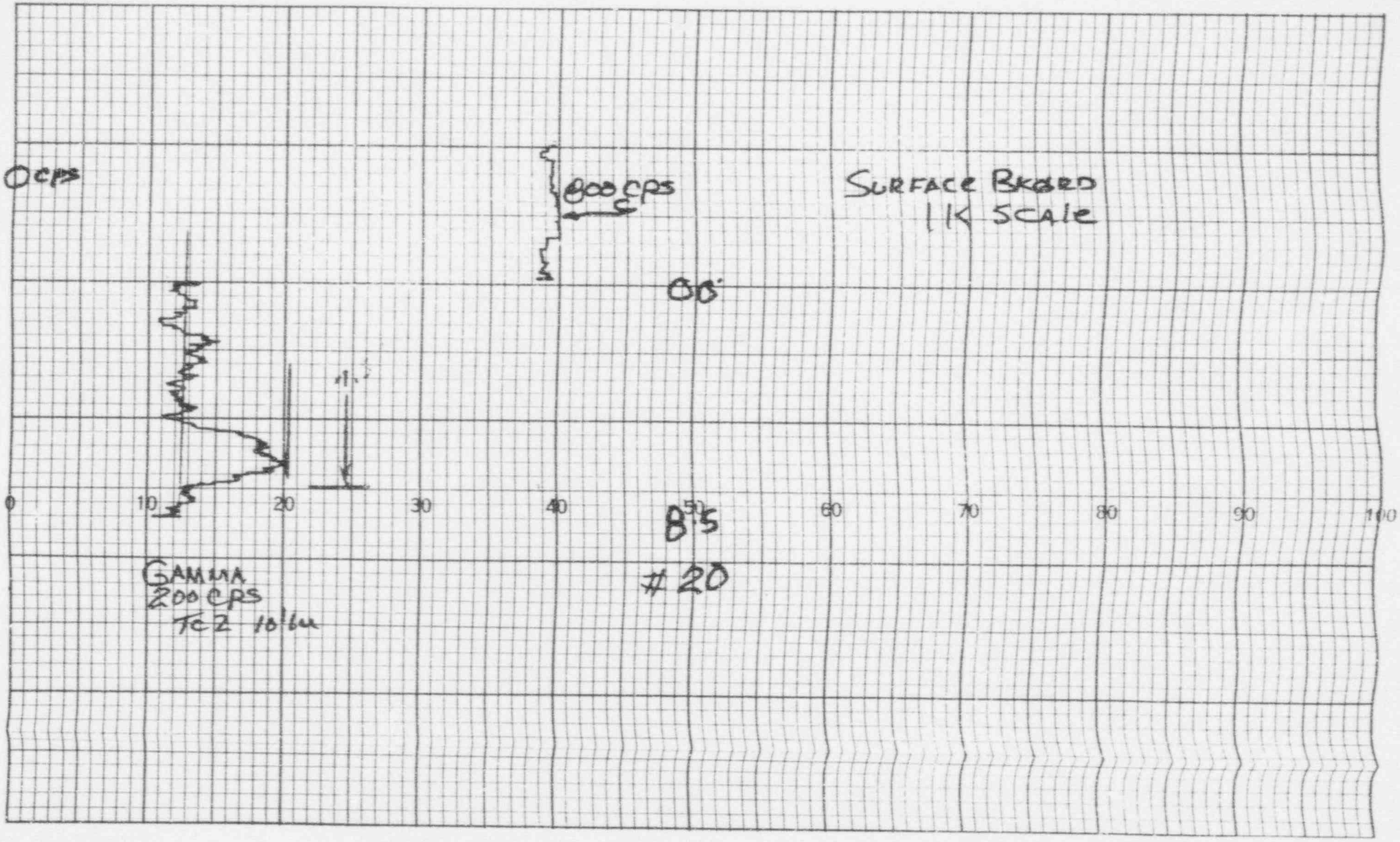

1990 CPS
SURFACE BACKGRD
2.5K scale
.00
0
10
20
30
40
50
60
70
80
90
100
8.7
#17
GAMMA
200 CPS
TC2 16"/m
MADE IN U.S.A.
CHART NO. WH-7

.75


GAMMA RAY CPS
SELF POTENTIAL MILLIVOLTS
RESISTANCE OHMS
0
10
20
30
40
50
60
70
80
90
100
0
380CPS
SURFACE BKGD
500 SCALE
00'
B-5
#18
GAMMA
200CPS
TC 2 10'/M
TEXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.


790 CPS
SURFACE BKGRD
1K Scale
.74
00
8.0
9.0
19
GAMMA
200 CPS
TC2 10"/M
0
10
20
30
40
50
60
70
80
90
100
CHART NO. WH-7

TEXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.



4765 INDEPENDENCE STREET
WHEAT RIDGE (DENVER), CO 80033
(303) 422-5478

NUCLEAR LOGGING SERVICE, INC.

BOX 670
NUCLA, CO 81424
(303) 864-2213

COMPANY: DAMES & MOORE
PROJECT AREA: ATLAS MILL SITE
HOLE NO: 21 THRU 45
DATE: 24 July 1987
COUNTY: GRAND
STATE: UTAH
SECTION: TWN: RNG:
ELEVATION:

–CALIBRATION–

.5 FT. K FACTOR (AIR)
WATER FACTOR CASING FACTOR
DEAD TIME: μ SEC.
PROBE NO. 771
PROBE DIAMETER: 1¼ IN.
5" = FULL SCALE

–HOLE DATA–

DRILLING CONTRACTOR:
DRILL NO:
DEPTH DRILLED: FT.
HOLE DIAMETER: 4.0 W/2.0" PVC IN.
DRILLING FLUID: AUGER
FLUID LEVEL: FT.
DEPTH LOGGED: FT.
TOTAL FOOTAGE LOGGED: FT.

INITIAL RUN

GAMMA–FULL SCALE 200 CPS
TIME CONSTANT 2 SEC.
LOGGING SPEED: 20 FT./MIN.
RESISTANCE OHMS/DIV.
SELF POTENTIAL: MV/DIV.

GAMMA RERUNS

SCALE: CPS.	SCALE: CPS.
TIME CONSTANT SEC.	TIME CONSTANT SEC.
LOGGING SPEED: 5 FT./MIN.	LOGGING SPEED: 5 FT./MIN.
FROM: FT.	FROM: FT.
TO: FT.	TO: FT.
TOTAL: FT.	TOTAL: FT.

DENSITY

SCALE: CPS.
TIME CONSTANT SEC.
LOGGING SPEED: FT./MIN.
FROM: FT.
TO: FT.
TOTAL: FT.

TOTAL DEPTH FT.
UNIT NO: 15
OPERATOR: T. FREEMAN
DRIVE 4.0 HRS.
STANDBY: HRS. TIME IN:
LOGGING 5.0 HRS. TIME OUT:
TOTAL: 9.0 HRS.
ROUND TRIP MILEAGE: 175 MILES

GAMMA RERUNS

SCALE: CPS.	SCALE: CPS.
TIME CONSTANT SEC.	TIME CONSTANT SEC.
LOGGING SPEED: 5 FT./MIN.	LOGGING SPEED: 5 FT./MIN.
FROM: FT.	FROM: FT.
TO: FT.	TO: FT.
TOTAL: FT.	TOTAL: FT.

NEUTRON–NEUTRON

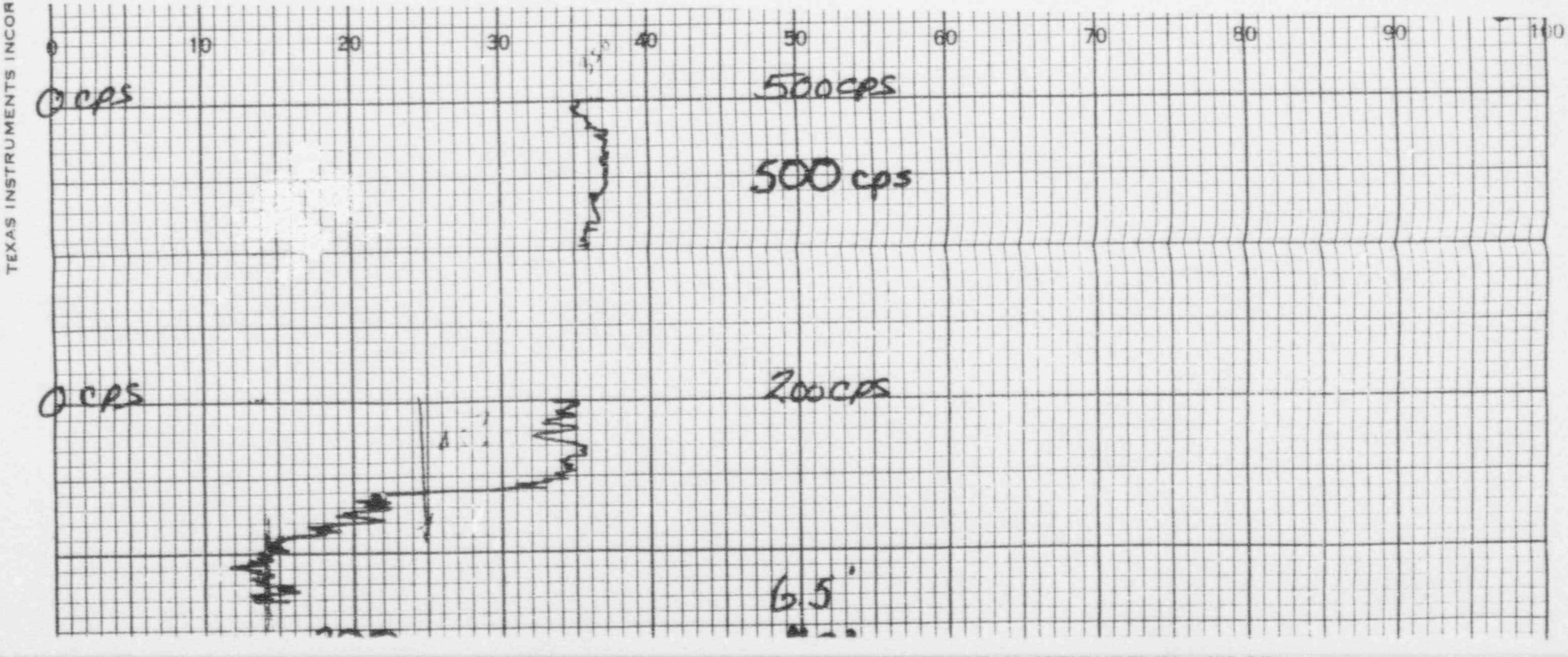
SCALE: CPS.
TIME CONSTANT SEC.
LOGGING SPEED: FT./MIN.
FROM: FT.
TO: FT.
TOTAL: FT.

