UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
URANIUM RECOVERY FIELD OFFICE
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DENVER, COLORADO 80225

SEP 23 1992

Docket No. 40-8943
SUA-1534, Amendment No. 18
04008943300E
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MEMORANDUM FOR: Docket No. 40-8943

FROM: Raymond O. Gonzales, Project Manager
Dawn L. Jacoby, Project Manager

SUBJECT: ENGINEERING REVIEW OF SOLAR EVAPORATION POND DESIGN FOR THE FERRET CROW BUTTE FACILITY IN NEBRASKA

BACKGROUND

Source Material License SUA-1534, which was issued on December 29, 1989, authorized Ferret Exploration Company of Nebraska (Ferret) to operate the Crow Butte in situ leach facility. The license authorized, in part, the construction of five solar evaporation ponds as shown on figure 1. To date, only ponds 3 and 4 have been constructed.

On July 2, 1992, the licensee responded to a Notice of Violation (NOV) which involved the construction practices that were used during construction of ponds 3 and 4. The NOV resulted from the failure of the licensee to place soils used in the construction of the ponds at moisture contents within the range set in the approved specifications. The licensee was requested to address the effect of the failure to meet the moisture specification on the embankments' stability. The July 2, 1991, response to the violation was acknowledged by NRC letter dated August 2, 1991. By letter dated September 26, 1991, the licensee was requested to provide additional information. Ferret responded in a submittal dated October 30, 1991, which, in part, requested the amendment of Source Material License SUA-1534.

The Crow Butte solar evaporation embankments are classified as high hazard structures due to the nature of the liquids that will be stored in the ponds. Therefore, the design of the ponds must be evaluated in accordance with Regulatory Guide 3.11 (RG 3.11), "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills" (NRC, 1977). On May 20, 1992, the licensee was requested to provide additional information to enable the staff to complete its RG 3.11 review. Ferret responded in a submittal dated June 8, 1992. A review of that submittal indicated that the evaporation pond design did not meet the criteria of RG 3.11. Additional comments were provided to Ferret on July 14, 1992. Ferret provided a revised evaporation pond design on July 16, 1992.

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DISCUSSION

The evaporation ponds have two basic geometries. Ponds 1, 2, and 5 have bottom dimensions of 850 feet by 200 feet, while ponds 3 and 4 are slightly shorter and wider with dimensions of 700 feet by 250 feet. Each pond has a uniform depth of 15 feet. Pond embankments have crest widths of 10 feet, inside slopes of 2H:1V, and outside slopes of 2.5H:1V.

Review of the solar evaporation design addresses two broad topics; flood design and stability analysis.

Flood Design

RG 3.11 was issued in 1977. In 1983, the hydrologic design criterion of RG 3.11 was amended in Staff Technical Position WM-8201 (NRC, 1983). This position paper describes the hydrologic engineering criteria considered satisfactory for determining design floods, designing diversion ditches, and determining the required storage capacity of impoundments.

Flood Determinations

As shown on figure 1, the evaporation ponds are located on a sloping hill side. Therefore, diversion ditches have been designed to safely divert flood flows away from the ponds. In addition, there is a drainage-way between the ponds.

In designing the ditches, the licensee analyzed flooding due to Probable Maximum Floods (PMFs) from the drainage areas to the east and south of the ponds. A PMF is based on the Probable Maximum Precipitation (PMP) which is defined as the greatest depth of precipitation that is physically possible at a particular geographic location. The licensee calculated a 6-hour PMP of 23 inches from Hydrometeorological Report (HMR) No. 55 (USDC, 1984). The 1-hour PMP amount was estimated to be 10.0 inches on the basis that there were no Hydrometeorological Reports available for estimating a 1-hour value.

