Comments on D'Appolonia's flow model and hydrologic impact analysis of the Crandon site as documented in appendix 4.14A of the EIR. January 1984

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[s.l.]: [s.n.], January 1984

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COMMENTS ON D'APPOLONIA'S FLOW MODEL AND HYDROLOGIC IMPACT ANALYSIS OF THE CRANDON SITE AS DOCUMENTED IN APPENDIX 4.1A OF THE EIR

COMMENTS PREPARED BY

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AUGUST 1983

REVISED JANUARY 1984

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D'Appolonia's simulation of mine dewatering using an application of their finite element model GEOFLOW indicates that the effects of mine dewatering will be tolerable from an environmental standpoint. However, a number of factors affect the validity of their simulation including selection of values for recharge rate, hydraulic conductivity, aquifer thickness, storage coefficent and definition of boundary conditions.

The ways in which these five factors influence the simulation results are discussed under sections I-V below. Water balance calculations, required to establish confidence in the validity of the modeling results, are discussed under section VI below. Throughout sections I-VI questions are raised concerning the validity of the modeling results. Section VII summarizes the main concerns and list specific recommendations for improving the modeling study.

I. RECHARGE RATE

The choice of recharge rate is directly related to the choice of hydraulic conductivity. In other words, it is possible to achieve similar model calibrations with different combinations of hydraulic conductivity and recharge rate. For example, if recharge rate is increased, a higher hydraulic conductivity will be needed to produce a similar head distribution. In the flow component of the Golder screening model (Golder Project Rept. #8), calibration was achieved with a choice of 37 ft/day for hydraulic conductivity and 12.5 in/yr (318 mm/yr) for recharge rate. D'Appolonia used a hydraulic conductivity of 35 ft/day except in the area north of the ore body where values of 0.8 and 11 ft/day were used.

The lower hydraulic conductivity values explain in part why D'Appolonia used a lower overall recharge rate of 8.7 in/yr (220 mm/y). For the calibration phase of the study, recharge rates different from the overall rate were used in 5 areas:

(1) In the wetland area northeast of Rolling Stone Lake recharge was set to zero;
(2) beneath Little Sand Lake recharge was set to 4.6 in/yr (117 mm/yr);
(3) beneath Oak Lake recharge was set to 4.6 in/yr (117 mm/yr);
(4) beneath Deep Hole Lake recharge was set to 13.7 in/yr (347 mm/yr);
(5) beneath Duck Lake recharge was set to 15 in/yr (380 mm/yr).

In the mine dewatering simulation, a special set of recharge rates was used for the tailings ponds (Table A-2), for the drainage ditches around the pond (369 mm/y or 14.5 in/yr), and for the reclaim ponds (p. A-45).

A. VALIDITY OF THE OVERALL RECHARGE RATE OF 220 mm/yr: According to a water budget analysis based on baseflow measurements, the groundwater recharge rate was calculated to be between 137 to 228 mm/yr (Attachment A.3 and p. A-29 of Appendix 4.1A). According to the EIR: "Two different time periods for the water years 1978, 1979, and 1980 were used: (1) February-March (low baseflow conditions) and (2) May-June (high baseflow conditions). The February-March period also represents the time during which ground water levels used in the model calibration were measured" (p. A.3-3). Presumably the lower value of 137 mm/yr for the recharge rate is representative of low baseflow conditions typical during February and March while the higher value is typical of conditions in May and June.