REMARKS: SURFACE BACKGROUND RECORDED @ EACH HOLE

GAMMA RAY CPS

SELF POTENTIAL MILL:VOLTS

#21


TEXAS INSTRUMENTS INCOR
0
10
20
30
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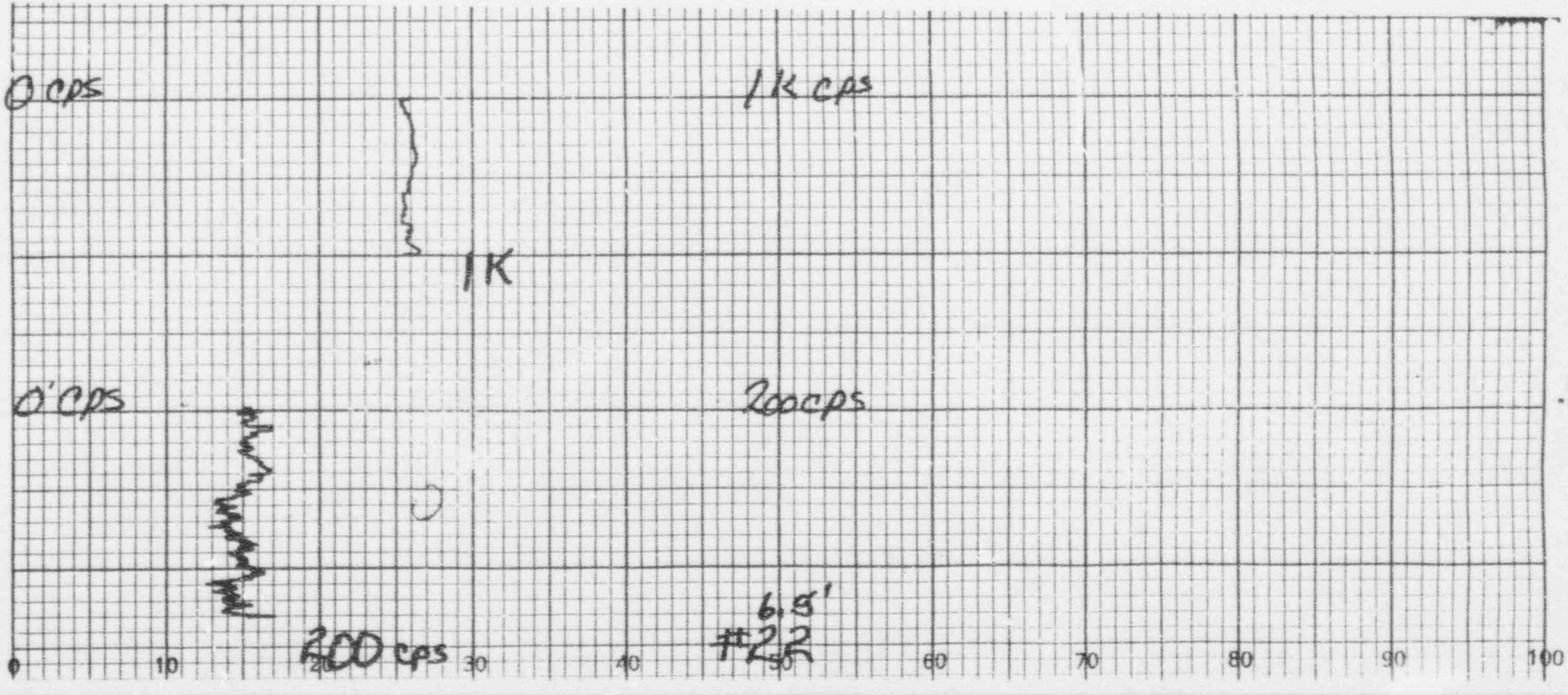
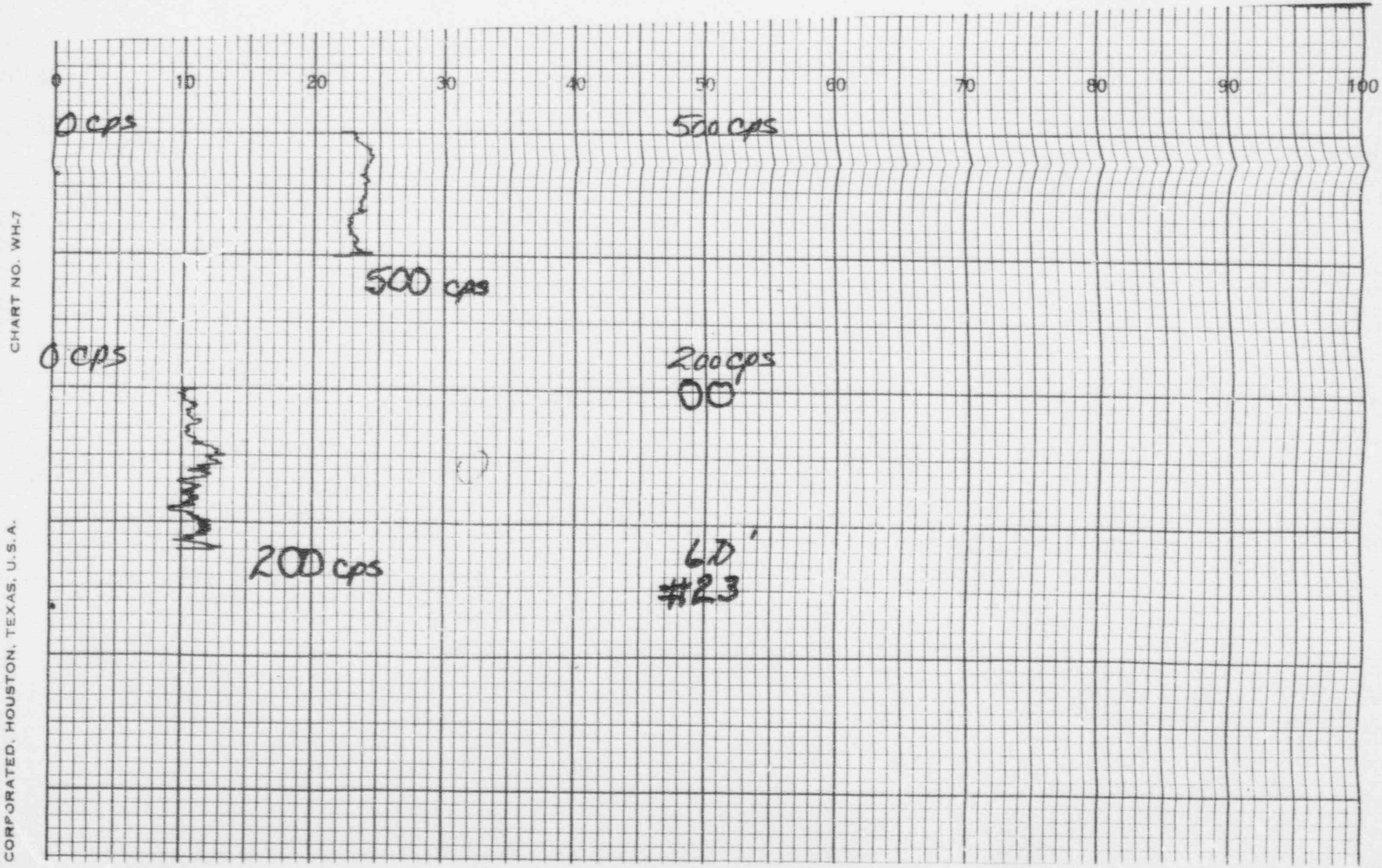
50
60
70
80
90
100
0 cps
500cps
500 cps
0 cps
200cps
6.5'



.57

MADE IN U.S.A.


0
10
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0 cps
500 cps
500 cps
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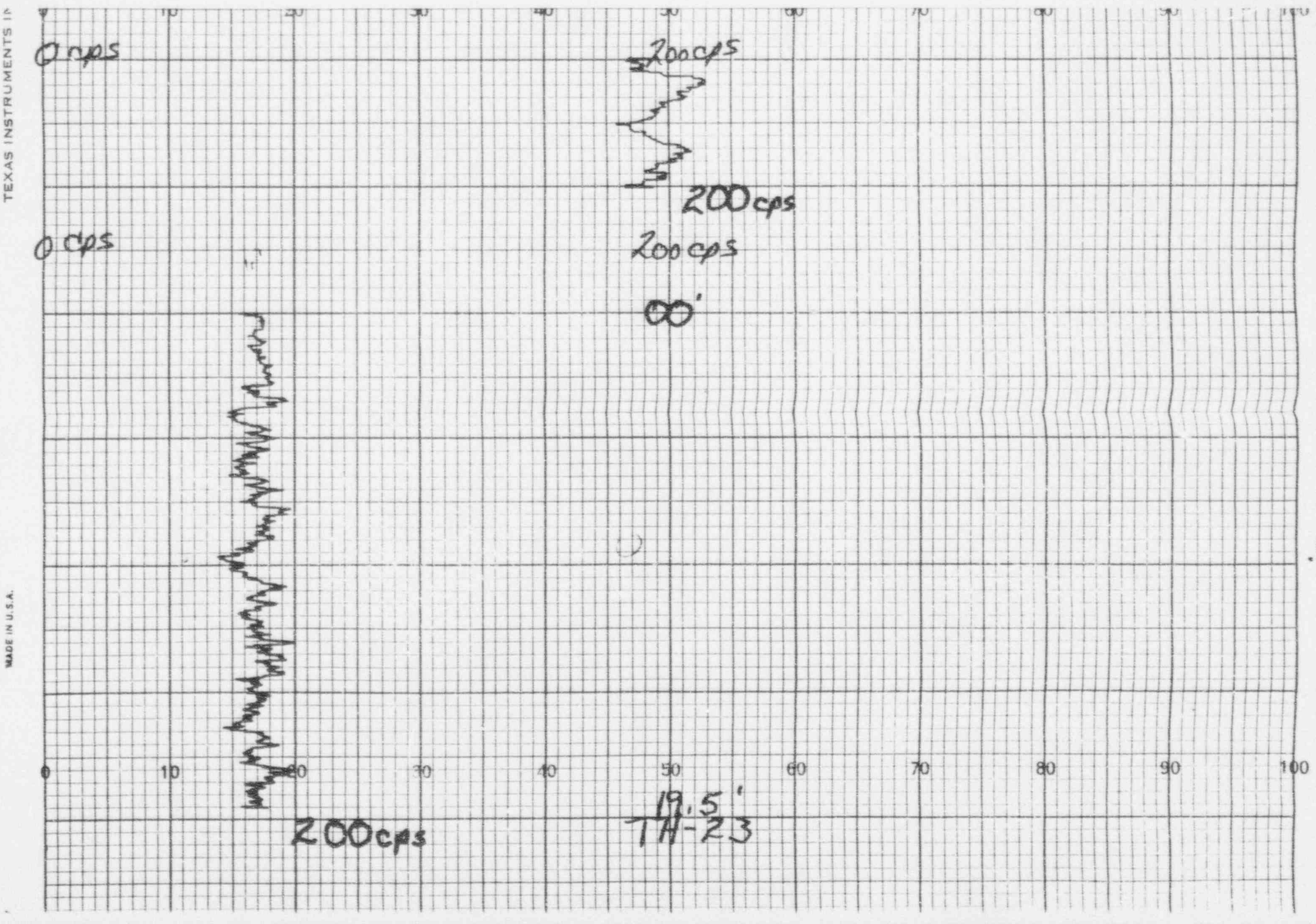
200 cps
00
200 cps
LD'
#23
CHART NO. WH-7
CORPORATED, HOUSTON, TEXAS, U.S.A.


TEXAS INSTRUMENTS IN
MADE IN U.S.A.
0
10
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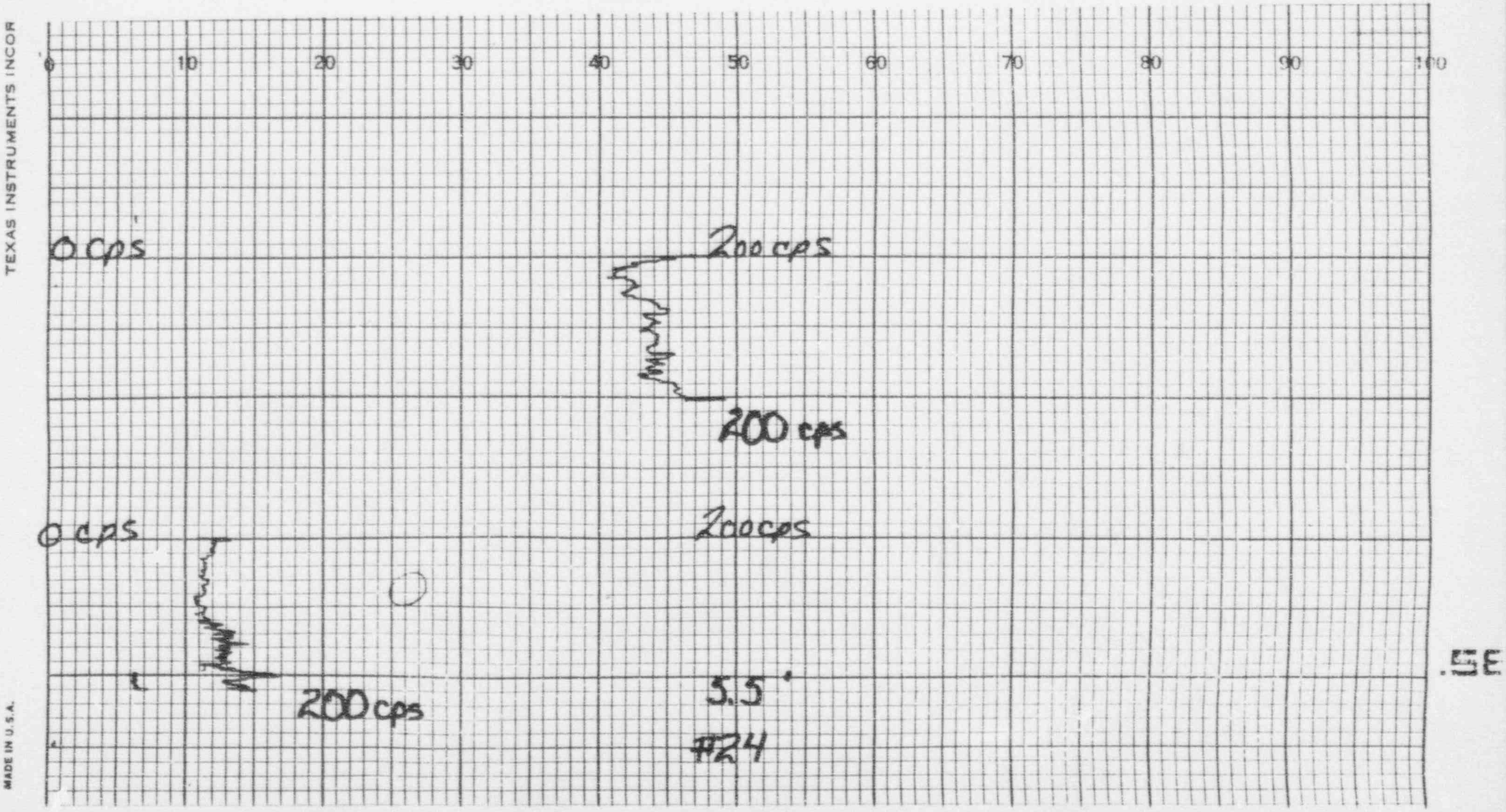
30
40
50
60
70
80
90
100
0 cps
200cps
200cps
0 cps
200cps
8'
19.5'
TH-23
200cps