The licensee's procedures for estimating appropriate PMP values, for use in estimating design flows, were reviewed and it was concluded that the use of HMR No. 55 was inappropriate. Hydrometeorological Reports Nos. 51 and 52 (USDC, 1978 and 1982, respectively), provide PMP values for areas east of the 105th meridian where the Crow Butte facility is located. Using these reports, it was determined that the appropriate PMP value for a 1-hour duration should be 16.6 inches. The 6-hour value was identical to the 23 inch value estimated by the licensee. The licensee was therefore requested to redesign the flood control ditches using the appropriate PMP values. It was also requested that in determining PMF peak discharges, the licensee assume that during the occurrence of a PMP event, the soil would be close to saturation so that a major portion of the PMP would result in runoff. Also, the temporal distribution of incremental PMP values to be used in the rainfall/runoff model should have the greatest intensities occurring near the center of the storm duration.

Probable Maximum Flood (PMF) Estimates

PMFs are dependent not only of the magnitude of the PMP, but also on the amount of precipitation that is lost by infiltration, surface storage, and evaporation. Other important parameters are the duration and temporal distribution of the PMP and the hydraulic characteristics of the drainage areas. By considering all of these parameters, a PMF can be estimated.

The licensee estimated PMF peak discharges using a rainfall/runoff computer model which utilizes the triangular hydrograph method developed by the U.S. Soil Conservation Service (SCS, 1972) and illustrated by the U.S. Bureau of Reclamation (USBR, 1977). The SCS method is widely used and accepted for estimating flood discharges. Basin characteristics used as input to the computer model were determined by using the SCS Curve Number (CN) Method. A CN value of 87 was determined by assuming that the soils in the drainage areas would be close to saturation at the beginning of the PMP event. This resulted in conservative PMFs, because if the ground is close to saturation, very little of the rainfall can infiltrate into the soil and most will result in surface runoff.

Other parameters that affect the magnitude of a PMF estimated using SCS procedures are the time of concentration (t_c) and the temporal distribution of rainfall. The t_c is the time it takes for runoff to travel from the most remote point in a drainage area to the diversion ditch. The peak runoff for a given drainage area is inversely proportional to the t_c. Therefore, if the t_c is estimated to be relatively small, the flood peak will be conservatively large. The licensee did not discuss the procedure that was used to estimate t_cs. However, based on an independent evaluation using the Kirpich Method, it was concluded that the t_cs estimated by the licensee were appropriate and thus acceptable. The Kirpich Method is considered to be appropriate for estimating t_cs for the small drainage areas at the site.

The temporal distribution of rainfall is the sequence in which a storm occurs. For example, in some storms, the largest increments of rainfall occur at the beginning of a storm and taper off as the rainfall continues. In other storms, rainfall begins slowly, increasing to a maximum near the center of the storm duration before tapering off. It has been shown that a rainfall distribution that peaks near the center of the storm duration results in the most conservative (largest) PMF peak discharge. The licensee did not discuss the temporal distribution that was used. Therefore, in order to evaluate the adequacy of the licensee's PMF estimates, independent calculations were made. These independent calculations resulted in PMFs that were about 30 percent higher than those of the licensee. In checking the adequacy of the design of the diversion ditches and of the drainage-way between the ponds, the PMFs estimated by the staff were used.

Diversion Ditches and Drainage-Way

RG 3.11, as amended, describes the criterion that is acceptable for designing diversion channels. The basic criterion is that a channel be designed to safely divert a PMF away from the evaporation ponds.

Water Surface Profiles and Flow Velocities

Once PMF peak discharges have been estimated, it is necessary to determine water depths and flow velocities associated with those discharges. These parameters provide the basis for determining whether diversion channels are necessary and for sizing those channels if they are required.

Water surface elevations and velocities for the diversion ditches were estimated by the licensee using the Manning equation (Chow, 1959). Manning's equation assumes uniform flow conditions. This means that the depth, velocity, and discharge are constant along the entire ditch and that the geometry of the ditch does not change. For the diversion ditches at the site, the assumption of uniform flow is reasonable and thus acceptable. For the drainage-way, the licensee used the Corps of Engineers' gradually-varied-flow computer program, HEC-2 (COE, 1986). HEC-2 is a widely used and accepted computational model that is recommended in the NRC Staff Position on Erosion Protection (NRC, 1990).