1. During model calibration, the overall recharge rate was varied along with the hydraulic conductivity in zones 1 and 3; the hydraulic conductivity in the low permeability zone (zone 2) was held constant (Table A-14). It is of interest to examine the final two entries in Table A-14. Apparently heads were

calibrated to the Feb. 1982 potentiometric surface using a recharge rate of 240 mm/yr. However, for prediction of mine dewatering the recharge rate was reduced to 220 mm/yr. According to the comment in Table A-14: "The possible dewatering conditions in the mine area was to be examined and the precipitation recharge rate was reduced to 220 mm/yr." During a meeting with EXXON on Jan. 11, 1984, it was said that the recharge rate was reduced to achieve better agreement with estimates of the long term average groundwater discharge to Swamp Creek. According to the EIR (p. A-42) and to a baseflow analysis in the Supplement to Appendix 4.1A (p. 9-11), the long-term average contribution to baseflow in Swamp Creek from the study area, estimated from streamflow measurements, is 2.8 cfs. The last two entries in Table A-14 indicate that a recharge rate of 240 mm/yr yields a simulated baseflow discharge of 2.50 cfs while a recharge rate of 220 mm/yr yields 2.36 cfs. Either value of recharge gives a reasonably good comparison with the field estimate of 2.8 cfs. It is more noteworthy that according to the baseflow analysis in the Supplement to Appendix 4.1A, the contribution to baseflow in Swamp Creek from the study area could be as low as 1.3 cfs.

Given the many assumptions used in the baseflow calculations, the uncertainty regarding the groundwater recharge rate is high. For example, it is difficult to know whether 1978, 1979, and 1980 are representative of long term average hydrologic conditions in Northern Wisconsin. According to the EIR: "From an evaluation of precipitation records and gaging station records for the Wolf River, the water years 1978, 1979, 1980 were found to reflect average baseflow conditions in the study area." (p. A.3-3). THE ANALYSES THAT SUPPORT THIS STATEMENT SHOULD BE PROVIDED TO DNR. FURTHERMORE, JUSTIFICATION FOR ASSUMING THAT 1982 (SPECIFICALLY FEB. 1982) WAS REPRESENTATIVE OF LONG-TERM AVERAGE GROUNDWATER LEVELS SHOULD ALSO BE PRESENTED.

2. EXXON AND DNR SHOULD ESTABLISH A REASONABLE RANGE OF VALUES FOR THE AVERAGE ANNUAL GROUNDWATER RECHARGE RATE. THE SENSITIVITY OF THE MODEL TO CHANGES IN RECHARGE RATE SHOULD BE ASSESSED USING STEADY STATE CALIBRATION RUNS. THE TRANSIENT IMPACT SIMULATION SHOULD BE DONE USING THE LOWEST VALUE IN THIS RANGE IN ORDER TO SIMULATE A WORST CASE CONDITION FROM THE IMPACT STANDPOINT. (Simulations using the Prickett mine inflow model should include consideration of the highest recharge rate to simulate worst case conditions from the point of view of flow into the mine.)

3. According to the last line under the comment column in Table A-14: "calculated piezometric heads were in good agreement with measured in the dewatering calibration". It is unclear what is meant by this because there are no measured values for long term dewatering. Furthermore it is inappropriate to compare the heads from the steady state calibration to heads that represent dewatering. EXXON SHOULD CLARIFY WHAT IS MEANT BY THIS STATEMENT.

B. VALIDITY OF THE RECHARGE RATES FOR THE TAILINGS POND AREA: The recharge rates from the tailings pond area during and after mining that were used in the impact simulation are presented in Fig. A-3 of the EIR.

1. THE VALIDITY OF THE ESTIMATED SEEPAGE RATES FROM THE TAILINGS PONDS DURING MINING SHOULD BE REVIEWED BY DNR. Analyses and justification for the use of these rates were not presented in Appendix 4.1A and hence were not examined during my review.

