DEWATERING OF THE JENKINS OPEN PIT URANIUM MINE

Straskraba, V. and Kissinger, L.E.

GEO-HYDRO CONSULTING, INC.

Denver, Colorado, U.S.A.

URANIUM SUPPLY SERVICES CORPORATION

Shirley Basin, Wyoming, U.S.A.

ABSTRACT

Mining of low grade uranium sandstones in the Jenkins open pit mine in the Shirley Basin, Wyoming was troubled by slope failures and wet conditions in the pit. Since the mine was expanding toward a river, the possibility of drainage from this river into the mine raised serious concern during the mine planning. A baseline hydrogeologic study was performed and dewatering measures were designed with the help of a numerical mathematical model. A combination of dewatering wells installed from the surface around the perimeter of the pit and horizontal drains in areas of high slope failure potential substantially improved the mining conditions and slope stability. This procedure consequently led to the successful ore recovery from the highly saturated sandstone strata. The development of drawdown during the dewatering of two separated aquifers in the overburden was close to that predicted by the model.

INTRODUCTION

The Shirley Basin is one of four major uranium districts in Tertiary rocks of central Wyoming (See Figure 1). Mining of uranium in this district was initiated in 1960 when underground mining methods were applied. Because of difficulties caused by high water inflow rates and ground support problems, underground mining was abandoned after several years. Later, the application of solution and in-situ leaching techniques provided limited production until 1970. Development of large scale open pit mining operations was initiated in 1965. Maximum production in the Shirley Basin was reached in the mid seventies with eight to ten pits operating [1]. Recently only three open pit mines have been operated by three different mining companies.

The Jenkins pit was operated by Uranium Supply Services Corporation and owned by Utility Fuels, Inc. The pit is located in the south-eastern part of the Shirley Basin.

Production in the Jenkins pit started in February, 1977; the recovery of the ore body was completed in April, 1981. The average pit production was close to 1,000 metric tons per day at an average ore grade of 0.125 percent of U_3O_8. The uranium ore body occurs in poorly cemented sandstones at a depth of 76 to 90 meters (250 to 300 feet) below the ground surface. The Jenkins pit started expanding toward north from an abandoned pit, and three distinctive pit sequences are denominated Area One, Two and Three. Area Three is of main interest in this paper (See Figure 2).

GEOLOGY

The Shirley Basin is located east of the Sweetwater Arch, a dominant structure in the Great Divide Basin of Central Wyoming. The uranium deposits are in fluvial sandstones derived from the granitic rock of the ancestral Sweetwater Arch and deposited in adjacent intermontane basins. The sandstones are subarkosic to arkosic, medium grained to conglomeratic, angular and poorly sorted. Sandstones intertongue with green and carbonaceous shale. Sedimentation was in a warm, humid climate with abundant vegetation. Decay of the organic material created reducing conditions in the sediment which caused partial carbonization of some of the plant debris, formation of pyrite, and precipitation of uranium minerals [2].

The uranium bearing sandstones belong to the Wind River formation of Lower Eocene age. Underlying formations are of Upper and Lower Cretaceous age. Overlying the ore bearing Wind River formation is the White River formation of Oligocene age which is formed mostly by 10 to 20 meters (33 to 66 feet) of coarse, arkosic, poorly cemented sandstones with some conglomerate, clay and shale laminations. This strata is not present in the area of the Jenkins pit.

The overburden in the Jenkins pit area consists of the Wind River formation. All strata are poorly cemented sandstones and siltstones, claystones, and lignitic shales (locally called lignite beds). There are three prominent lignite beds in the pit area called the upper, middle and lower lignites (See Figures 3 and 4).

HYDROGEOLOGY

Ground water occurs in sandstone strata above the upper lignite, in the upper and middle lignites, and within the ore bearing sandstones. The presence of water and high water pressures in the lignite beds is of considerable importance for slope stability. The sandstone aquifer above the upper lignite is composed of relatively poorly cemented sandstone about 4.6 meters (15 feet) thick, with its base at an elevation of approximately 2,096 meters (6,877 feet). This aquifer is hydraulically interconnected with the upper lignite aquifer through approximately 9.1 meters (30 feet) of sandstone and claystone strata which acts as an aquitarde. The hydraulic interconnection between these two aquifers was indicated by similarity in potentiometric surfaces and by the effect of pumping from the upper lignite on the discharge of horizontal drains installed in the sandstone aquifer.

The upper lignite seam has an average thickness of 1.8 meters (6 feet) and its base at an approximate elevation of 2,086 meters (6,842 feet). It is composed of moderately fractured black lignitic shale. The upper and middle lignites are separated by practically impermeable shale bed. The middle lignite seam has an average thickness of 2.1 meters (7 feet) and a base at an approximate elevation of 2,080 meters (6,825 feet). The characteristics of the middle lignite are similar to those of the upper lignite. Between the middle lignite and the lower lignite is an impermeable layer composed of claystone and shale. The ore body sandstone is composed of medium to coarse grained sand with some fine gravel and is poorly cemented. Between the lower lignite and the ore body sandstone are also relatively impermeable strata.

All aquifers are of artesian (confined) character with their potentiometric surfaces about 20 meters (66 feet) above the bottom of aquifers.

The regional ground water flow direction is from the northwest to the southeast. However, the regional ground water flow is locally altered by effects of operating and abandoned pits in the area.

Ground water in the sandstone and lignite aquifers is fresh water of sodium sulfate or calcium sulfate type with total dissolved solids in the range of 500 to 800 mg/l.