The licensee determined that a 6.5-foot deep triangular ditch having 2H:1V side slopes is the largest diversion ditch required. Conservatively, this ditch configuration will be used for all diversion ditches. For ease of construction, the licensee proposes to have the option of using a 5-foot deep trapezoidal ditch having 2H:1V side slopes and a 10-foot bottom width. For the drainage-way, the licensee determined that PMF water surface elevations will be lower than the toes of the embankment slopes of the evaporation ponds.

The design of the diversion ditches was evaluated using Manning's equation and the higher PMF peak discharges estimated by the staff. Based on this evaluation, it was concluded that either a 6.5 foot deep triangular ditch with 2H:1V side slopes or a 5-foot deep trapezoidal with a 10-foot bottom width and 2H:1V side slopes as proposed by the licensee are adequate to divert PMF peak flows away from the evaporation ponds.

For the drainage-way, an independent evaluation was performed using HEC-2 and the larger PMF estimated by the staff. Based on this evaluation, it was concluded that the drainage-way is adequate to safely convey the PMF between the evaporation ponds. Therefore, no alteration of the drainage-way is required.

Evaporation Pond Freeboard

RG 3.11 as amended, also describes the criterion that is acceptable for designing freeboard for storage impoundments. Freeboard is defined as the difference in elevation between the crest of an embankment and the elevation of the maximum operating water level. Basically, the criterion requires that freeboard be equal to or greater than the sum of the 6-hour PMP plus the estimated vertical distance that a design wave will run up onto the embankment slope. The licensee proposes to maintain the maximum operating level at least 5 feet lower than the crests of the embankments.

As discussed above, the 6-hour PMP was estimated as 23 inches. Since the proposed freeboard is 5 feet, this allows 3 feet, 1 inch for wind wave runup. Based on an independent estimate of runup, it was concluded that the proposed freeboard of 5 feet is conservative and thus acceptable.

Stability Analyses

RG 3.11 recommends that the static stability of the embankment be analyzed using commonly accepted detailed stability methods. Appropriate static soil and rock properties established on tested representative samples over anticipated in situ and placement conditions should be used in the analyses. Conventional pseudostatic analysis may be considered acceptable if the seismic coefficient appropriately reflects the geologic and seismological conditions of the site and if the materials are not subject to significant loss of strength under dynamic loads. Liquefaction potential and the dynamic stability of the structures and foundation should be addressed using appropriate state-of-the-art methods.

Site Characterization

Prior to construction of ponds 3 and 4, the licensee characterized the site conditions with an exploration and laboratory testing program described in the licensee's May 23, 1988, submittal. The exploration program consisted of five auger borings located at the center of each of the five proposed ponds. The borings were taken to depths of up to 17.5 feet. One "undisturbed" shelby tube sample was taken in the 10- to 11-foot interval from the boring in the center of pond 5. The blow count associated with this sample was 8-8-9 for 18 inches. The field logs indicated that the material was a silty sand. Some calcareous material was encountered in four of the five borings at depth. The log for the boring in the center of pond 4 indicated that the material contained a larger percentage of silt (20-30 percent) than the material encountered in the other four borings (10-15 percent).

The laboratory testing program consisted of one classification test series (gradation and Atterberg), a laboratory compaction test, a direct shear test, and a permeability test. Each test was performed on a composite sample from the boring located at the center of pond 2. In addition, a permeability test was performed on the undisturbed sample taken from the center of pond 5. The in-place moisture content of this sample was also provided.

The laboratory testing identified the material as a SM-ML soil with 49 percent passing the No. 200 sieve; a maximum dry density of 105 pcf at an optimum water content of 16.5 percent; and a laboratory permeability of 10^{-6} cm/sec when remolded to 96 percent of the laboratory maximum density. The licensee classified the material as a SM material. The direct shear test resulted in a recommended friction angle of 40 degrees and a cohesion of zero. The undisturbed sample had a laboratory permeability of 10^{-5} cm/sec.