2. Simulations in the EIR assume that drainage ditches surrounding the tailings ponds will intercept runoff from the reclaimed pond areas and that recharge

from the ditches will be 369 mm/yr (14.5 in/yr) after closure so that there is no net loss of groundwater recharge from the area. As a result, water levels are expected to return to pre-mining conditions, except for some reduction in the size of the groundwater mound in the MWDF recharge area (Fig. A-30). It may not be reasonable to assume that drainage ditches can be maintained after closure. THE FEASIBILITY OF THE PROPER OPERATION OF THESE DITCHES IN PERPETUITY SHOULD BE EXAMINED FROM A DESIGN STANDPOINT. As a point of interest it should be noted that simulations using the Golder Screening Model (Golder Project Rept. #8) assume that a reduction in net recharge will occur in the MWDF (Fig. 8.16-8.17 in Proj. Rept. #8). Golder's comment on these simulations is as follows: "Note that the groundwater mound beneath the Site 41 area has not fully recovered to its original configuration. This is because the reclamation cap limits the infiltration to a level much lower than the present rate." (p. 127 of Project Rept. #8).

C. VALIDITY OF THE LAKE RECHARGE RATES: The model uses recharge rates different from 220 mm/yr for the areas beneath Oak, Little Sand, Deep Hole and Duck Lakes. The model assumes that these four lakes will recharge the aquifer at constant rates throughout the simulation. In effect it is assumed that the potentiometric surface beneath the lakes will drop instantaneously to the bottom of the lacustrine deposit at the start of mine dewatering. Recharge rates are calculated based on a hydraulic gradient equal to the sum of the depth of the lake and the thickness of the lacustrine deposit divided by the thickness of the lacustrine deposit (S. Haji-Djafari, personal communication, July 28, 1983; also see p. A-29 and A-65 and Table A-12 of Appendix 4.1A).

The assumptions made regarding the treatment of the lakes is critical in view of the potential for mine dewatering to effect lake levels.

1. According to Table A-12 of Appendix 4.1A, the lake level of Little Sand Lake is currently 2.5-3.5m above the potentiometric surface. This information is said to be taken from cross sections in Golder Project Report #8. However, there are no cross sections of this type in that report. I assume the cross sections intended are those in Golder's Geohydrologic Characterization Report. According to information on p. 90 of that report, the lake level in Little Sand Lake is about 2.51 m (8.23 ft) above the surrounding groundwater level. Additional data on lake relationships are given in Table 5.2 of Project Report #8. However, these data do not agree with the numbers in Table A-12. For example, according to Table 5.2 groundwater levels beneath Little Sand Lake are 1.8 to 4.9 meters lower than lake level. Moreover, the EIR assumes that the water level differences beneath Oak Lake are the same as beneath Little Sand Lake. However, according to Table 5.2, the groundwater levels at Oak Lake are "at least" 14.9 to 19.2 m below lake level. Data for Deep Hole and Duck Lakes show similar discrepancies. THE DISCREPANCIES BETWEEN TABLE 5.2 IN THE GOLDER GEOHYDROLOGIC CHARACTERIZATION REPORT AND TABLE A-12 IN THE EIR SHOULD BE RESOLVED.

2. I was not able to reproduce the numbers for maximum and minimum recharge rates given in Table A-12. Little Sand Lake is used as an example. I assumed a maximum lake depth of 6.4 m (from Table A-10) and an average depth of 10 m for the lacustrine deposit beneath the lake (from Table A-12). The vertical hydraulic conductivity of the lacustrine deposit was assumed to be 3E-9 m/s (from Table A-6). My calculations are shown in Figure 1.