MINING PROBLEMS RELATED TO WATER

Slope stability problems related to ground water conditions occurred in most of the uranium open pit mines in the Shirley Basin. Most of these slope failures have been progressive or time-related slope failures. The failures begin by overstressing in a portion of the slope, usually in the lignitic shales or clay shale layers. These zones of overstressing gradually extend to the surface and failure occurs.

The experience from the Jenkins pit has not been an exception. During 1978, several slides developed in the northwest corner of Area Two (See Figure 5). These slides were caused by increasingly less favorable hydrogeological conditions as the excavation of the pit proceeded toward the north.

Also, the increasingly wet conditions at the pit bottom affected the working environment and efficiency of mining equipment.

The possibility of a sudden water inrush from the Little Medicine Bow River into the open pit was of great concern. The river is located only slightly over 100 meters (330 feet) from the proposed final eastern pit crest. The geologic conditions between the river and the pit were not known with certainty. It was possible that some highly permeable sediments could develop between the river and the pit.

A hydrogeologic study composed of field investigation, office analysis and mathematical modeling was undertaken to assess the hydrogeologic conditions in the direction of the expanding pit and to evaluate the feasibility of and methodology for mine dewatering.

HYDROGEOLOGIC STUDY

The purpose of the study was to evaluate the existing hydrogeologic conditions within Area Three and to evaluate and recommend the most technically feasible and cost effective methods of dewatering. The investigation was oriented toward the upper and middle lignite aquifers which were considered of principal importance for slope stability.

During the field investigation program six piezometers and one test well were installed. Piezometers were installed at four locations as shown on Figure 2. Piezometers consisted of 1 1/2 inch PVC (Polyvinyl Chloride) Schedule 40 pipe, perforated within the aquifers being monitored.

The test well installation consisted of 6 inch PVC casing with a 5 inch PVC screen. Drilling was performed with air or Revert, a degradable drilling fluid (manufactured by Johnson). All boreholes were geologically logged from drilling cuttings and geophysically logged. The geophysical logs consisted of natural gamma, spontaneous polarization, and resistivity. Falling head permeability tests were performed in all piezometers to evaluate the permeability of aquifers and whether the piezometers were functioning properly. A constant discharge pumping test with discharge for 10 hours and measurement of recovery, also for 10 hours, was run in the test well.

The tested aquifer was the upper lignite strata. With a pumping rate of only 6.4 l/min. (1.7 gallons per minute) the drawdown in the pumped well after 10 hours was 8.5 meters (28 feet). In a piezometer 17.5 meters (57.4 feet) from the pumped well, the corresponding drawdown was only 0.77 meters (2.54 feet). The average hydraulic conductivity or transmissivity for the upper lignite calculated from drawdown and recovery, using the Jacob and Theis methods [3], were the following:

Hydraulic Conductivity	$K = 1.6$ m/day	(5.3 ft/day)
Transmissivity	$T = 2.9\ m^2/day$	($9.5\ ft^2/day$)
Storage Coefficient	$S = 5.4 \times 10^{-4}$	

Results of the field permeability testing of the middle lignite and sandstone strata above the upper lignite showed approximately one order of magnitude lower values of permeability than the upper lignite. This is very probably caused by higher fracturing of the upper lignite than of the other aquifers.

One borehole (PN-4) drilled between the pit and the Little Medicine Bow River indicated that the excessive seepage from the river into the pit was not probable due to relatively impermeable strata.

EXISTING DEWATERING

Prior to completion of the described hydrogeologic study, the Jenkins pit dewatering was accomplished by means of natural seepage on the pit slopes collected by a perimeter ditch at the pit bottom (See Figure 6) and by the installation of horizontal drains.

A total of 12 horizontal drains had been installed in the western slope of Area Two. A fan with seven drains produced about 72.7 l/min. (19.2 gpm) in the winter 1979 from the upper lignite and sandstone above the upper lignite. A lower fan with five drains discharged only a minor amount of water from the middle lignite and overlying strata.

Monitoring of water levels in the installed piezometers indicated that existing horizontal drains were lowering the original potentiometric surface in both middle and upper lignites within the area. However, the ground water pressure in the vicinity of the pit slopes was still considered too high.

MODELING STUDY

Mathematical modeling study was undertaken utilizing the data obtained during the field investigation. The purpose of the modeling study was to evaluate the effectiveness of various well configurations and pumping schemes in dewatering the three major aquifers in advance of the pit expansion in Area Three.

The calculations were conducted using the numerical mathematical model TARGET [4] to predict the extent of influence of the dewatering wells. This model, a finite-difference, partly-implicit numerical model, can be used to analyze transient behavior in a saturated flow regime of aquifers under artesian or water table conditions. TARGET utilizes a combination of the experimentally justified Darcy's Law and the mass balance of a small volume in a partial differential equation for two dimensional ground water flow through porous media.

The region being studied is divided into control volumes within which the hydrogeological properties (permeability, porosity, storage coefficient, aquifer thickness) are assumed to be homogeneous and are specified. The permeability can be different in the x and y directions within each control volume. The properties of the materials together with the appropriate boundary conditions (in the case studied here, these are fixed head boundaries, zero-flux boundaries, and the discharges from the wells) define the ground water flow problem uniquely and allow numerical solutions of the flow equation to be obtained. The program achieves this by solving a matrix set of equations, each of which describes the mass balance within a control volume for a small time step. The matrix of potentiometric heads is updated at the end of the time step and the process is repeated for subsequent time steps.