.59


TEXAS INSTRUMENTS INCOR
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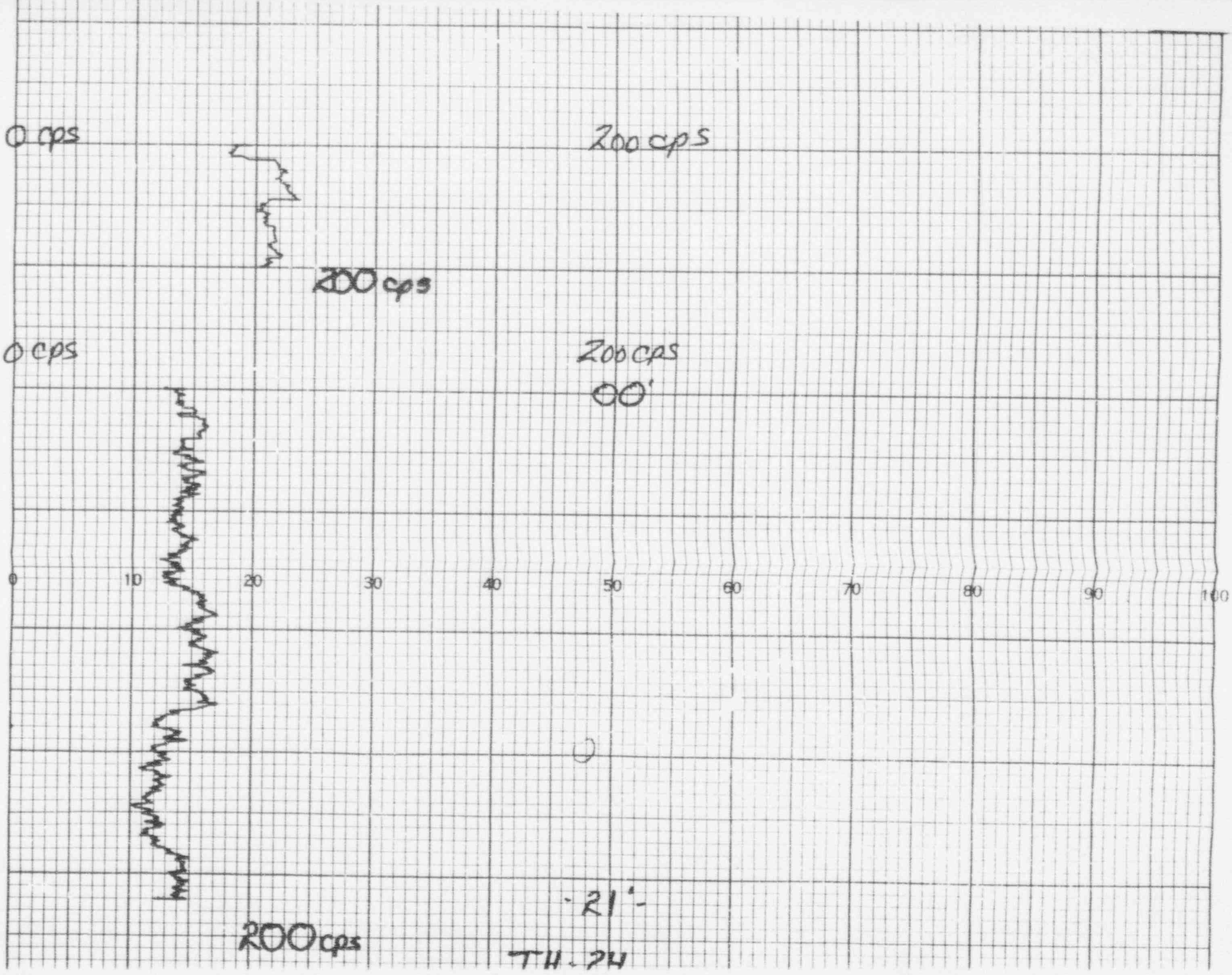
70
80
90
100
0 Cps
200 cps
200 cps
0 cps
200cps
200 cps
5.5'
#24
.5E
MADE IN U.S.A.


0 cps
200 cps
200 cps
0 cps
200 cps
00'
0
10
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40
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60
70
80
90
100
·21'-
200 cps
TH-24

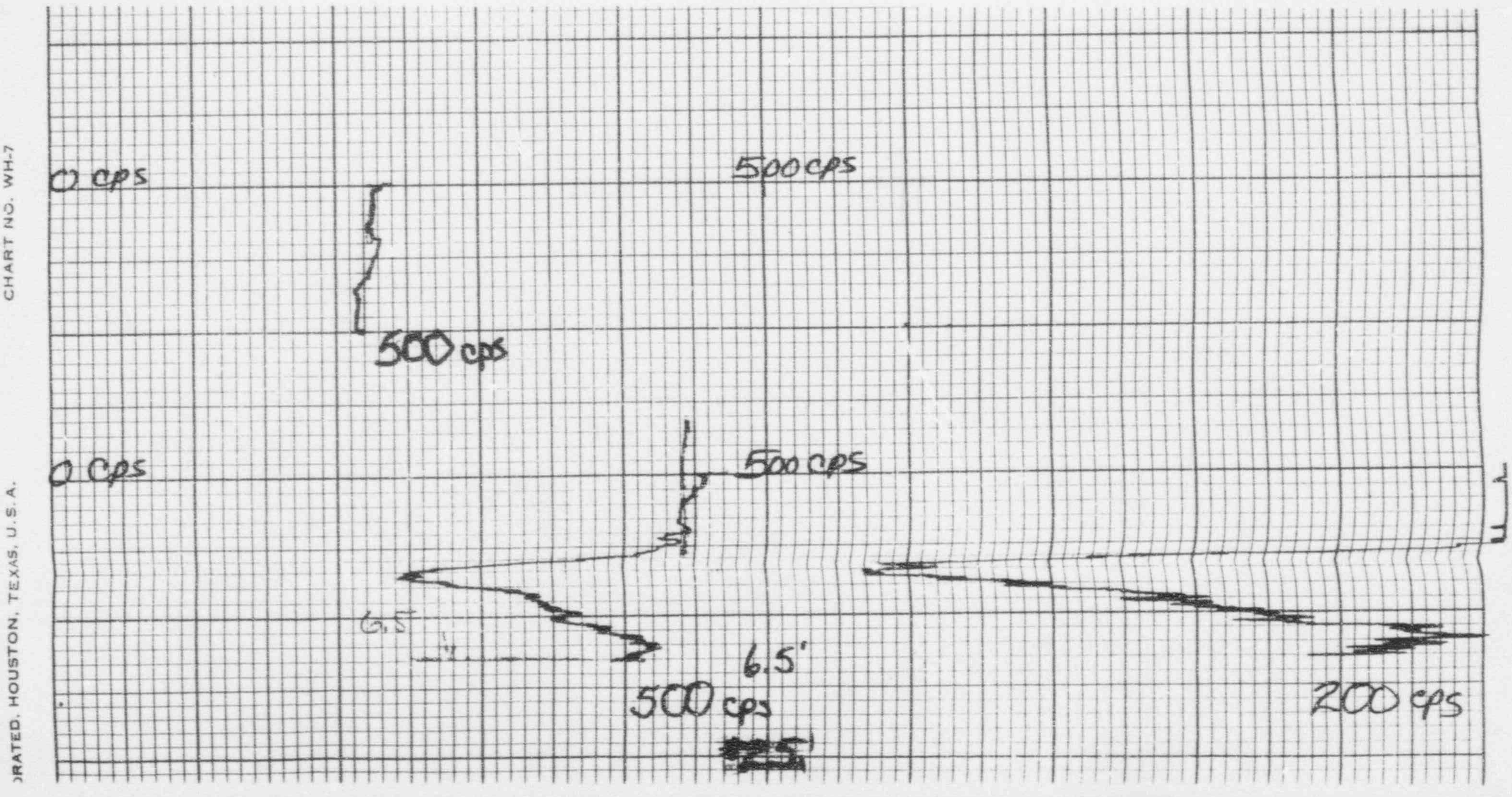
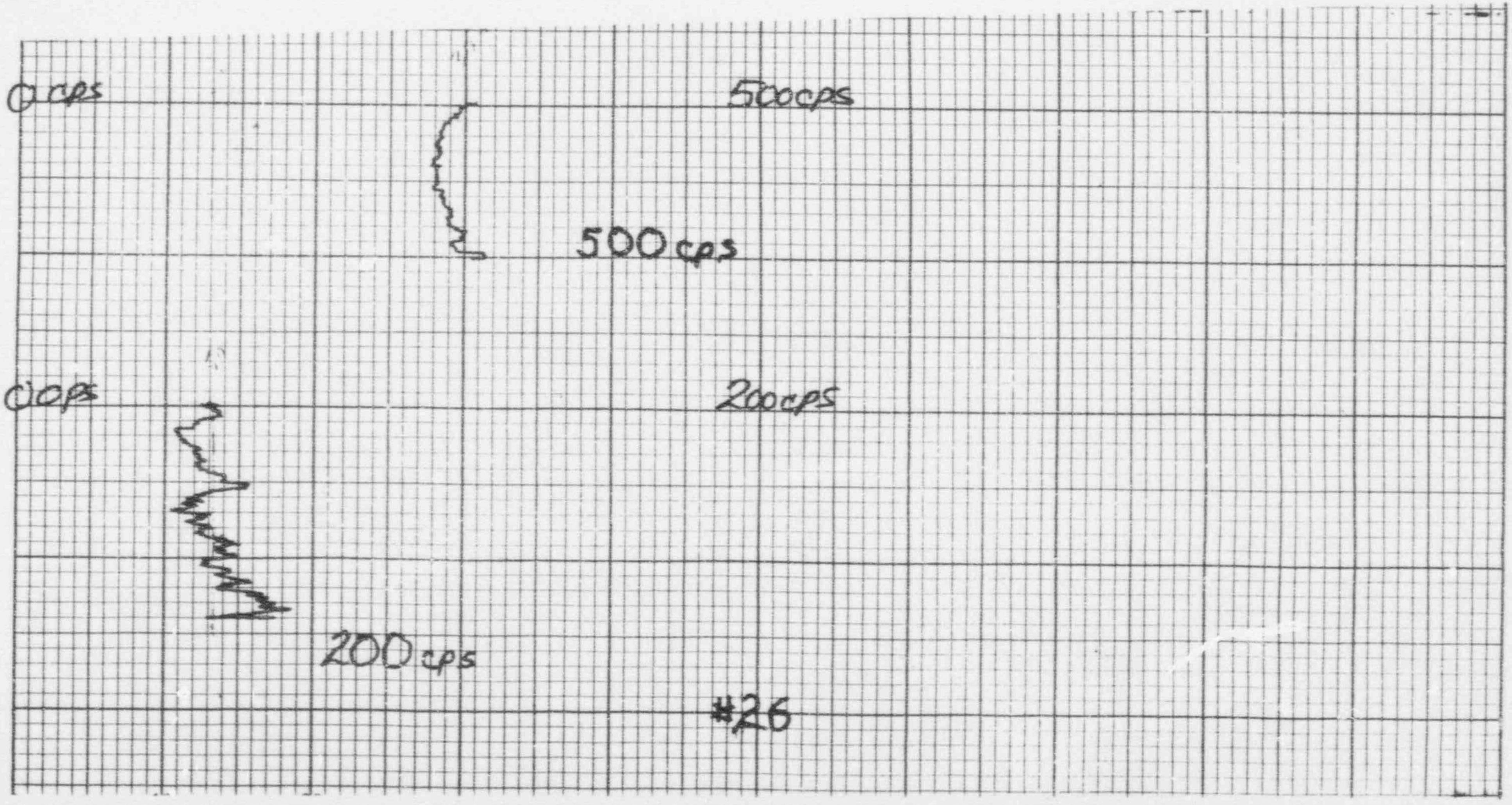


CHART NO. WH-7
…ORATED, HOUSTON, TEXAS, U.S.A.
0 cps
500 cps
500 cps
0 cps
500 cps
6.5
6.5'
500 cps
~~25'~~
200 cps