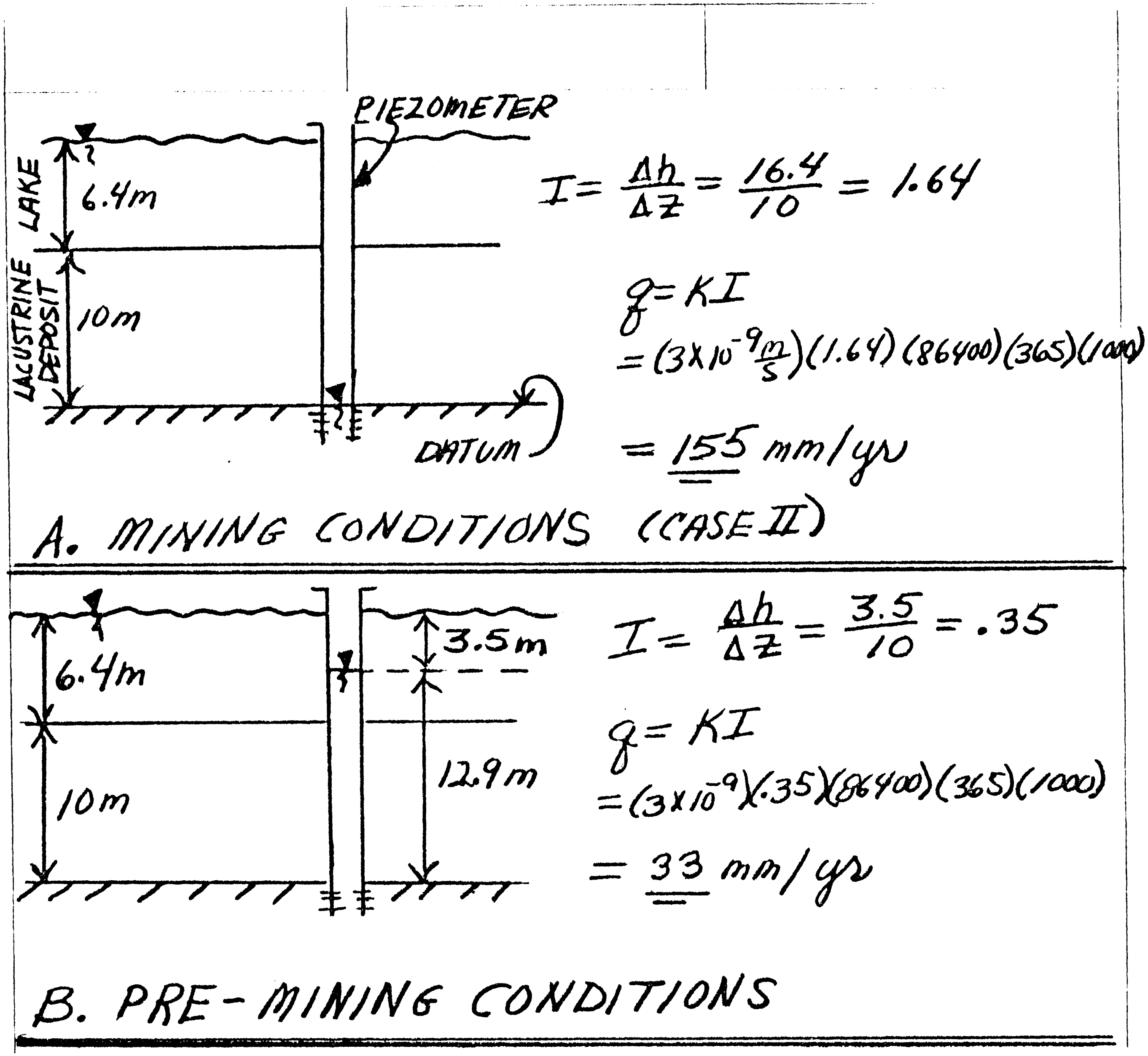

FIGURE 1. LAKE RECHARGE RATES

According to my calculations the recharge rate beneath Little Sand Lake would be 155 mm/yr if the potentiometric surface drops to the base of the lacustrine layer (my Fig. 1A). Under pre-mining conditions the recharge rate is only 33 mm/yr (my Fig. 1B). EXXON used a value of 117 mm/yr for seepage from Little Sand Lake both before and during mine dewatering. My calculations indicate instead that seepage rate will increase by 122 mm/yr during mining. This increase translates to a drop in lake level of 0.122 m/yr, assuming no net inflow of water to the lake (i.e., assuming that precipitation equals evaporation and that there is no surface runoff to the lake). If the potentiometric surface drops to the base of the lacustrine layer after 3 years, the lake level will drop 0.122 m/yr for 30 years or a total of 3.66 meters, again assuming no net inflow of water to the lake. Given that precipitation exceeds evaporation in Wisconsin, it would be expected that contributions of water from precipitation and possibly from surface runoff would mitigate any decline in lake level. EXXON SHOULD PROVIDE WATER BUDGET ANALYSES FOR ALL THE INTERNAL LAKES TO DEMONSTRATE THE EFFECT OF DEWATERING ON LAKE LEVEL. Without results of lake water budget analyses, there is no justification for the statement that: "The results showed a small increase in recharge from the lakes and a negligible variation in lake levels." (p. A-65 of Appendix 4.1A).