The finite-difference grid generally consists of a system of orthogonal but irregularly-spaced intersecting lines. The spacing between grid lines (i.e. the size of the control volumes) as well as the small finite time steps themselves, influence the convergence of the procedure and the resulting accuracy of the solution. However, the implicit nature of the scheme permits it to be nearly unconditionally stable for steady state solutions. The discretization permits the geometry of regions of particular interest to be modeled more carefully (finer discretization) and allows the hydrogeological properties to vary from place to place. To model composite materials correctly, the properties across boundaries of dissimilar materials are averaged geometrically. Fine details in areas where the heads may be changing rapidly are obtained at the expense of having to solve many more local equations.

It is believed that hydrogeologic conditions in the neighborhood of the proposed pit extension were fairly well known. However, detailed data relating to the surrounding area was not available and hence some assumptions as described below were necessary.

- o The potentiometric contours were interpolated from data obtained at piezometer and test well installations and extended over the area adjacent to the pit.
- o Estimated mine schedules were used to obtain the time available to lower the water levels in each aquifer of interest.
- o Since each dewatering well would be pumping from all three aquifers at once, an estimate of the contribution of each aquifer to the total pumped volume was made in order to determine the extent of dewatering of each aquifer.

Two main objectives were identified for the modeling study:

- o The most reasonable well spacing for both effectiveness and economy in dewatering.
- o The pumping rates which would be required at each well given by dewatering schedule.

In each of the cases considered at the Jenkins mine the following sequence of calculations was carried out. Firstly, calculations were made of the pumped volumes being extracted from each aquifer corresponding to a particular rate of dewatering at a pump. Each aquifer was then pumped at their separate rates until one reached its steady-state. At that time only the maintenance pumping volume would be drawn from that aquifer and so the pumped volumes from the remaining aquifers would alter. Maintenance pumping rates and corresponding radii of influence were calculated. This sequence was repeated until the hydraulic pressures were predicted in each of the aquifers as a function of space and time, until the total time available for dewatering is reached.

In determining the well spacing, hand calculations indicated that a spacing in the range of 46 to 61 meters (150 to 200 feet) would be adequate for dewatering purposes. Therefore, a selection of spacing was made using this range as a starting point. Numerical modeling resulted in a series of computer generated plots. These plots illustrated the progression of dewatering with time in and around Area Three of the Jenkins pit for each aquifer, summarizing the results for a well spacing of 61 meters (200 feet) and a pumping rate of 57 l/min. (15 gpm). The plots illustrated how a dewatered strip, progressively widening with time at a rate dependent upon the transmissivity and storage coefficient of each aquifer, will develop. It could be seen that the final dewatered strip in the north and west slopes of Area Three were similar for each of the aquifers. These results were plotted in both plan view, and in a vertical cross section through all aquifers in the area of the west slope. This vertical cross section indicated that for all aquifers, including the middle lignite which was of primary concern for a slope stability, a well spacing of 61 meters (200 feet) and a pumping rate of 57 l/min. (15 gpm), would be adequate to sufficiently reduce the pore pressures to the desired levels in the time available for dewatering.

RELIABILITY OF PREDICTED RESULTS

Inital tests were made to ensure that the solution procedure showed convergent behavior in predicting results. This was undertaken by making tests to check that reducing the time step size and/or increasing the number of iterations used during calculations did not alter the predicted results. Also a check was made on the overall changes of head to make sure that rapid alterations were not being produced. Having determined that the numerical model gave accurate results, an analysis of the physical reliability of the results was made.

Calculations of the expected radii of influence of the wells indicated that external and internal boundaries (that is, the fixed head boundaries and the seepage faces around Areas One and Two) were at distances greater than the expected extent of influence. Hence no significant numerical influence on the solution would be felt due to these boundaries.

The results of any calculation procedure can only be as accurate as the data used in the calculations and the assumptions inherent in providing that data. A test of the sensitivity of the results to variations in input data was made by assuming hydraulic conductivities one tenth of the measured values and repeating the same computer runs.

The sensitivity analyses indicated that the reduced hydraulic conductivities did not significantly alter the ability to relieve pore pressure in the time available. Hence, it appeared that the predicted results, at least in the timescale of concern, were relatively insensitive to likely ranges of parametric changes.

Based on these checks, it was concluded that the computer model could provide a reliable tool for the selection of the dewatering scheme [5].

The results of the modeling studies indicated that a well spacing of 61 meter (200 feet) and a pumping rate of 57 l/min. (15 gpm) would provide adequate dewatering for the western slopes of Area Three of the Jenkins pit.

Since slope stability problems had historically not occurred on the eastern side of the pit, it was decided not to install dewatering wells in that area immediately. However, the area was to be continuously monitored for indications of ground water related problems.

DEWATERING DESIGN AND IMPLEMENTATION

The results of the hydrogeologic investigation and computer modeling indicated that dewatering of the Jenkins pit was technically feasible and that the most effective dewatering would be by means of vertical wells from the surface around the perimeter of the pit combined with the installation of a limited number of horizontal drains in the areas most critical for slope stability.

The permeability testing performed in the various aquifers showed relatively low hydraulic conductivities. According to Klimentov [6] these are at the limit of permeabilities for which dewatering by means of wells is considered economically feasible. However, this method was considered the most suitable for improving hydrological mining conditions in the relatively limited time available before the development of Area Three.

From the analytical evaluation of the pumping test in the upper lignite it was estimated that the steep part of the cones of depression developed around a dewatering well would extend about 45 meters (150 feet) from the pumped well.

The following recommendations for dewatering resulted from the studies:

- Horizontal drains would be a more cost effective means of dewatering. However, since they could be installed only after exposure of the slope, slopes failures could develop before installation of horizontal drains would be possible.