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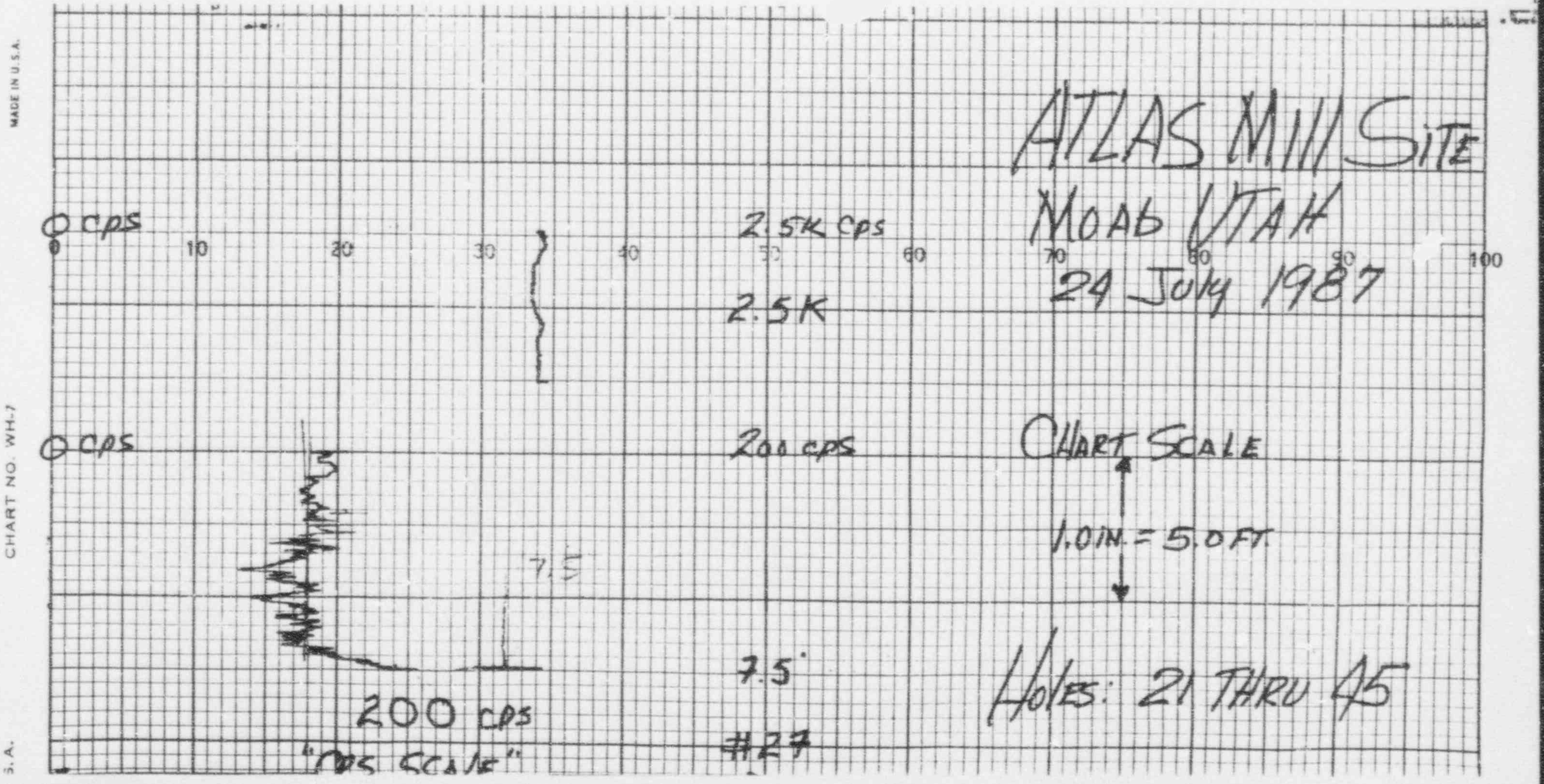
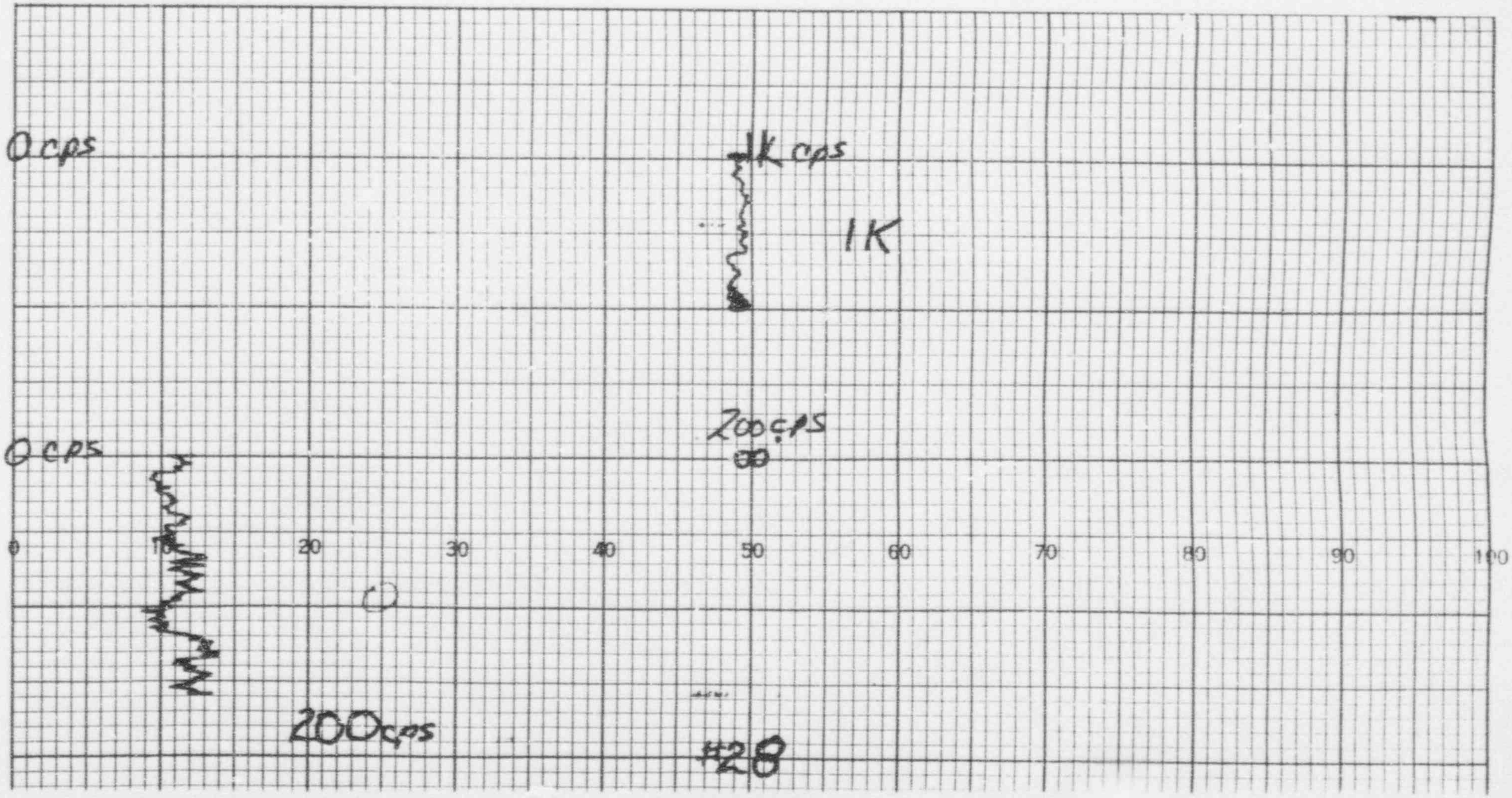
CORPORATED, HOUSTON, TEXAS, U.S.A.



ATLAS Mill Site
Moab UTAH
24 July 1987

CHART SCALE
1.0 IN = 5.0 FT.

Holes: 21 THRU 45



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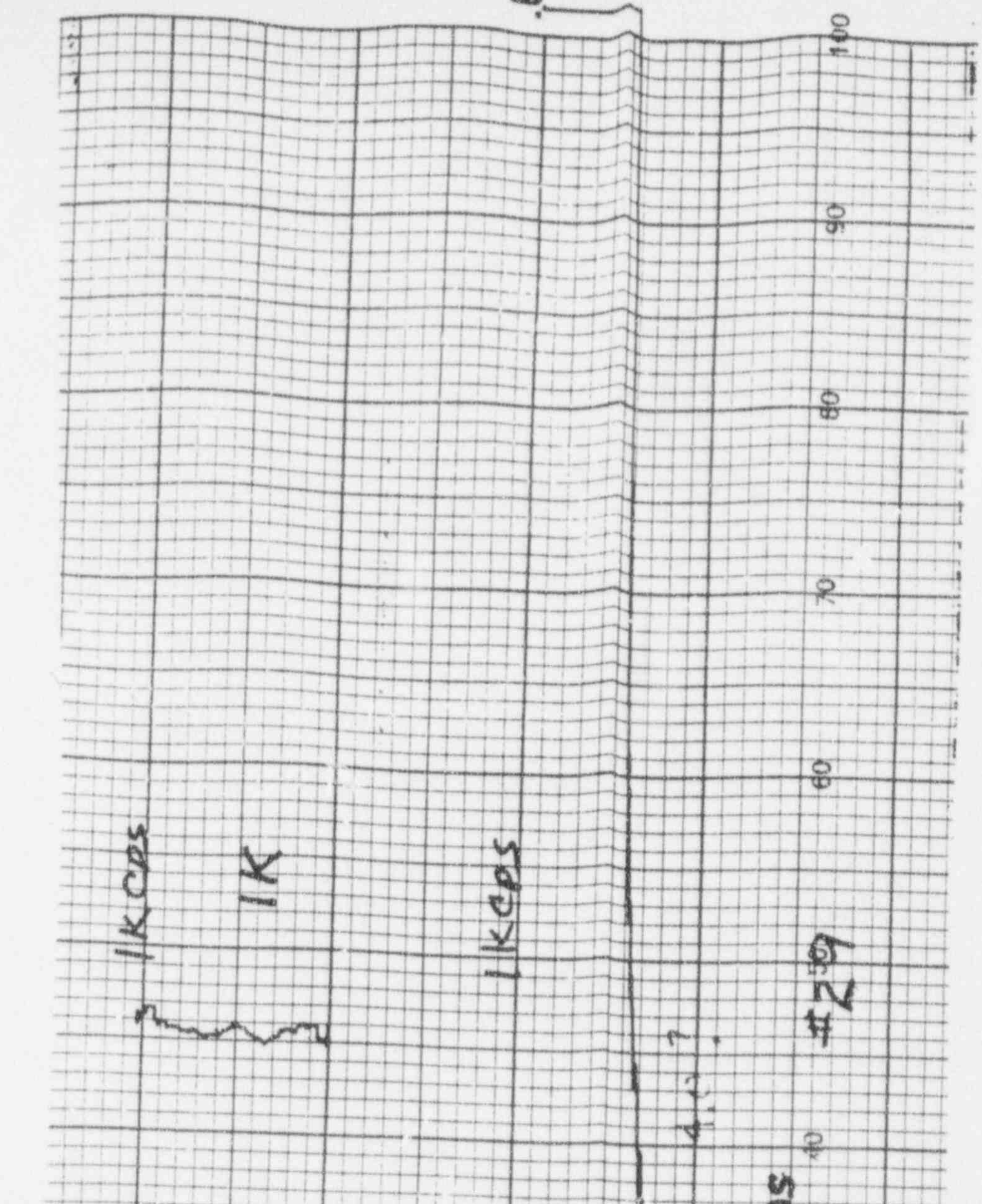
0 cps
1K cps
1K
0cps
1Kcps
1K
200cps
#29
4.0?
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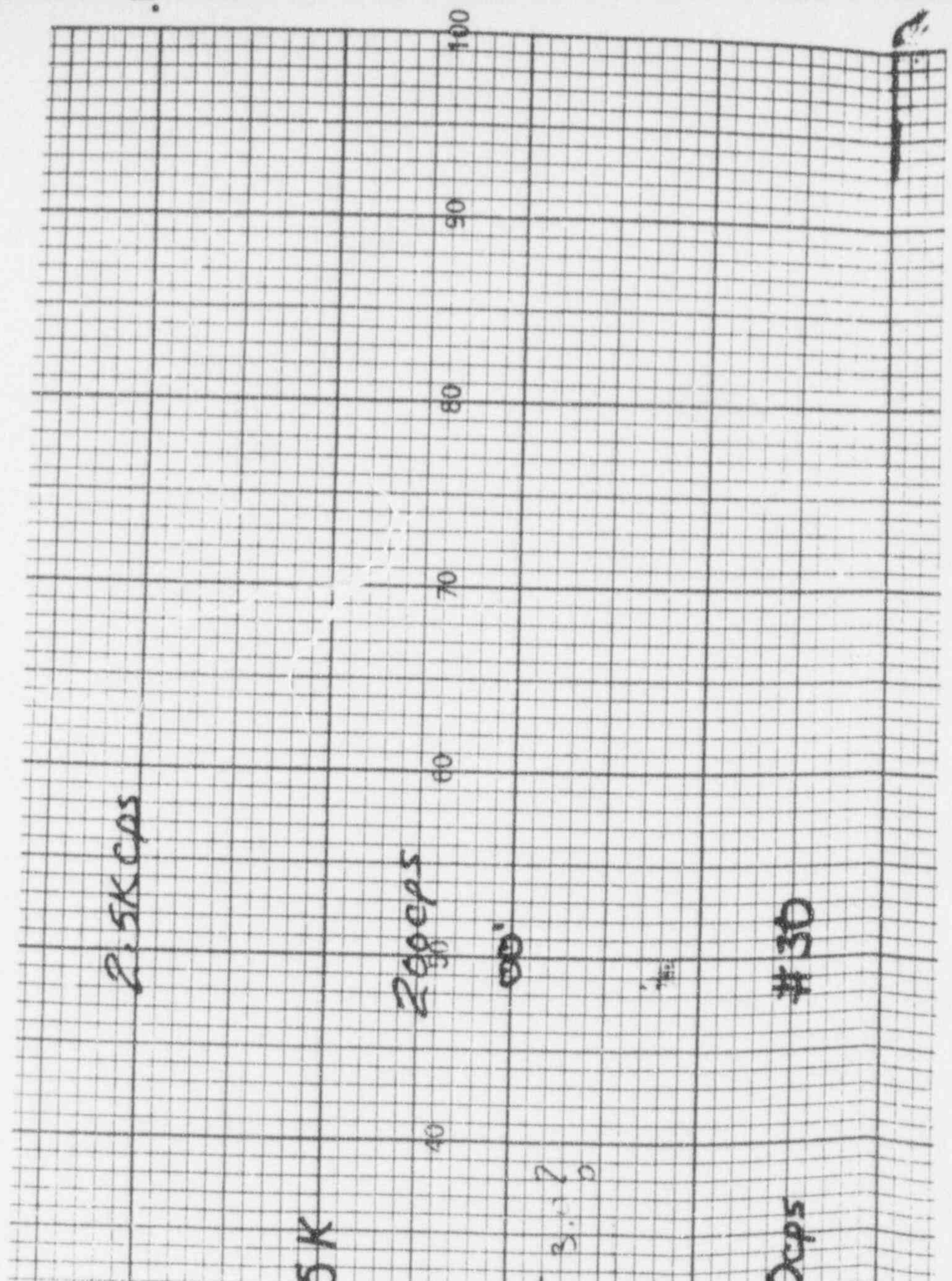
100
MADE IN U.S.A.