Stability Analysis

To determine the slope stability of the structures, the licensee's consultant performed a static stability analysis using the computer code REAME which is based on the simplified Bishop method of analysis. The analysis was performed on the maximum embankment section which was taken from the northwest corner of pond 3. Both the inside and outside slopes were evaluated. A seismic coefficient of 0.05g was applied to simulate dynamic loading. The figures submitted in the May 23, 1988, submittal identify two material types; the embankment and original ground. No soil parameters were defined. It was assumed that the recommended strength parameters were utilized. No phreatic surface was discussed or illustrated. The licensee's analysis resulted in the following factors of safety for the structures.

SLOPE	STATIC FACTOR OF SAFETY	DYNAMIC FACTOR OF SAFETY
Inside	1.9	1.7
Outside	2.2	1.9

These factors of safety are greater than those recommended in RG 3.11.

The slope stability of the as-built structures was addressed in attachment 4 of the licensee's October 30, 1991, submittal in response to the NOV regarding pond construction. The analysis used the SB-Slope program published by Gunten Engineering Software which reportedly uses the simplified Bishop method. In the 1991 analysis, an average value for the friction angle was based on available literature rather than the results of the direct shear test. It was determined that a friction angle of 34 degrees with zero cohesion should be used to model the as-built slopes. The submittal states that "analyses were done over the range of compaction indicated by the field compaction test and the worst case was selected." The actual density used in the modeling was not provided. Foundation soil parameters were not discussed in the analysis. The slopes were modeled with no phreatic surface. Licensee identified conservatism in the analyses included disregarding the buttressing effect of the liner and stored solution. A sensitivity analysis indicated that with the given model, the friction angle could be reduced to 21 degrees before a safety factor of 1.0 was reached.

As basic input parameters for both of the licensee's analyses were not provided, an independent analysis was performed. To model the structures, the system cross section shown as section D-D in the May 23, 1988, submittal was selected as the critical section, figure 2. This section contains the inside slope of pond 3 and the outside slope of pond 1. The Bishop method of slices was used to analyze the stability of the section.

Evaluation of the limited laboratory testing indicated that the material was not as sandy as the boring logs indicated. The composite sample classified as a SM-ML material with the majority of the sand sized particles passing the No. 100 sieve. Therefore, a friction angle of 30 degrees and zero cohesion were selected to represent the embankments. This value is based on the available published values for ML, SM, and SM-ML values (USBR, 1977, 1987). These soil types were selected based on the laboratory maximum density values reported in the licensee's October 30, 1991, construction report for ponds 3 and 4. Construction specifications required the fill density to be a minimum of 95 percent of the laboratory maximum dry density. Therefore, the fill's density was selected based on 95 percent of the reported maximum laboratory density of 105 pcf. As-built laboratory compaction data for ponds 3 and 4 submitted by the licensee on October 30, 1992, indicated that the maximum value of 105 pcf is not conservative. However, a maximum laboratory density of 105 pcf is reasonable for SM material.

It was assumed, based on the logs, that the foundation material would be similar to the material that was excavated to provide the fill for the embankments. The section was therefore assumed to be homogenous as no information was provided to indicate the in place conditions of the foundation.

The phreatic surface through the section, figure 2, was conservatively assumed to begin at the low point in pond 1 and daylight at the toe of the inside slope of pond 3. Water level measurements made in the second quarter of 1992 indicated that the phreatic surface was well below the surface in the area. The water surface elevation at monitoring wells MW 1 and 2 located near pond 3 were reported to be 45 feet and 38 feet below the surface, respectively. No pond solutions were included in the model.

The results of the analyses indicated that the minimum factor of safety 1.6 can be expected under the prescribed conditions. This factor of safety is greater than those recommended in RG 3.11. The critical circle cut through the upper section of the pond 1 outslope near the crest and exited near the toe of the slope, above the crest of pond 3. A smaller circle with a factor of safety of 1.2 was located on the inside slope of pond 3. This circle intersected the assumed phreatic surface, hence the low factor of safety. As the assumed phreatic surface is not reasonable for lined ponds, this circle was analyzed only to demonstrate that the effect of allowing a phreatic surface to develop within the embankments. Amendment No. 17 to Source Material License No. SUA-1534 evaluated the liner system and found it adequate.