- Approximately fourteen dewatering wells should be located along the northern and western perimeter of Area Three. The wells should be located about 61 meters (200 feet) from the middle of the slope and within 61 meters (200 feet) from each other.

- The dewatering wells should be screened through all water bearing strata from the top of the sandstone strata above the upper lignite to the bottom of the middle lignite strata. A submersible pump should be located in at least 6 meters (20 feet) of non perforated casing below the lowest aquifer.

- The estimated cost for installation of a dewatering well was approximately $5,000.00 and for installation with 1 HP submersible pump approximately $2,500.00.

- All wells should be pumped at their maximum possible discharge rate of approximately 57 l/min. (15 gpm). Pumping should be initiated immediately after installation and continue to the completion of mining.

In February 1979 a total of thirteen dewatering wells were drilled at the locations shown on Figure 2. All wells were between 55 and 67 meters deep (180 to 200 feet) and were installed with 5 inch PVC casing; factory slotted casing was installed through all aquifers of interest. The slotted casing was gravel packed. One horsepower submersible pumps were placed in the bottom, nonperforated part of each well (See Figure 7). Pumping and piezometers monitoring was initiated immediately after installation.

Original pumping rates per a well of between 11 and 106 l/min. (3-28gpm) declined sharply and it became apparent that the permeability of the aquifers was highly variable and was overall lower than predicted from the single pumping test. Problems with maintenance of the dewatering wells, particularly during the severe winter months, also caused the total discharge to be lower than predicted and used in modeling study.

After about six months of dewatering, a small slope failure occured in the eastern portion of Area Three, close to the Little Medicine Bow River.

To improve slope stability in the eastern portion of Area Three it was recommended to install an additional five dewatering wells (Nos. 14 to 18) around the perimeter of the pit and to install approximately 30 horizontal drains in the area of the slope failure (See Figure 2).

Five 61 meters (200 feet) deep, dewatering wells were installed in January, 1980 and furnished with Reda, 1.5 HP submersible pumps. Initial discharge from four wells (Well No. 18 was used for water level monitoring) of about 246 l/min. (65 gpm) decreased within a week to about 136 l/min. (36 gpm).

Twenty six horizontal drains drilled with a specialized "Aardvark" drilling rig were installed in May, 1980 in the area of slope stability problem. These drains, which were on average 45 meters (150 feet) long, discharged initially 310 l/min. (82 gpm). However, the flow decreased within a month to about 223 l/min. (59 gpm).

RESULTS OF DEWATERING

Although a relatively small amount of water was discharged out of aquifers by means of vertical dewatering wells and horizontal drains a considerable drop in potentiometric surface of all aquifers was achieved. This resulted in improved slope stability conditions in Area Three and the ore recovery in the Jenkins pit was completed in April, 1981, without any additional significant slope stability problems. The working conditions in the pit were also improved by reducing the amount of water on the pit floor.

After one year of dewatering the potentiometric surface in the upper lignite dropped by 13 meters (42.5 feet) in the vicinity of the pit crest (piezometer PM-2A) and only 2.7 meters (9 feet) at a distance of approximately 305 meters (1000 feet) northwest of the pit (piezometer PN-3), toward the recharge area.

The potentiometric surface of the Upper lignite aquifer in the vicinity of the pit crest was lowered to 5.6 meters (18.5 feet) above the top of the aquifer. This drawdown was 2.9 meters (9.5 feet) short of the drawdown predicted by the computer study. The lower average pumping rate achieved by dewatering system (approximately 38 l/min. or 10 gpm per well) against that used in modeling study (57 l/min. or 15 gpm per well) is undoubtedly a major reason for the actual drawdown being less than that predicted by the modeling study.

In the middle lignite aquifer a maximum drawdown of 20.6 meters (67.5 feet) was achieved in the piezometer PN-2B, located near the pit crest. This drawdown was only 0.8 m (2.5 feet) short of that predicted by the modeling study. Since the lowered water table was within the middle lignite strata, it means the artesian conditions changed into water table conditions in this aquifer. Graphs showing drawdown predicted by modeling study and measured during one year of dewatering are presented on Figure 8 and 9.

CONCLUSIONS

This paper intended to demonstrate that a simple but properly designed dewatering system can improve slope stability and mining conditions. Understanding of regional and site hydrogeology was essential for a successful dewatering design and implementation.

The discussed case of the Jenkins pit is not considered a typical case in dewatering practice because of location of dewatering wells only at a small part of pit perimeter and a relatively low discharge of water from the whole dewatering system. However, the scope of the dewatering project was to improve slope stability and mining conditions in a particular part of the mine and not to dewater the whole open pit.

Other experience gained on this project is that it is very difficult to simulate hydrogeologic characteristics of a highly anisotropic aquifer as is the case of the discontinuous fluvial sandstones and irregularly fractured lignites present at the Jenkins pit site in a mathematical mode and at reasonable cost. Even if one year of dewatering of the Jenkins pit did not lower the potentiometric surfaces of the aquifers to the levels predicted by mathematical modeling we belive that the relatively inexpensive computer study was useful for the successful completion of ore recovery in the Jenkins pit.

ACKNOWLEDGEMENTS

The authors wish to thank management of the Utility Fuels, Inc. for permission to publish this paper and to Dr. Devraj Sharma, Manager of the Advanced Technology Group for Dames and Moore, Denver, who performed the mathematical modeling study for this project. Suggestions and contributions from GEO-HYDRO Consulting, Inc. principals Dr. M. Bukovansky and G. Major, who were involved on slope stability aspects of the Jenkins project, are gratefully acknowledged.