0 cps
2.5K cps
2.5K
0 cps
200 cps
200 cps
#3D
10
20
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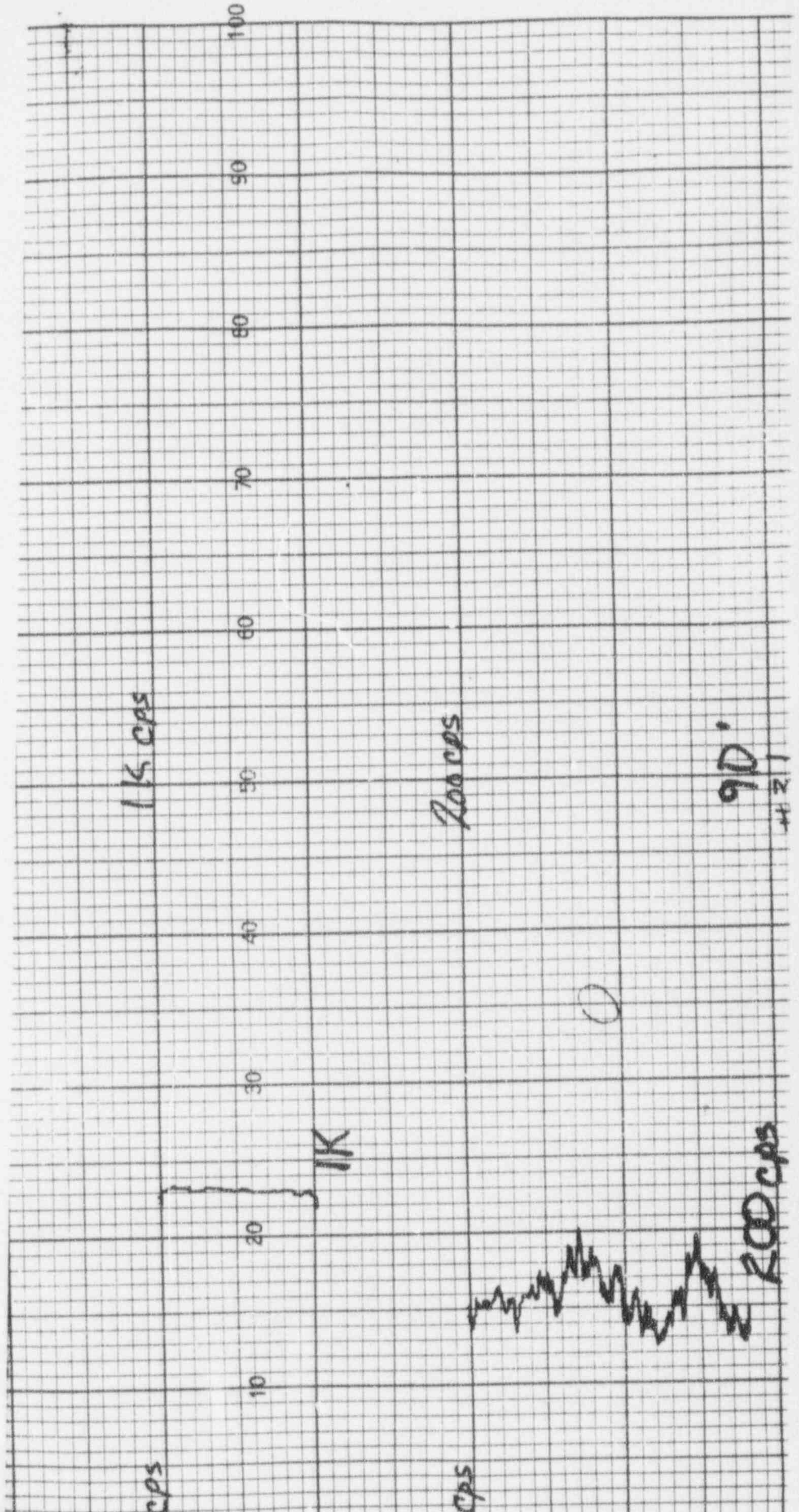
80
90
100
CHART NO. WH-7
MADE IN U.S.A.


0 cps
1.16 cps
1K
0 cps
200 cps
0
800 cps
90'
#21
0
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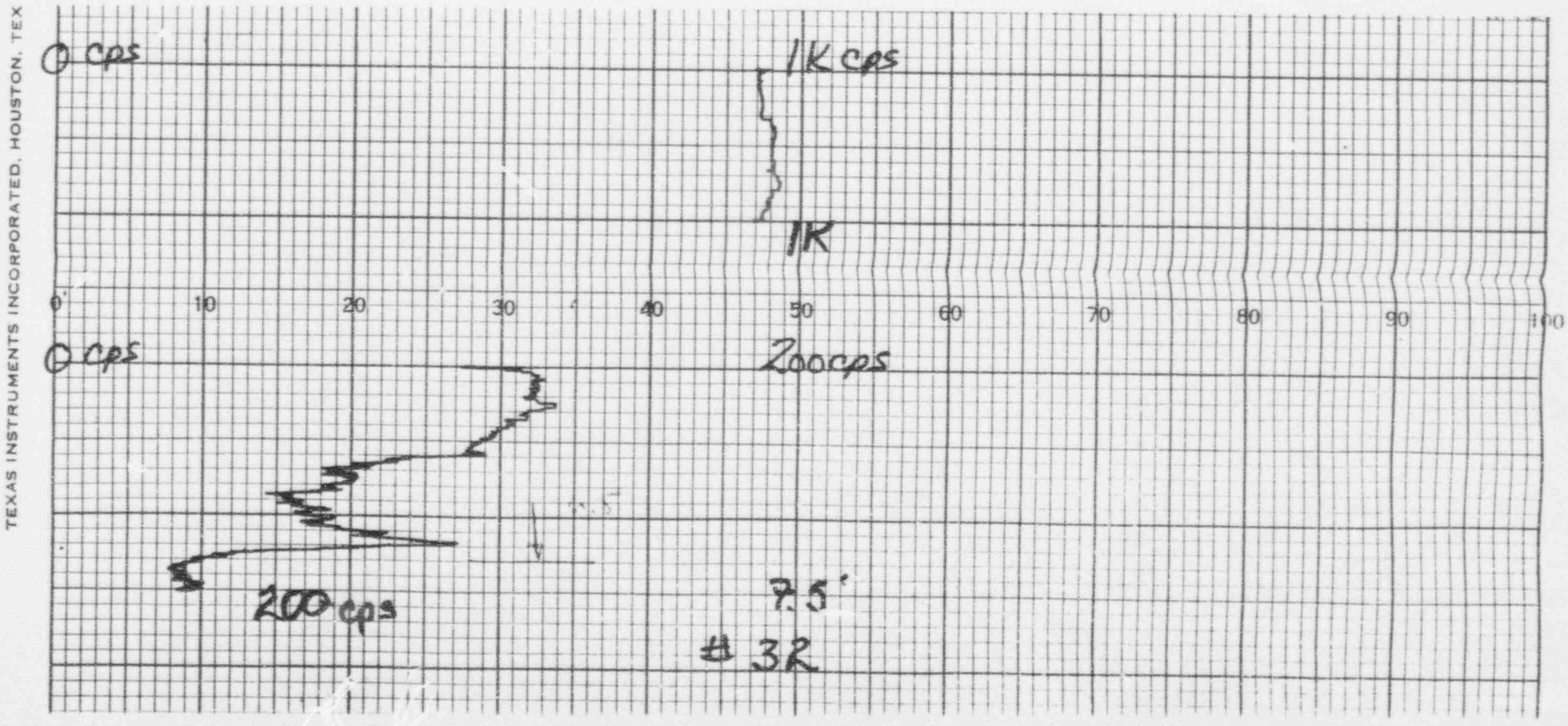
100
CHART NO. WH-7
MADE IN U.S.A.


TEXAS INSTRUMENTS INCORPORATED, HOUSTON, TEX
0 cps
1K cps
1K
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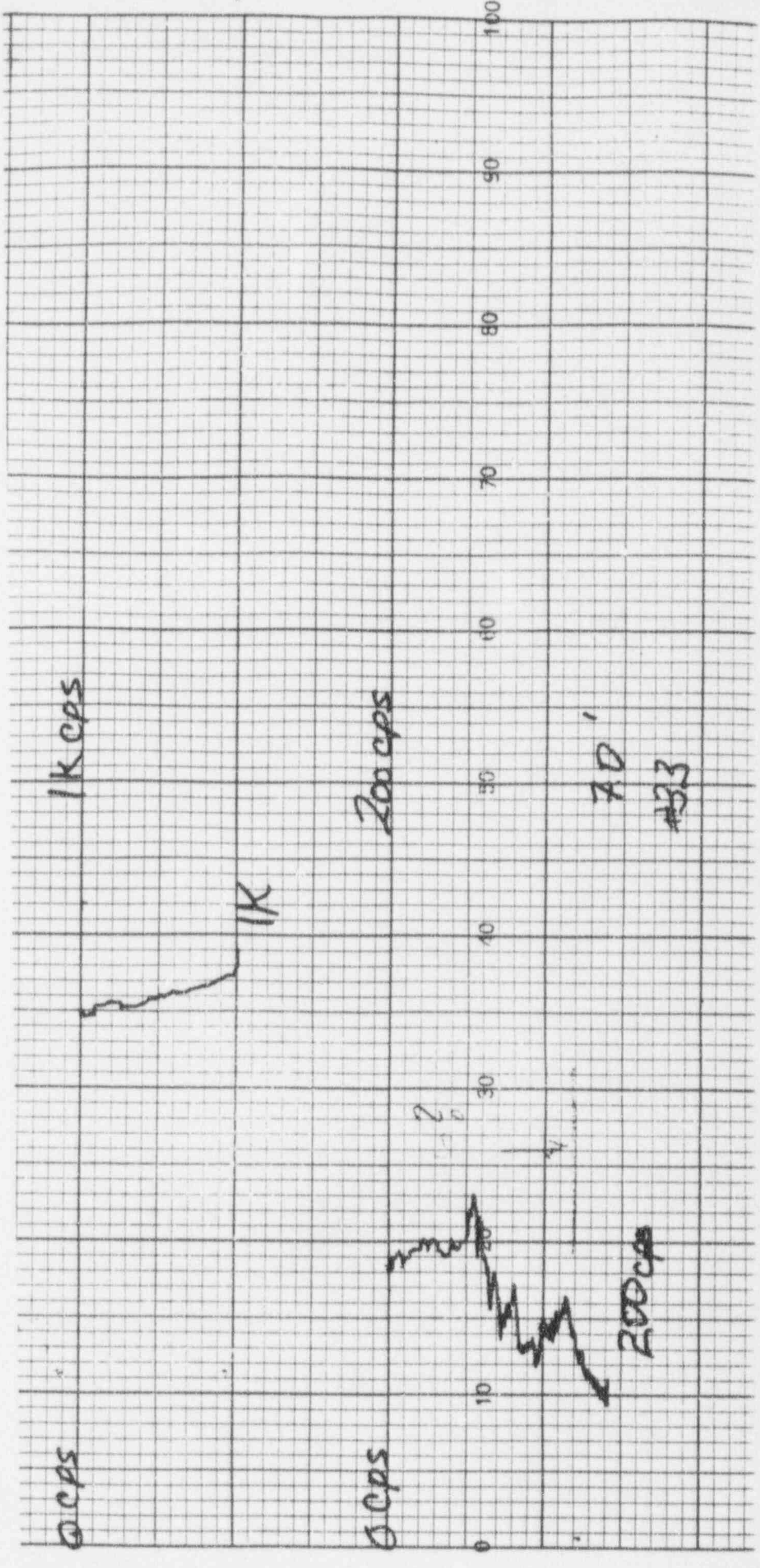
0 cps
200cps
200 cps
7.5'
#3R