3. Furthermore, it does not make sense to use lake recharge rates based on dewatering conditions to calibrate the model. The Feb. 1982 potentiometric surface was used for calibration; consequently, estimates of current (1982) lake recharge rates should be used for calibrating the model. Yet, the model could be calibrated to Feb. 1982 water levels using the lake recharge rates shown in Table A-12, which are based on dewatering conditions. This suggests that either these rates are more or less in the right order of magnitude for pre-mining recharge rates or that the model is insensitive to these paramters

at the lake nodes. Still the fact remains that lake seepage rates during mining must be greater than current rates. All this suggests to me that the value assumed for the hydraulic conductivity of the lacustrine material is too low. If a value of 3E-8 m/sec is used for the hydraulic conductivity of the lacustrine material instead of 3E-9 m/sec, the current lake recharge rate would be 330 mm/yr, which is not unreasonable if 220 mm/yr is assumed for the overall recharge rate. One would expect the current recharge rate beneath Little Sand Lake to be higher than the overall recharge rate if the placement of the 482 m contour line shown on Fig. A-10 is correct. (The 482 m contour line shows that a slight groundwater mound exists beneath Little Sand Lake.)

AS PART OF A SENSITIVITY CHECK, THE STEADY STATE CALIBRATION AS WELL AS THE TRANSIENT IMPACT ANALYSIS SHOULD BE DONE USING A HIGHER VALUE (e.g., 3E-8 m/sec) FOR THE HYDRAULIC CONDUCTIVITY OF THE LACUSTRINE DEPOSITS.

4. The recharge rates for the lakes supposedly were calculated based on the assumption that the potentiometric surface would drop to the base of the lacustrine layer in response to mine dewatering. My Figure 1B shows that this means that the potentiometric surface is expected to drop 12.9 m beneath Little Sand Lake. However, the results of the model simulations in Fig. A-25 show that at Project Year 33 drawdown beneath most of Little Sand Lake will be less than 5 m for the Case I simulation. Hence, the validity of the Case I simulation is suspect. For the Case II simulation, Fig. A-29 shows that drawdowns beneath Little Sand Lake range from 6 - 22 m, with most of the lake area showing less than 13 m. Prickett's mine inflow model indicates that inflow rates cannot be reduced to 1000 gpm. Therefore, only the Case II simulation is relevant. Hence, an assumed average drop in water level of 12.9 m beneath Little Sand Lake is not unreasonable for the Case II simulation.

However, in view of the importance of establishing the impact of mine dewatering on the lakes, a more elegant treatment of lake seepage is warranted. THE MODEL SHOULD BE CONSTRUCTED TO ALLOW PREDICTION OF LAKE RECHARGE RATES BY THE MODEL, BY TREATING THE LAKES AND THEIR UNDERLYING LACUSTRINE DEPOSITS AS SOURCES AND LEAKY CONFINING LAYERS. This treatment of partially penetrating surface water bodies is a standard option in both the Prickett-Lonnquist (1971) flow model and the USGS two-dimensional flow model (Trescott et al. 1976). In this way the necessity of estimating lake seepage a priori would be avoided. Furthermore, it would be possible to input arrays of values representing the hydraulic conductivities and thicknesses of the lake sediments for all elements beneath each lake. The model would calculate variable seepage rates using the variable head conditions beneath the lake.