REFERENCES

1. Atkins, J.T., and Pasha, M.A., Controlling Open-Pit Slope Failures at Shirley Basin Mine, Proceedings of AIME Annual Meeting, Chicago, 1973.

2. Rackley, R.I., Environment of Wyoming Tertiary Uranium Deposits, The American Association of Petroleum Geologists Bulletin, Vol. 56, No. 4, 1972.

3. Bukovansky, M., and Straskraba, V., Hydrogeologic Study, Jenkins Project Uranium Mine, (Dames & Moore Unpublished Report), 1979.

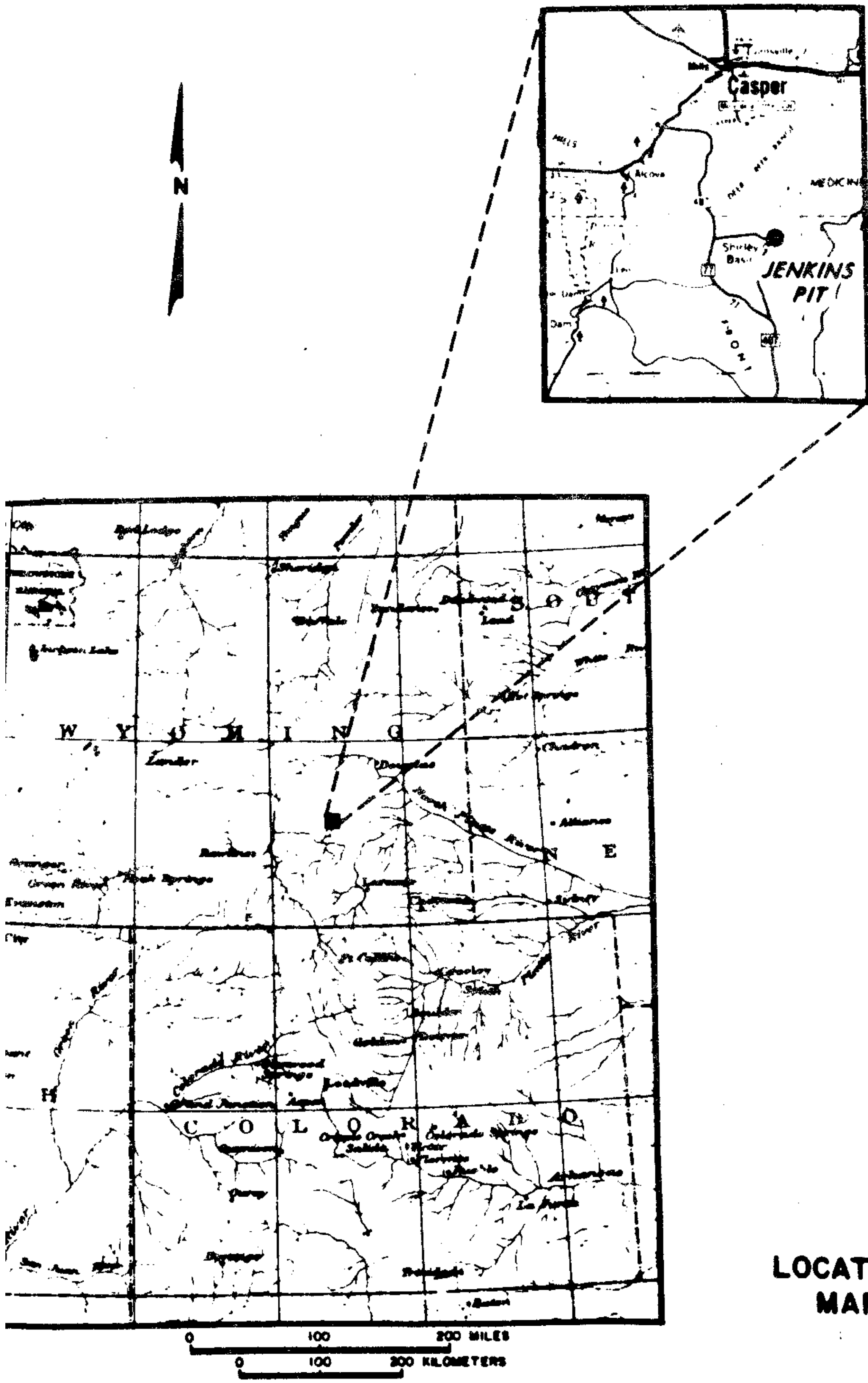
4. Sharma, D., A Comprehensive Mathematical Model (TARGET) Capable of Predicting Flow and Chemical-Species Transport in Parous Media. (Dames & Moore Unpublished Report), 1979.

5. Sharma, D., and Straskraba, V., Dewatering Design, Jenkins Project Uranium Mine, Mathematical Modelling Studies. (Dames & Moore Unpublished Report), 1979.

6. Klimentov, P.P., and Syrovatko, M.V., Hydrogeology of Hard Mineral Deposits, NEDRA, Moscow, Vol. I and II, 1966 (Original in Russian).

7. Bukovansky, M., Major G., and Straskraba, V., Evaluation of Hydrogeological Conditions, Jenkins Project, Shirley Basin, (GEO-HYDRO Consulting Unpublished Report), 1980.