.55



0 cps
1K cps
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200 cps
200cps
7D'
#33
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80
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100
MADE IN U.S.A.
T NO. WH-7

34


CHART
S INCORPORATED, HOUSTON, TEXAS, U.S.A.
0 cps
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500cps
0 cps
200cps
200 cps
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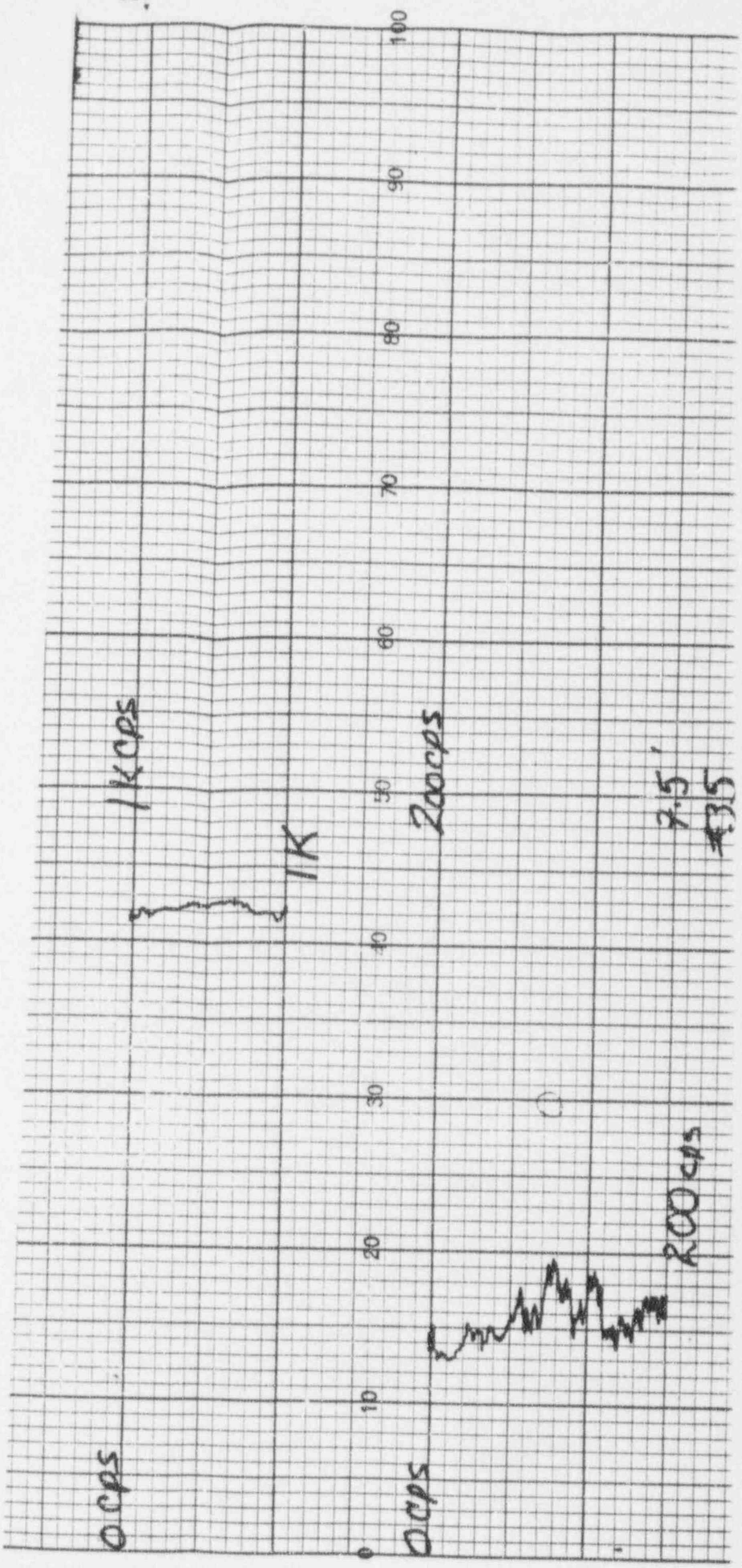
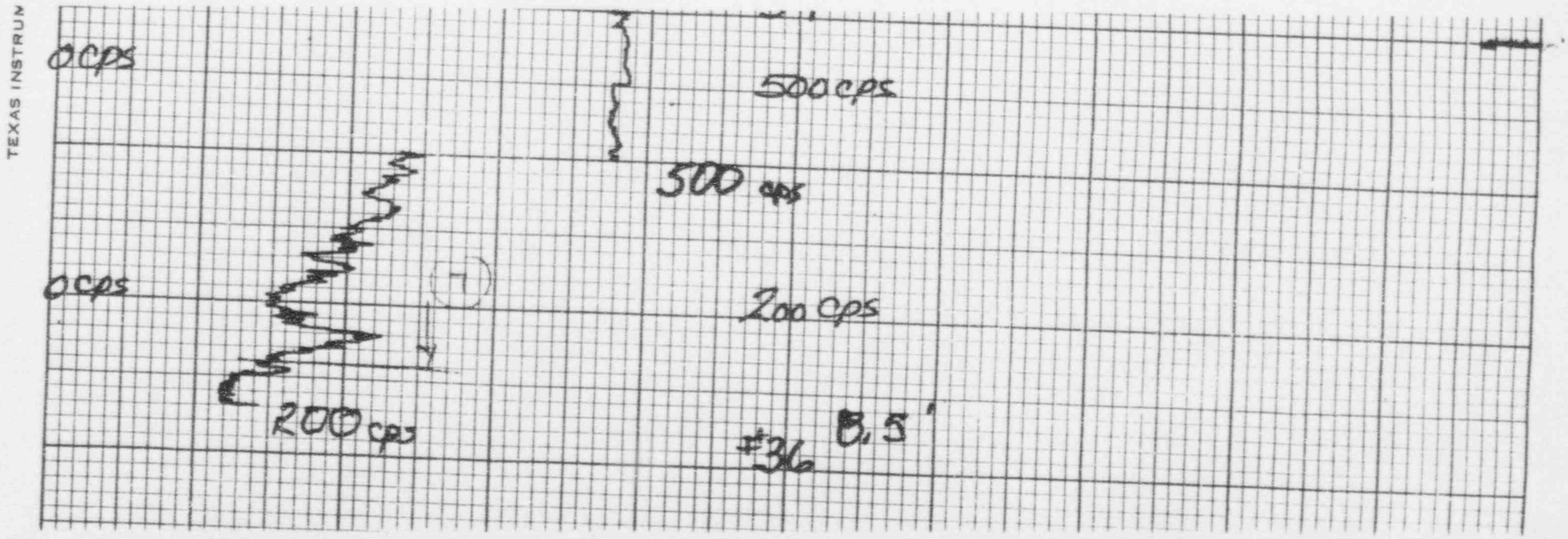
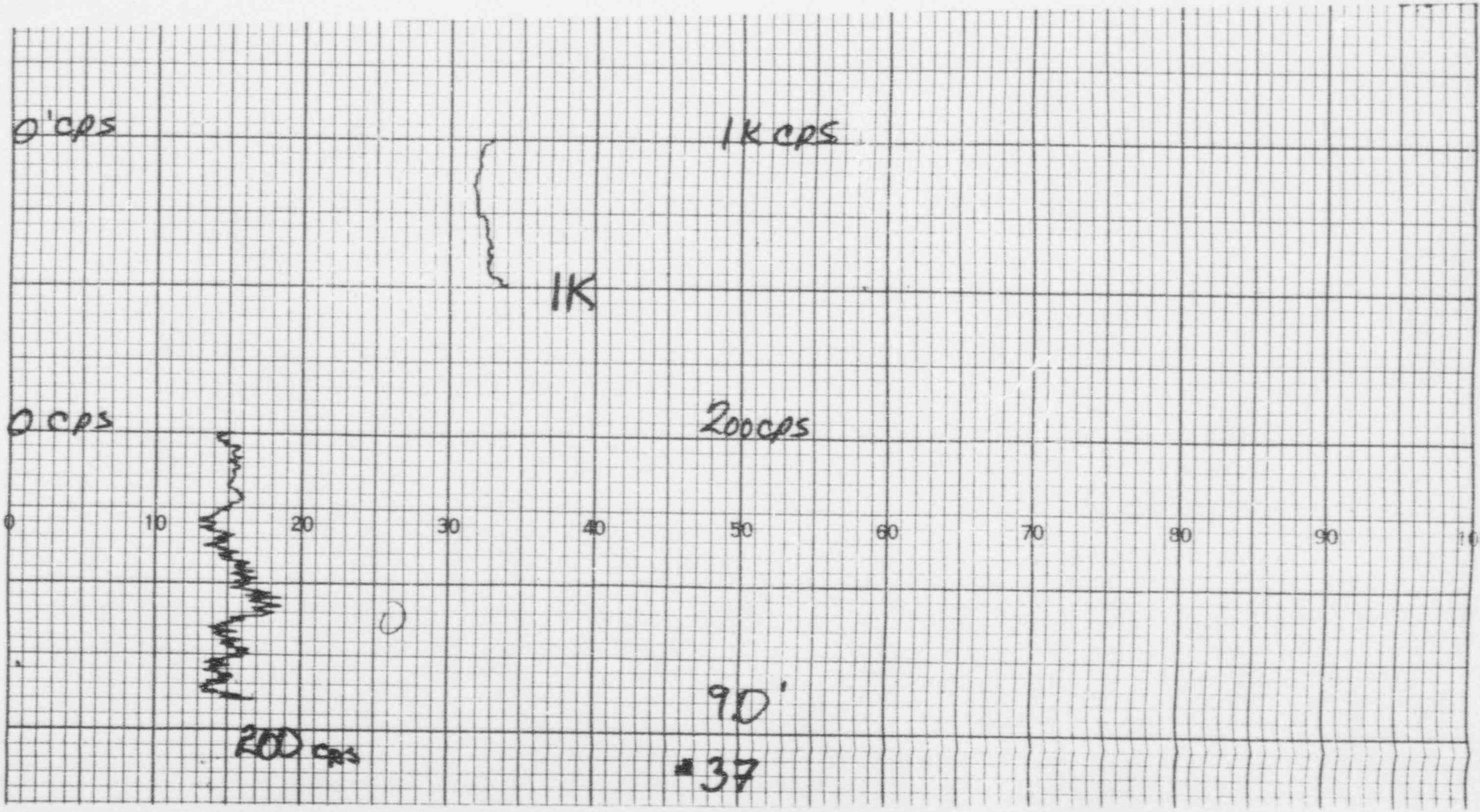


MADE IN U.S.A.