II. HYDRAULIC CONDUCTIVITY

A. ZONES OF LOW HYDRAULIC CONDUCTIVITY NORTH OF THE OREBODY: The isopach map of the coarse-grained stratified drift was apparently revised subsequent to Golder Project Report #8. The map shown in Project Report #8 (Fig. 8.10) does not show the thinning of the drift north of the orebody, which is a prominant feature on Fig. A-11 of Appendix 4.1A. Fig. A-11 is, in part, the basis for the introduction into the GEOFLOW model of two zones of low hydraulic conductivity north of the orebody (zones 2 and 3 on Fig. A-18). These zones have hydraulic conductivities considerably lower (11 and 0.8 ft/day) than the rest of the modeled area (35 ft/day). It is likely that an acceptable model calibration could have been achieved without the introduction of these zones of low hydraulic conductivity. In fact, the Golder Screening Model was calibrated without using these low hydraulic conductivity zones. Fig. 8.12 of Project Report #8 shows that equipotential lines predicted by the Golder model mimic the lines drawn using measured head values in the area north of the orebody.

1. Justification for introduction of the areas of low hydraulic conductivity must be based not on model calibration but on field evidence. Comparison of the boring location maps in Golder Project Report #8 (Fig.5.2) and Fig. A-8 of Appendix 4.1A does not show any new borings. EXXON SHOULD PROVIDE AN EXPLANATION FOR THE DIFFERENCE IN THE ISOPACH MAPS USED IN THE GOLDER SCREENING MODEL (report dated Jan. 1983) AND THE EIR WHICH BEARS AN EARLIER DATE (Dec. 1982).

2. The existence of the zones of low hydraulic conductivity is probably critical to the validity of the model simulations. The model simulations show that the cone of depression is flattened to the north of the orebody (e.g., Fig. A-25)

and that a groundwater divide forms between the ore body and Swamp Creek during dewatering (e.g., see Fig. A-24). This suggests that the areas of low hydraulic conductivity act to restrict the spread of the cone of depression and cause it to expand preferentially to the south. According to the isopach maps in both the Golder report and the EIR, the aquifer is thicker to the south of the ore body. Therefore, even if the areas of low hydraulic conductivity were removed from the model, the cone would still spread preferentially to the south. However, without the results from a sensitivity analysis of the effect of these zones of low hydraulic conductivity, it is unclear how important they are in restricting the movement of the cone of depression to the north and in minimizing impacts on the flow in Swamp Creek. SENSITIVITY ANALYSES, INCLUDING A TRANSIENT DEWATERING SIMULATION, SHOULD BE PERFORMED IN WHICH THE AREAS OF LOW HYDRAULIC CONDUCTIVITY ARE REMOVED FROM THE MODEL.

B. COARSE-GRAINED STRATIFIED DRIFT: Most of the modeled area (zone #1) was assumed to have a hydraulic conductivity of 35 ft/day. A hydraulic conductivity of 35 ft/day is reasonable for the coarse grained stratified drift of Northern Wisconsin and has been used for simulation of a lake/groundwater system centered around Snake Lake in Vilas County (Anderson and Munter, 1981). Their simulation was based on field data from Born et al. (1973) who estimated the hydraulic conductivity of the sandy outwash aquifer in the area around Snake Lake to be in the range of 20-80 ft/day.

C. LACUSTRINE MATERIALS: The lacustrine materials for Snake Lake were estimated to be around 1.34 ft/day whereas the lacustrine materials in the Crandon area are estimated to be 0.00085 ft/day but range from 0.00085 to 11.3 ft/day (Table

A-6). A value of 0.00085 ft/day (3E-9 m/sec) is in the middle of the range of suggested values for the hydraulic conductivity of glacial till recommended by Freeze and Cherry (1979, p. 29). Values of 1-11.3 ft/day are at the high end of range. The hydraulic conductivity of the lacustrine materials is critical in predicting the effect of mine dewatering on lake level. For example if a value of 3E-8 m/sec instead of 3E-9 m/sec (0.00085 ft/day) is used in the calculations shown in my Fig. 1, the decline in lake level would be 1.22 m/yr for 30 years or 36.6 m total, assuming no net inflow of water to the lake. This can be compared to 3.66 m total if hydraulic conductivity of the lake sediments is assumed to be 3E-9 m/sec. SEE RECOMMENDATION UNDER SECTION I-C.3 OF THIS REPORT.