LIST OF FIGURES

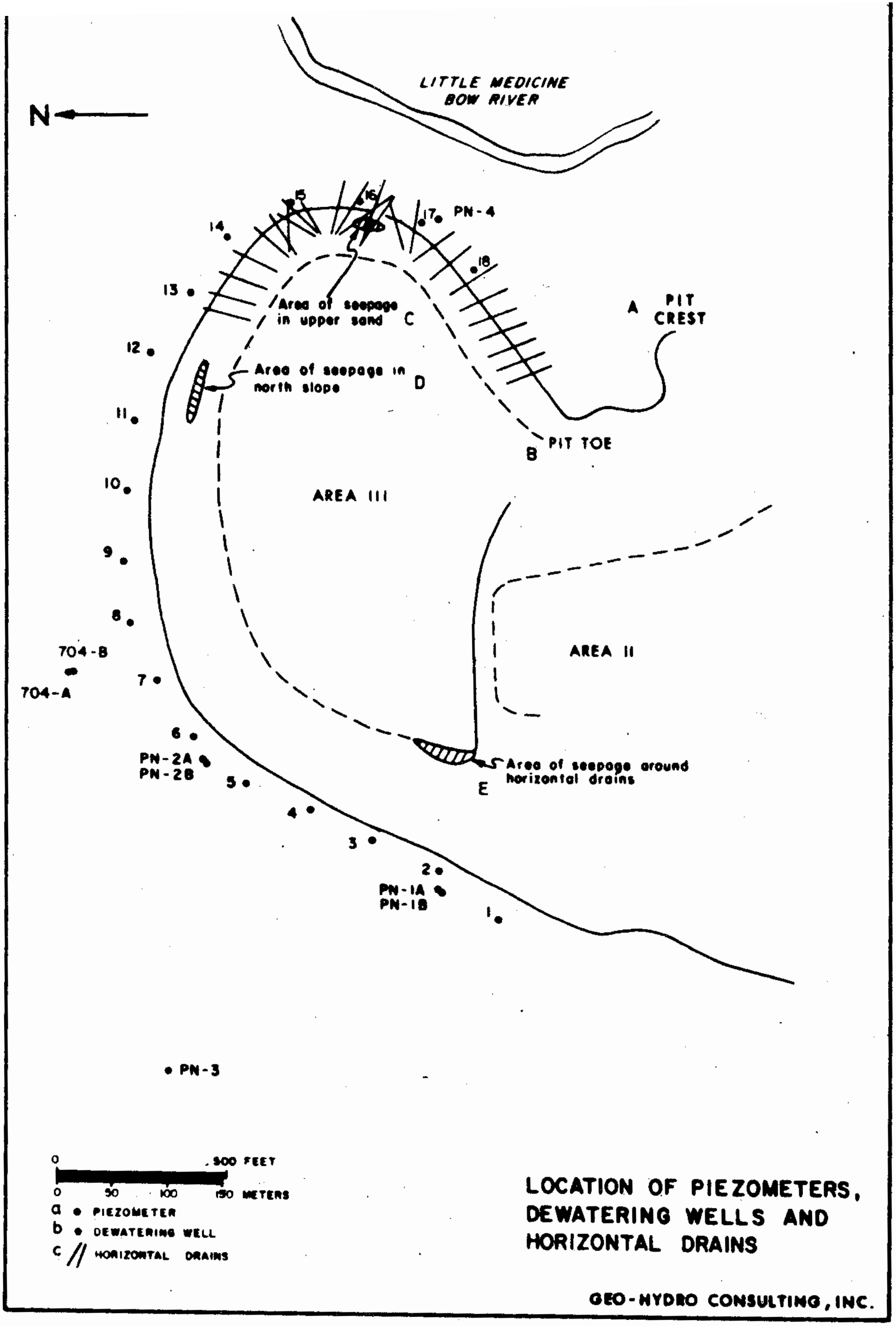


LOCATION MAP

I. ABRA

GEO-HYDRO CONSULTING, INC.