Seismic Stability

The use of conventional pseudostatic analysis can be considered appropriate for the embankments due to the location and size of the structures. With the limited amount of testing that was performed for the project, it is not possible to use any other methods. Current seismic zone maps (Algermissen and others, 1990) substantiate the use of 0.05g in the pseudostatic analyses.

Liquefaction

The liquefaction potential of the structures is considered minimal by the licensee due to the absence of a means to saturate the fill or the foundation. It is agreed that this evaluation is correct; however, the importance of the liner and leak detection system to the overall design of the structures is once again demonstrated. If a phreatic line is allowed to develop within the embankments or near surface foundation, the liquefaction potential of the soils must be addressed.

Settlement

RG 3.11 recommends that the differential and total settlements of the foundation be evaluated. The magnitude and rate of the anticipated settlement should be estimated from the results of laboratory consolidation tests performed on foundation and remolded embankment materials. RG 3.11 indicates that predicted settlements based on laboratory data may be modified by actual measurements to provide reasonably accurate long-term estimates.

As the exploration and laboratory testing program did not include consolidation tests, the licensee submitted data from the two existing ponds 3 and 4 embankments demonstrating that the two structures have experienced minimal total settlements from construction in August 1990 to July of 1992. These embankments were not constructed with moisture content control. Therefore, it is expected that the proposed embankments, which will be constructed with acceptable fill moisture control, will perform as well or better. At this point, it is suggested that the inspection program for the structures be relied on to address differential settlement. Inspection personnel can be trained to recognize the distress signals of settlement.

Construction Specifications and Quality Control Program

Appendix D of the May 23, 1988, submittal contains the construction specifications and quality control program for the embankments. The specifications require the upper 6 inches of the pond and fill foundations be scarified and compacted to 95 percent of the laboratory maximum density within 2 percent of the optimum moisture content. Embankment fill shall be placed in 6-inch compacted horizontal lifts to 95 percent of the laboratory maximum density within 2 percent of the optimum moisture content. The maximum particle size for the fill shall be 4 inches. No organic or frozen material shall be allowed in the fill. All fill material shall be worked to a uniform moisture content. When necessary, water should be added to the fill material in the borrow area. All areas failing to meet the compaction specifications shall be reworked until the specifications have been met.

The following summarizes the proposed quality control program:

TEST	FREQUENCY
Foundation In Place Density	one test/1[illegible],000 ft^2
Fill In Place Density	three tests/lift

Field tests shall be conducted by the sand cone method, the rubber-balloon method, or by a nuclear gauge.

The proposed specifications and quality control program do not reflect the current practice for high hazard embankments. Therefore, due to the limited amount of site characterization and the deviations from the specifications during the construction of the existing two ponds, the specifications are not considered adequate. The following additions to the specifications and quality control program should be required.

1. Fill material shall be classified as a SM material in accordance with the Unified Soil Classification System.

   This requirement supports the strength and density parameters assumed in the stability analyses.

2. Quality control of the fill shall be performed in accordance with the guidance provided for radon barrier materials in the Staff Technical Position on Testing and Inspection (NRC, 1989).

   This requirement will help ensure that the design assumptions made regarding stability, settlement, and control of the phreatic level are met. The Staff Technical Position is referenced as NRC does not have specific guidance on construction quality control programs for retention embankments.

Inspections

License Condition No. 25 of Source Material License SUA-1534 currently requires weekly visual inspections of all evaporation pond embankments, liners, freeboards, and leak detection systems. The licensee is required to operate the ponds so there is sufficient reserve capacity in the evaporation pond system to enable transfer of the contents of one pond to the other ponds.