III. AQUIFER THICKNESS

The GEOFLOW simulation assumes that flow occurs only through the coarse-grained stratified drift. Movement of water through and release of water from storage in the till is neglected.

It could be argued that much of the till is nearly as permeable as the coarse-grained stratified drift and that part of the till should be included in the model. However, by using only the thickness of the coarse-grained stratified drift, the model simulates a worse case in terms of impact. Hence, for the hydrologic impact analysis, this assumption is justified. HOWEVER, THE TILL LAYER, OR AT LEAST PORTIONS OF THE TILL SHOULD BE INCLUDED IN THE PRICKETT MINE INFLOW MODEL IN ORDER TO SIMULATE A WORST CASE FROM THE POINT OF VIEW OF FLOW INTO THE MINE.

IV. STORAGE COEFFICIENT (S)

A. RATIONALE FOR CHOICE OF S=0.05: In the GEOFLOW model a storage coefficient of 0.05 was used for zones 1 and 3 and a value of 0.054 was used for zone 2. In the Golder Screening Model, two values of storage coefficient were used: 0.07 was used for the unconfined portions of the aquifer and 0.054 was used where the aquifer is semi-confined by saturated till (Fig. 8.11). According to the EIR, p. A-17, "Since the majority of the planned hydrologic actions are in the area of the semiconfined aquifer, the value of 0.05 was selected as the storage coefficient for use in the hydrologic analysis." However, Fig. A-13 shows that more than half of the mine area is located below the unconfined aquifer. Hence, if only one value were to be used, it would seem more reasonable to select a storage coefficient representative of unconfined conditions. Values of S in the range of 0.1 - 0.2 are more reasonable values for unconfined aquifers. EXXON SHOULD COMMENT AND PROVIDE ADDITIONAL JUSTIFICATION FOR THE CHOICE OF 0.05.

B. MODEL CALIBRATION TO S=0.05: The D'Appolonia model was not calibrated to transient conditions. Therefore, the validity of the value for storage coefficient was not tested in the calibrations reported in the EIR. However, the model was later used to simulate the Golder pumping test of well TW-41, which is in the semi-confined portion of the aquifer. The results of this simulation are reported in the supplement to Appendix 4.1A and suggest that the value of 0.05 could be reasonable for the semi-confined portion of the aquifer.

A transient calibration was performed by Prickett for his mine-inflow model. He found that in order to match drawdown curves from a pumping test in the ore body, it was necessary to use values of storage coefficient of 0.001 for the semi-confined portion of the glacial aquifer and 0.15 for the unconfined portion. The pumping test that Prickett used for calibration purposes was only 7 days in duration and it may be that the value of 0.001 is too small to be representative of long-term pumping. However, the value of 0.15 is larger than the value of 0.05 assumed by D'Appolonia. Moreover, 0.15 is a more reasonable value for the storage coefficient of an unconfined aquifer. Prickett switched to D'Appolonia's values for impact assessment in order to be consistent with the GEOFLOW model. EXXON SHOULD COMMENT ON WHY MR. PRICKETT WAS INSTRUCTED TO SWITCH FROM 0.15 TO 0.05 AND WHY D'APPOLONIA DID NOT INSTEAD SWITCH FROM 0.05 TO 0.15.