FIGURE



LOCATION OF PIEZOMETERS, DEWATERING WELLS AND HORIZONTAL DRAINS

FIGURE 2

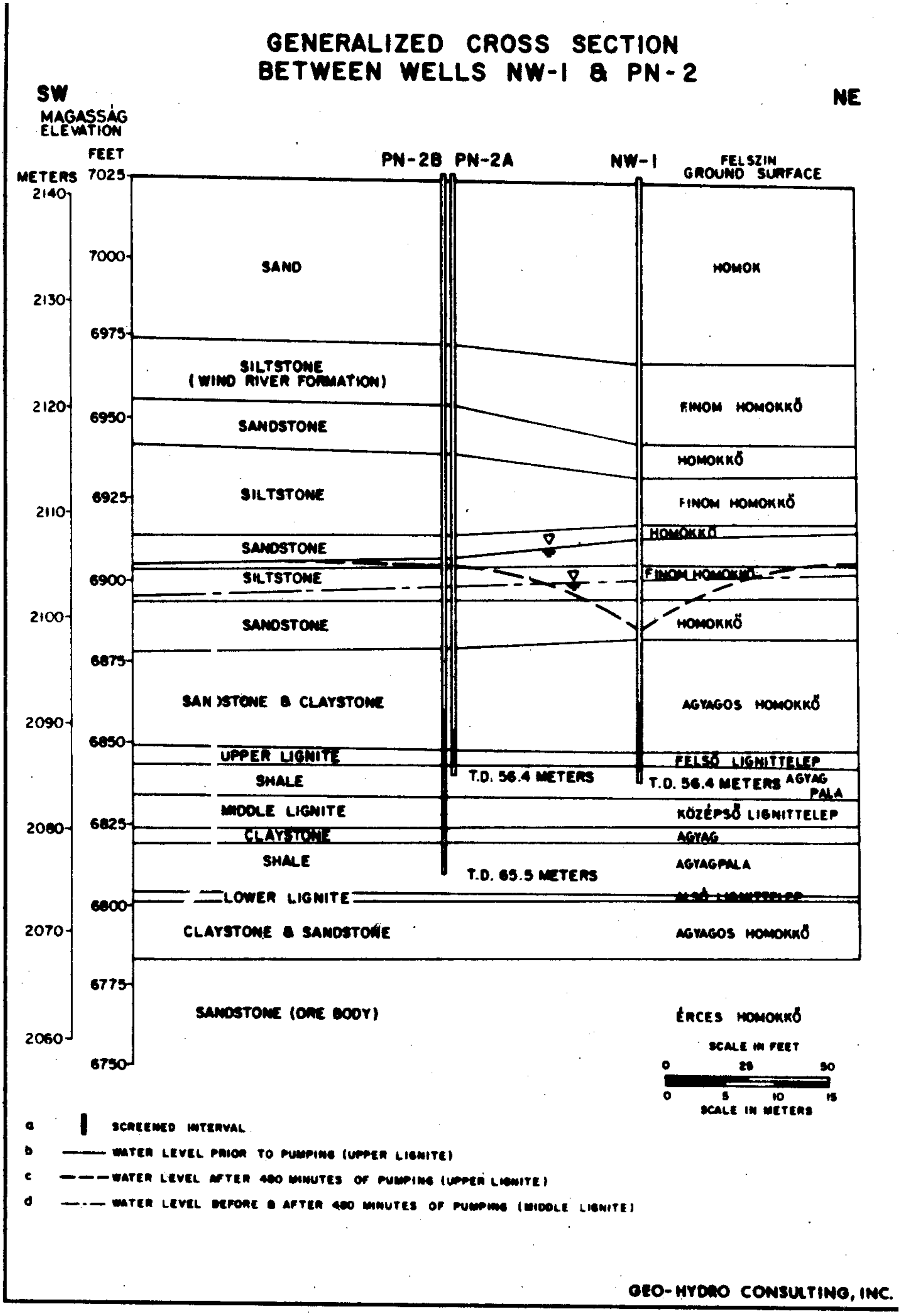

GENERALIZED CROSS SECTION
BETWEEN WELLS NW-1 & PN-2
SW
NE
MAGASSÁG
ELEVATION
FEET
METERS
PN-2B PN-2A
NW-1
FELSZIN
GROUND SURFACE
SAND
HOMOK
SILTSTONE
(WIND RIVER FORMATION)
FINOM HOMOKKŐ
SANDSTONE
HOMOKKŐ
SILTSTONE
FINOM HOMOKKŐ
SANDSTONE
HOMOKKŐ
SILTSTONE
FINOM HOMOKKŐ
SANDSTONE
HOMOKKŐ
SANDSTONE & CLAYSTONE
AGYAGOS HOMOKKŐ
UPPER LIGNITE
FELSŐ LIGNITTELEP
SHALE
T.D. 56.4 METERS
T.D. 56.4 METERS
AGYAG PALA
MIDDLE LIGNITE
KÖZÉPSŐ LIGNITTELEP
CLAYSTONE
AGYAG
SHALE
T.D. 65.5 METERS
AGYAGPALA
LOWER LIGNITE
CLAYSTONE & SANDSTONE
AGYAGOS HOMOKKŐ
SANDSTONE (ORE BODY)
ÉRCES HOMOKKŐ
SCALE IN FEET
0 25 50
0 5 10 15
SCALE IN METERS
a SCREENED INTERVAL
b WATER LEVEL PRIOR TO PUMPING (UPPER LIGNITE)
c WATER LEVEL AFTER 480 MINUTES OF PUMPING (UPPER LIGNITE)
d WATER LEVEL BEFORE & AFTER 480 MINUTES OF PUMPING (MIDDLE LIGNITE)
GEO-HYDRO CONSULTING, INC.