Due to the unacceptable practices used during the construction of ponds 3 and 4, it is recommended that the licensee be required to submit an onsite inspection program which meets the guidelines found in Regulatory Guide 3.11.1 (NRC, 1980). Training of field personnel performing the systematic inspections should be done annually, as a minimum. In addition, the individual who performs the annual inspection and technical evaluation should be a registered professional engineer experienced in dam safety. The result of the annual inspection shall be a technical evaluation of the hydraulic and hydrologic capacities and structural stability of the embankments. Review and evaluation of the required surveillance and inspection reports should also be included as part of the report. A copy of each annual technical evaluation report shall be submitted to the NRC, Uranium Recovery Field Office, within 1 month of the inspection.

CONCLUSIONS

It is recognized that the exploration and laboratory testing program represents an extremely limited approach that is not usually considered appropriate for dam design and construction. It is also recognized that although the program was very weak and the design was unsupported in several areas, it was previously approved and two of the structures have already been constructed and put into operation. No operational problems have been reported to date. The two structures that are built and operational provide a large scale prototype which may help verify that the design is acceptable. With the additional provisions to the specifications discussed above, it was concluded that the proposed design of the evaporation pond embankments are acceptable. A large part of the design depends on the integrity of the liner and leak detection system. Amendment No. 17 to Source Material License No. SUA-1534 evaluated the liner system and found it adequate.

The adequacy of the existing embankments remains unknown due to the questionable construction practices used and the reported problems encountered with differing material types. Drilling of the embankments would therefore not provide as built information that could be considered representative of the structures. The only reasonable assurance that the embankments will remain stable is to monitor their performance. The increased inspection program addressed above is adequate to identify situations that may indicate that the structures are being unstable before a danger exists to the public health and safety. The operating procedures will allow the contents contained by an embankment in possible distress to be transferred to another pond.

Therefore, it is recommended that Source Material License SUA-1534 be modified by adding the following license conditions:

53. The licensee shall submit by November 1, 1992, for NRC review and approval, an onsite inspection program which meets, as a minimum, the guidelines found in Regulatory Guide 3.11.1, "Operational Inspection and Surveillance of Embankment Retention Systems for Uranium Mill Tailings." Training of field personnel who will perform the systematic inspections shall be done annually, as a minimum. In addition, the individual performing the annual inspection and technical evaluation shall be a registered professional engineer experienced in dam safety. The result of the annual inspection shall be a technical evaluation of the hydraulic and hydrologic capacities and structural stability of the embankments. Review and evaluation of the required surveillance and inspection reports shall also be included as part of the report. A copy of each annual technical evaluation report shall be submitted to the NRC, Uranium Recovery Field Office, within 1 month of the inspection.

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54. The licensee shall construct ponds 1, 2, and 5 in accordance with their submittal dated May 23, 1988, as modified by their July 16, 1992, submittal. In addition, the ponds shall be constructed as follows:

A. Fill material shall be classified as a SM material in accordance with the Unified Soil Classification System.

B. Quality control of the fill shall be performed in accordance with the guidance provided for radon barrier materials in the Staff Technical Position on Testing and Inspection, 1989.

C. As-built drawings shall be submitted to NRC within 3 months of completion of construction of each pond.

In accordance with the categorical exclusion contained in paragraph (c)(11) of 10 CFR 51.22, an environmental assessment is not required for this licensing action. That paragraph states that the categorical exclusion applies to the issuance of amendments to licenses for uranium mills provided that (1) there is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite, (2) there is no significant increase in individual or cumulative occupational radiation exposure, (3) there is no significant construction impact, and (4) there is no significant increase in the potential for or consequences from radiological accidents.

The licensing action discussed in this memorandum meets these criteria as the proposed amendment only involves enlargement of the ditches which will divert flood flows away from the evaporation ponds. The design of the evaporation ponds was previously approved by NRC when license SUA-1534 was issued in December 23, 1989. This licensing action requires a change in the construction specifications as discussed below. However, this change will result in improved quality control and will not result in any significant construction impacts. An environmental report is not required from the licensee since the amendment does not meet the criteria of 10 CFR 51.60(b)(2).