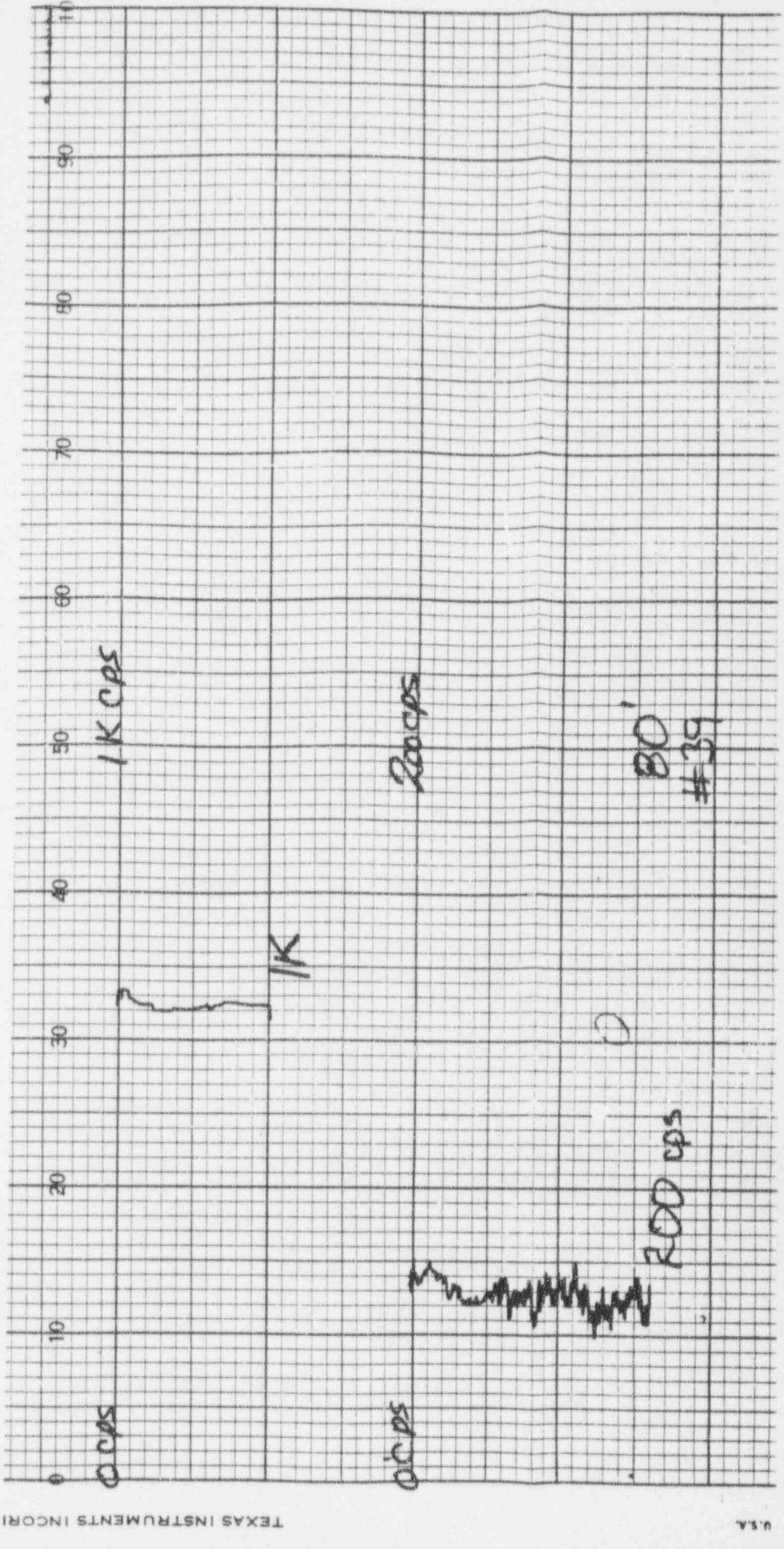
CHART NO. WH-7

TEXAS INSTRUM
0cps
500 cps
500 cps
0cps
200 cps
①
200 cps
#36 8.5'

TEXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.



.54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1K cps
1K
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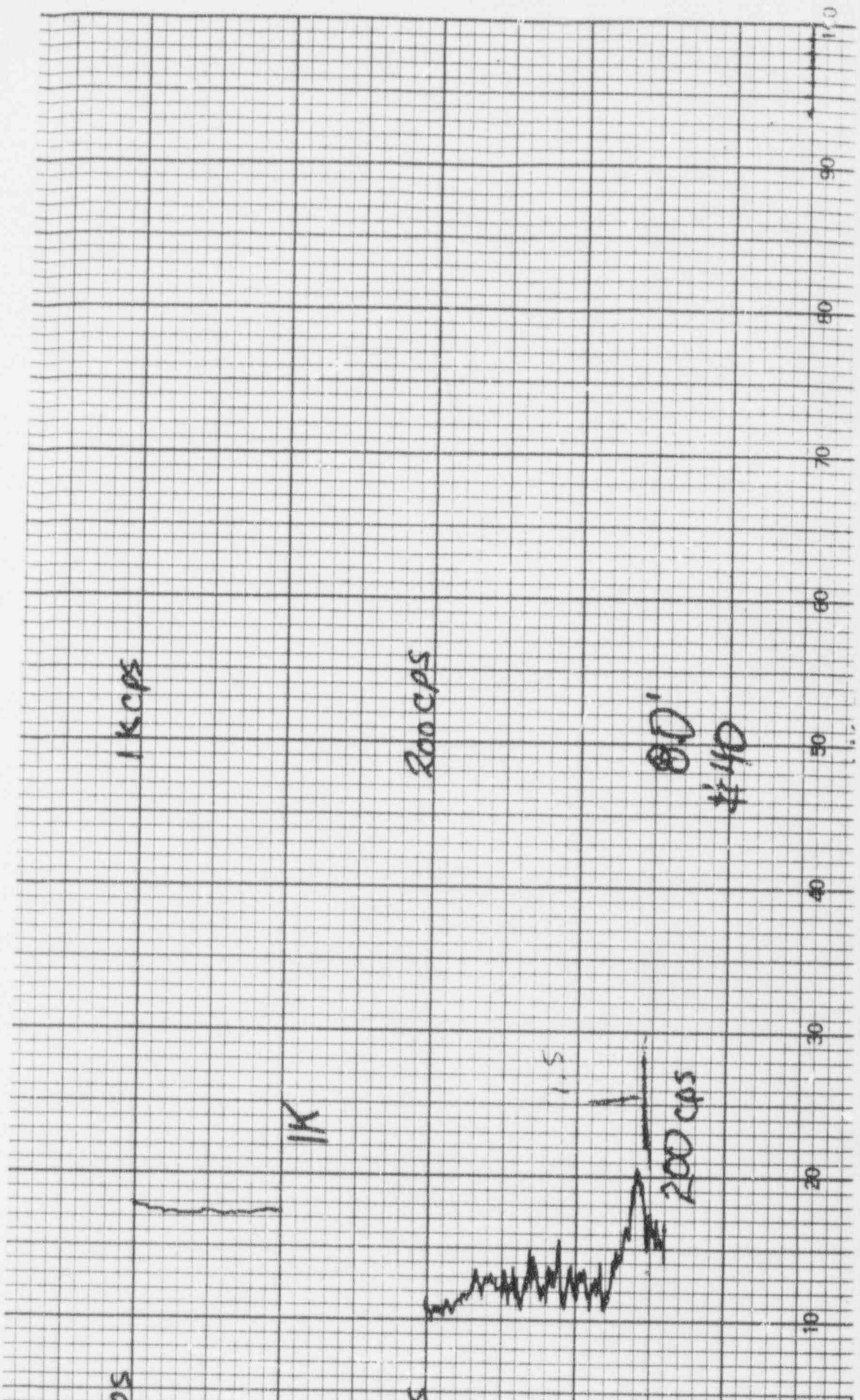
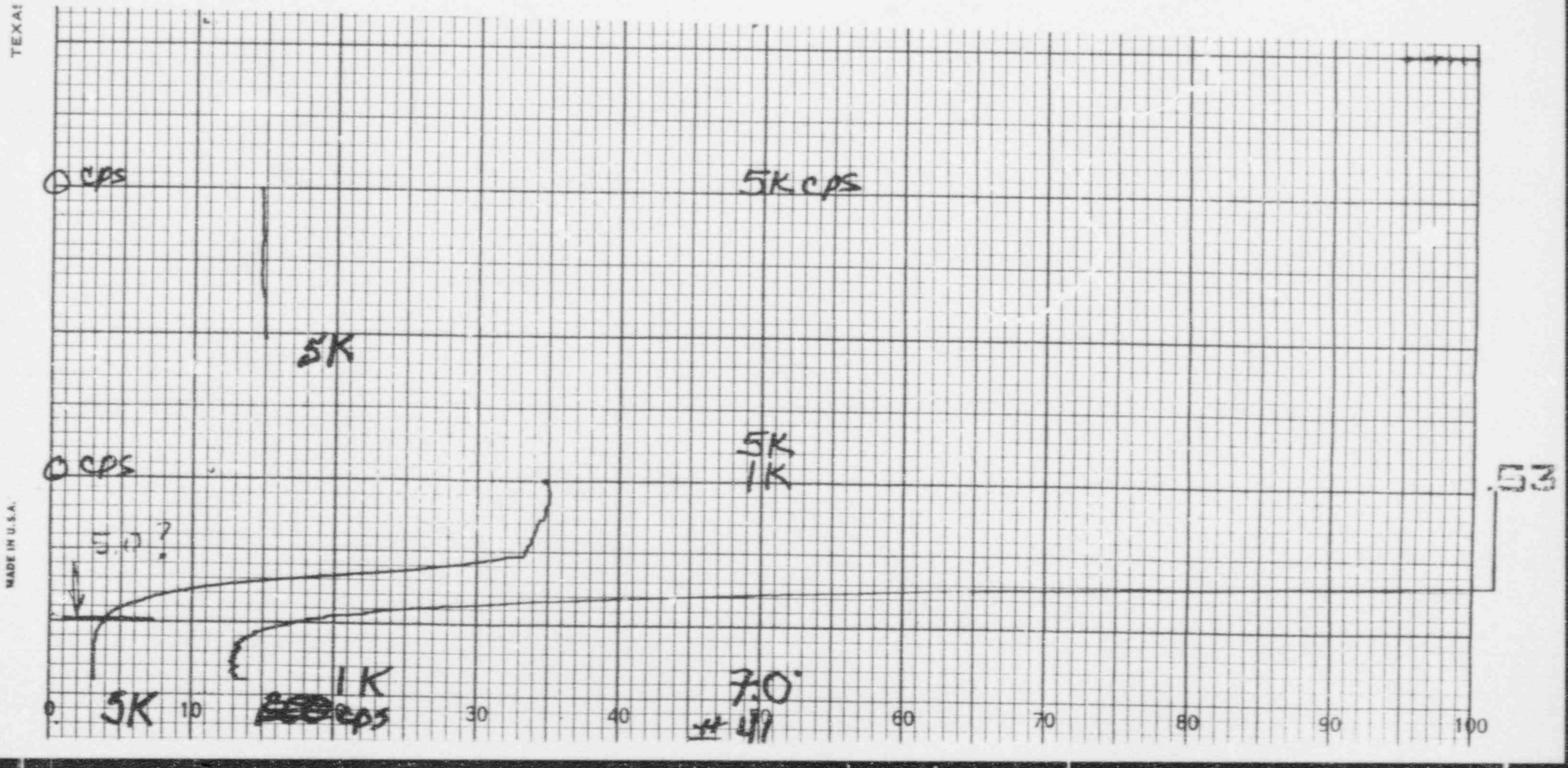
200 cps
200 cps
0
80'
#39
TEXAS INSTRUMENTS INCORP
U.S.A.



TS INCORPORATED, HOUSTON, TEXAS, U.S.A.