FIGURE 3

Figure 4 General View of the Jenkins Pit

Figure 5 Slope Failure North-West Corner Area 11

Figure 6 East slope, Area 11 With Seepage

Figure 7 Dewatering Well- Detail

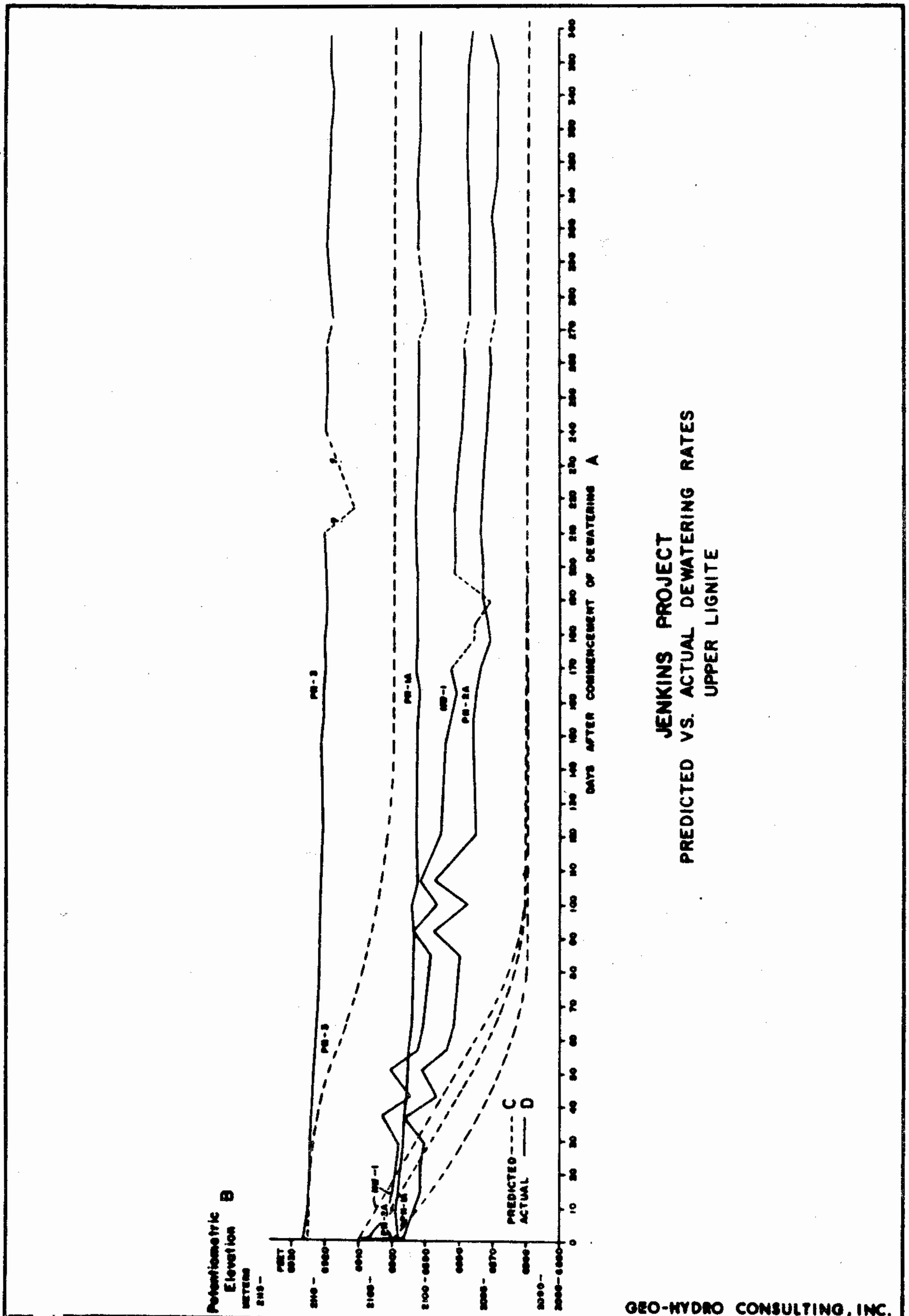
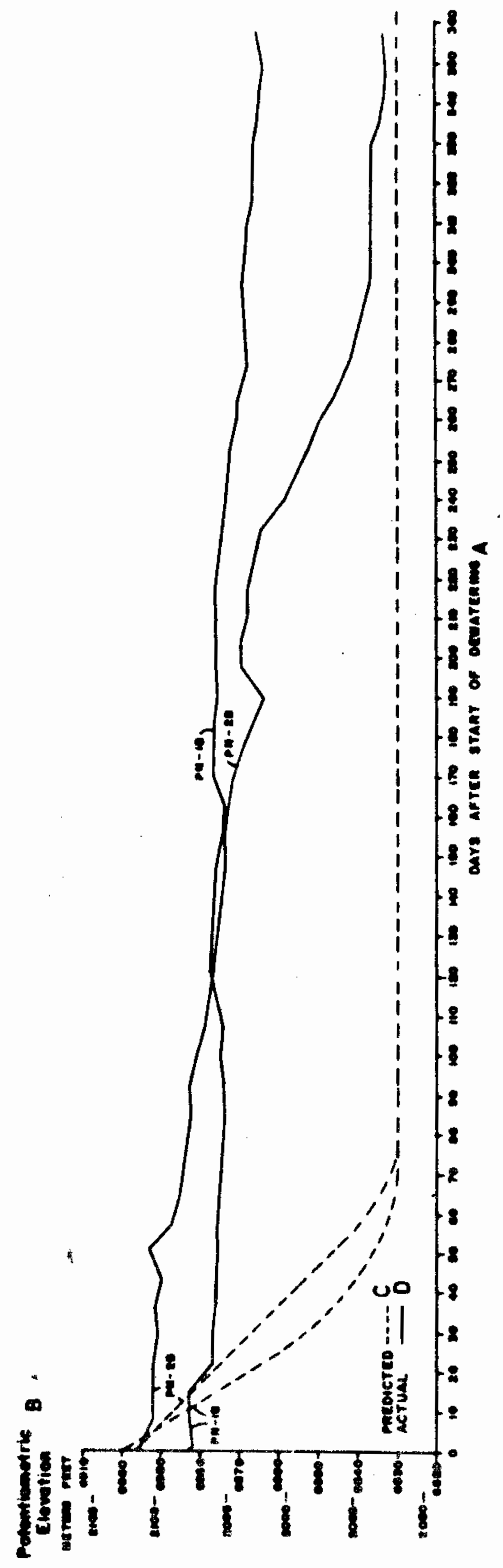

Potentiometric Elevation B
METERS
FEET
DAYS AFTER COMMENCEMENT OF DEWATERING A
PREDICTED ---- C
ACTUAL —— D
JENKINS PROJECT
PREDICTED VS. ACTUAL DEWATERING RATES
UPPER LIGNITE
GEO-HYDRO CONSULTING, INC.

FIGURE 8



JENKINS PROJECT
PREDICTED VS. ACTUAL DEWATERING RATES
MIDDLE LIGNITE

GEO-HYDRO CONSULTING, INC.

FIGURE 9