for Raymond O. Gonzales
Project Manager

Dawn L. Jacoby
Project Manager

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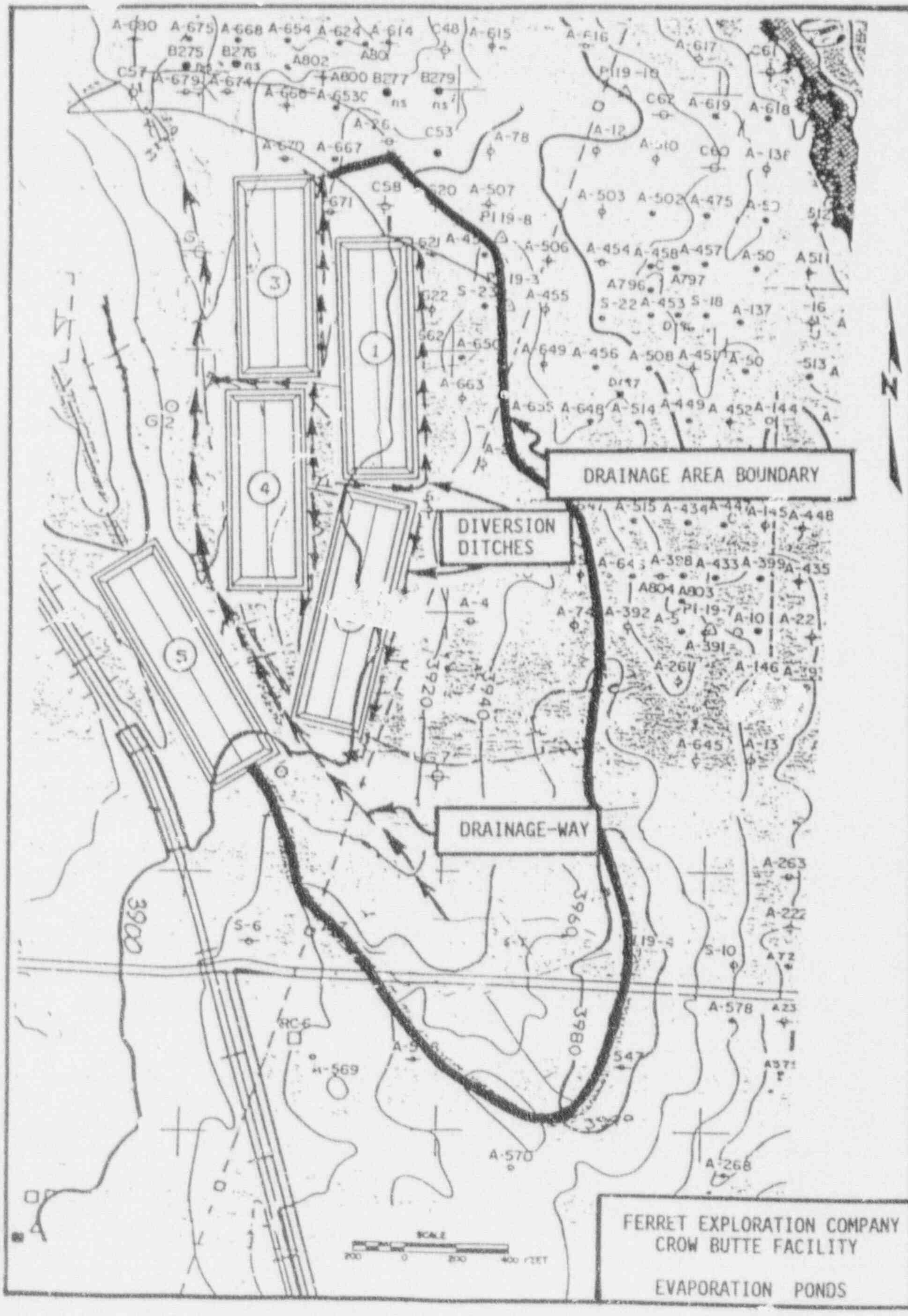
DRAINAGE AREA BOUNDARY
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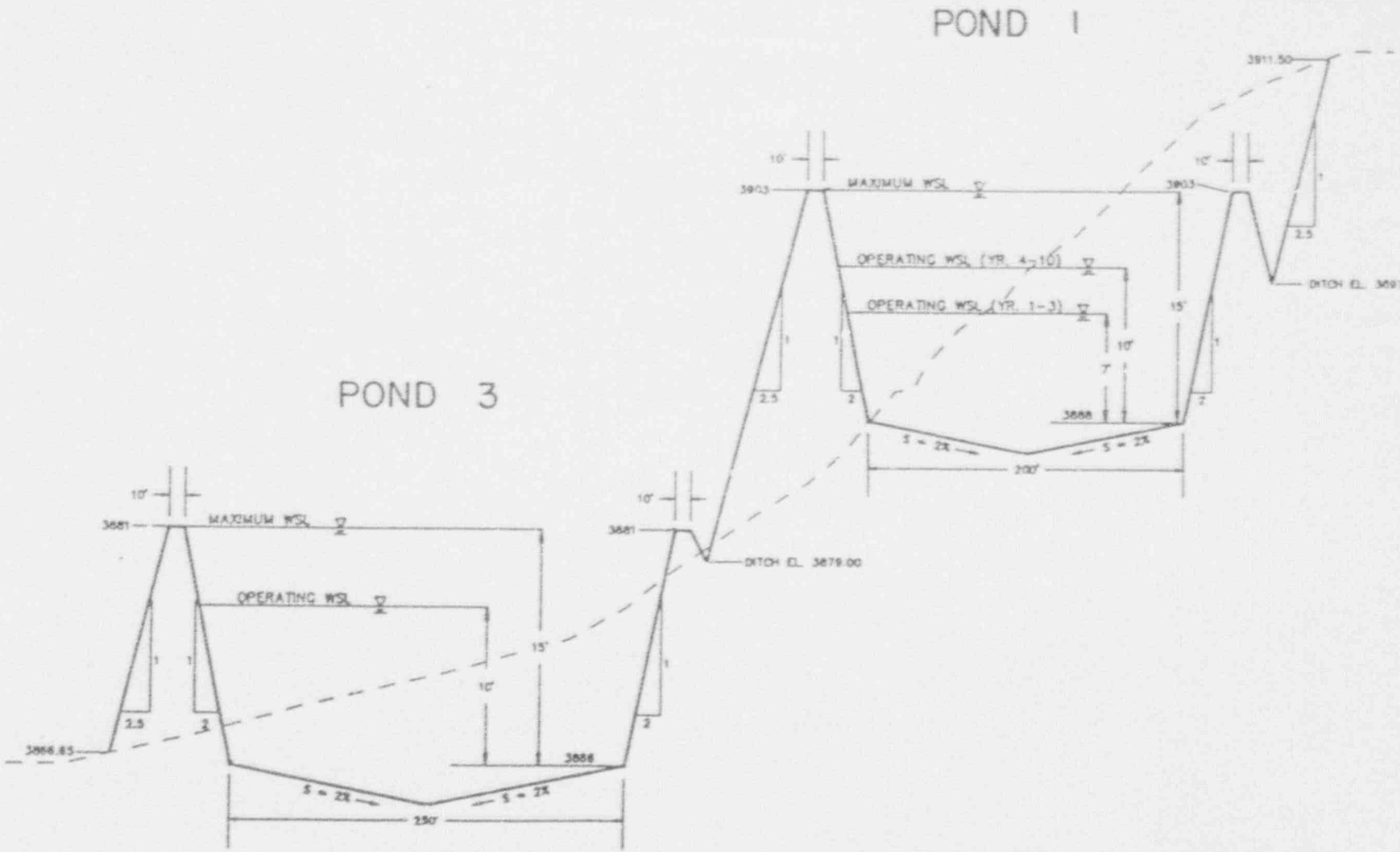
EVAPORATION PONDS

FIGURE 1



FROM SECTION D-D [illegible] 3,
OF THE LICENSEE'S
MAY 23, 1988, SUBMITTAL

FIGURE 2

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DLJacoby/lv	ROGonzales	JPGrimm	EFHawkins	REHall
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