CHART NO. WH-7


TEXAS
MADE IN U.S.A.
0 cps
5K cps
5K
0 cps
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5.0 ?
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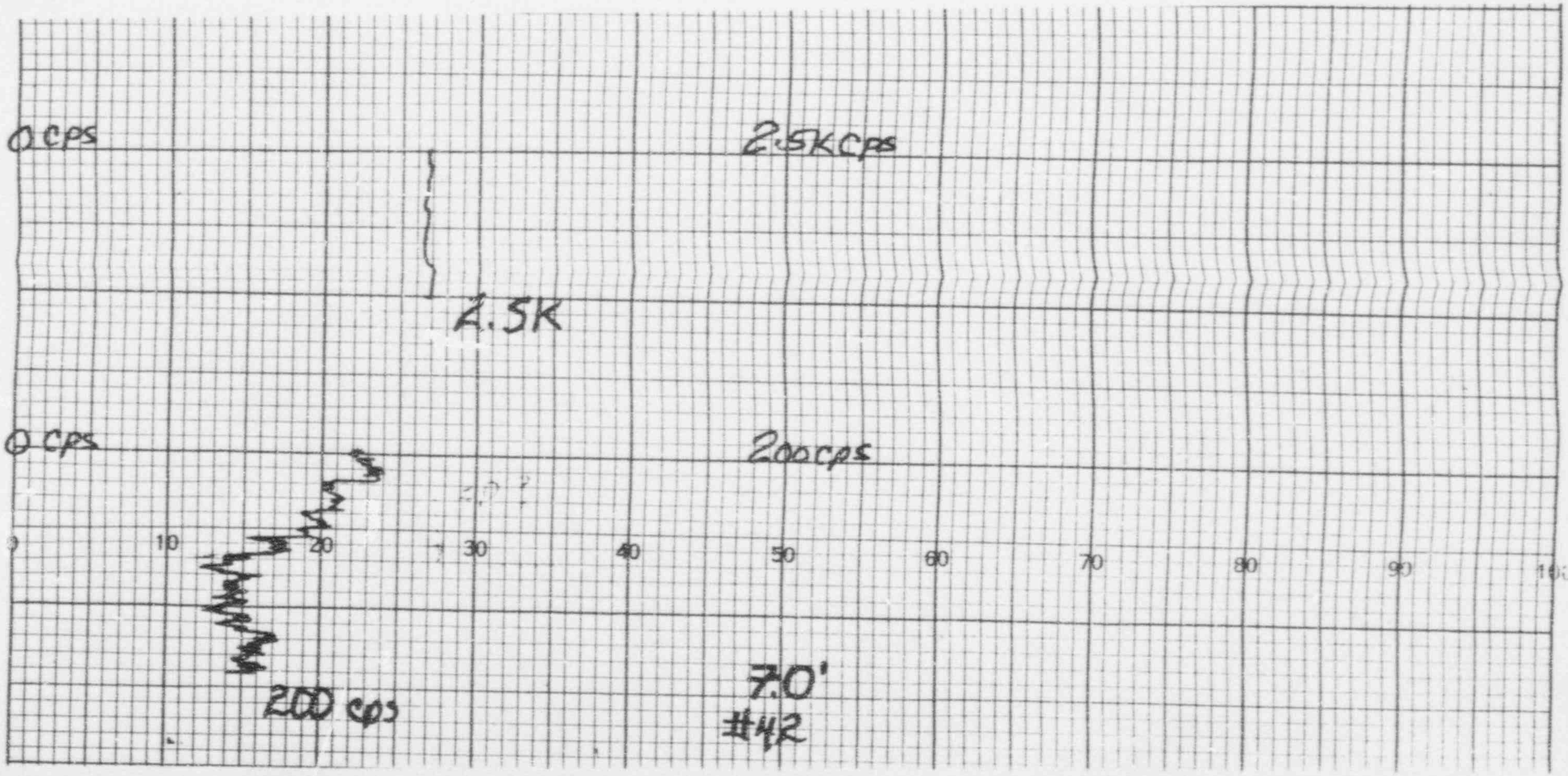
EXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.
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2.5K
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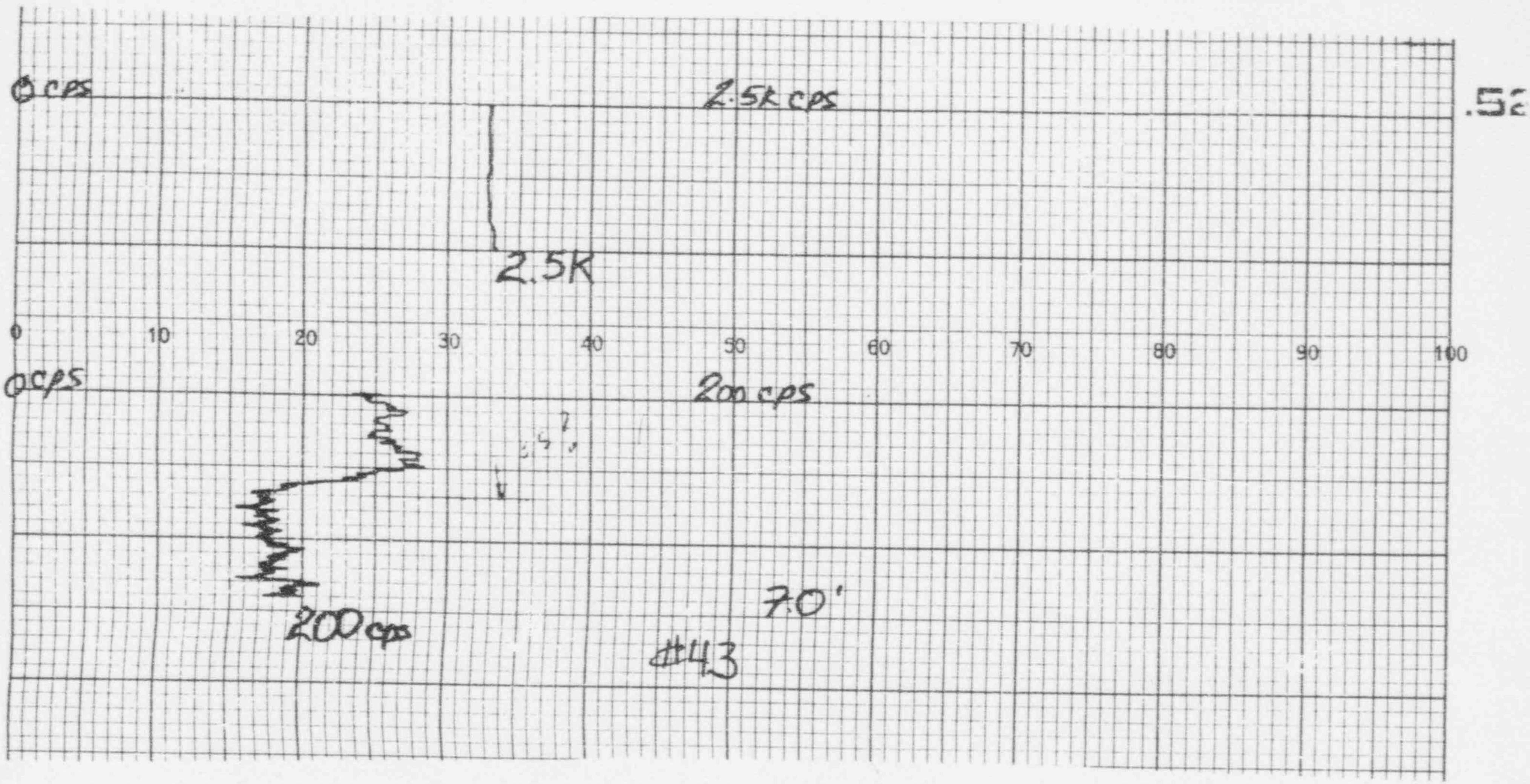
200 cps
7.0'
#42



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2.5K
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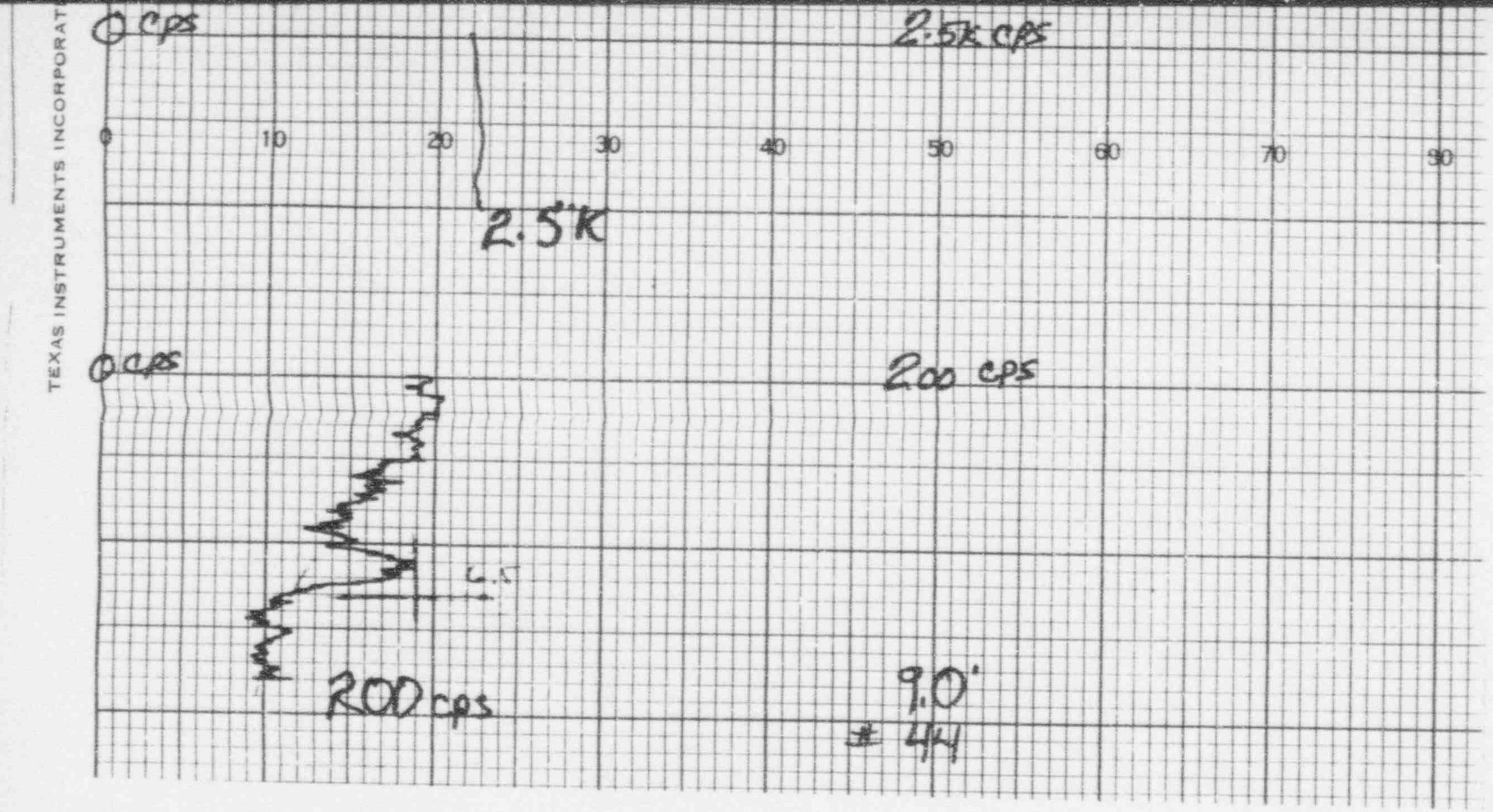
200 cps
200cps
7.0'
#43


TEXAS INSTRUMENTS INCORPORAT
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2.5K cps
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2.5K
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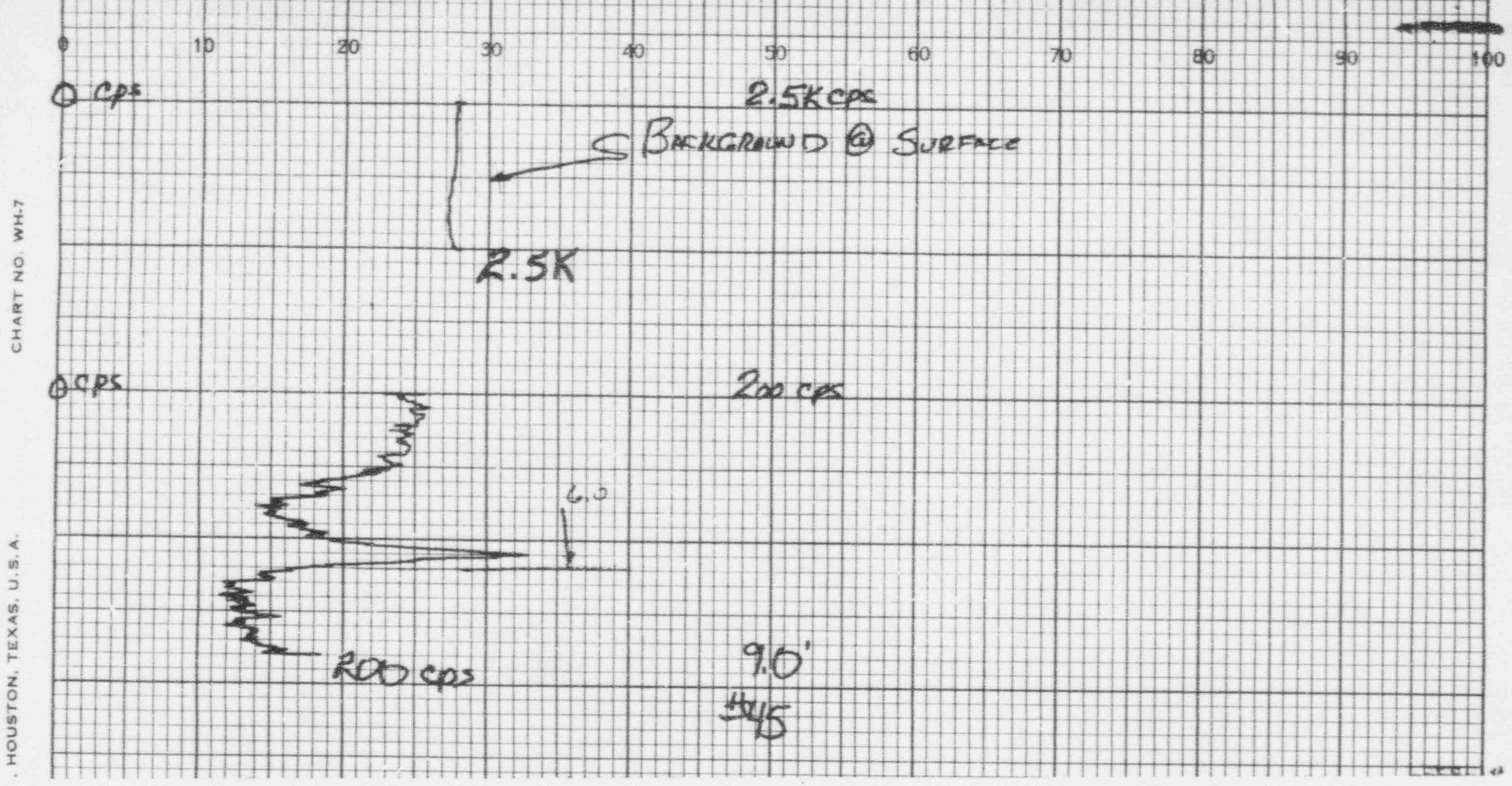
C.S
200 cps
9.0'
44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100
0 cps
2.5K cps
S Background @ Surface
2.5K
0 cps
200 cps
6.0
200 cps
9.0'
#45
CHART NO. WH-7
. HOUSTON, TEXAS, U.S.A.