C. EFFECT OF S ON IMPACT ANALYSIS: It could be argued that the use of a storage coefficient of 0.05 is a conservative assumption because a smaller value of storage coefficent will cause the cone of depression to spread more rapidly. For impact analysis, the choice of storage coefficient is less critical than estimates of hydraulic conductivity and recharge rates because the steady state solution is independent of storage coefficient. However, it is also true that the use of a higher storage coefficient would increase the time to reach steady state and in this sense 0.05 is not a conservative choice for storage coefficient. Yet, comparison of Fig. A-23 and A-25 shows that the configuration of the cone of depression does not change significantly between Project Years 5 and 33. Prickett shows that mine inflow rates reach steady state after about 1100 mine plan days (3 years). It is probable that the time to steady state would not be significantly longer with a somewhat higher storage coefficient (e.g., 0.15).

More importantly, it should be noted that use of a small storage coefficient is not a conservative assumption in predicting the volume of mine inflow before steady state is reached. Lower values of storage coefficient mean that less water will flow into the mine at early times. Hence, the choice of value for storage coefficient could be important in predicting mine inflow rates. SENSITIVITY TO CHOICE OF S IS BETTER EVALUATED USING THE PRICKETT MINE INFLOW MODEL.

V. BOUNDARY CONDITIONS

D'Appolonia used all specified head boundary conditions. Specified head boundaries are favored by modelers because they speed up the calibration process. Fixing the boundaries at the "correct" head values, will keep the edges of the model calibrated while adjustments are made to the parameters in the interior of the model. Rarely are specified heads justified for use in a two-dimensional areal model based on hydrogeologic field data. An example of a true specified head boundary would be a stream or lake that fully penetrates the aquifer. Most streams and inland lakes are not fully penetrating. However, some specified heads are necessary in most modeling applications. Therefore, one tries to specify heads in areas where field conditions most nearly approximate a constant head condition or where the choice of boundary will not affect the model results.

A. STREAMS AND BOUNDARY LAKES: The information at my disposal suggests that none of the lakes and streams in the study area fully penetrate the aquifer. The simulation for Case II dewatering (unmitigated mine inflow) (Fig. A-28) suggests that the impacts are largely confined to the northern portion of the study area, roughly north of an east-west line drawn across the area from Walsh Lake. Therefore, only the boundaries north of this line will be examined.

Assuming that the head will remain constant in time along the boundary means that heads along the boundary cannot be affected by dewatering. Furthermore, these boundary nodes provide a source of water to the model which could act to "give" the model "extra" water. For example, consider the area along the eastern boundary of the model, immediately north of Walsh Lake. Fig.

A-19 shows that under pre-mining conditions water flows eastward across this segment of the boundary. Comparison of Fig. A-19 (pre-mining) and A-28 (year 33 of Case II) shows that during mining, water flows westward across this boundary. In the real world (in contrast to the world of the model) water levels might decline in this area. Keeping the heads at a constant level here could act to provide a source of water in the model that doesn't exist in the real world. Such a source could act to minimize flow diversions from Hemlock Creek.

Similar sorts of effects in the model could be acting to draw water to Swamp Creek and Pickerel Creek rather than to the mine area, thereby minimizing impacts on the creeks. The model's use of constant head boundaries and the corresponding assumption of fully penetrating streams could create a higher horizontal gradient toward the stream in the model than a partially penetrating stream. If the streams were simulated as partially penetrating, the head in the aquifer below the stream would be higher than the head in the stream. This might induce a lower horizontal head gradient toward the stream which would cause more of the regional flow to flow toward the mine rather than to the streams.

AS A SENSITIVITY CHECK, THE MODEL SHOULD BE RE-RUN USING NO FLOW BOUNDARY CONDITIONS ALONG THE STREAM.

B. ROLLING STONE WETLAND AREA: A similar sort of boundary effect is evident in the wetland area northeast of Rolling Stone Lake. This wetland is assumed to act as an internal specified head boundary (see Fig. A-18). It is unclear why this is necessary. These constant head nodes seem to act to keep the cone of depression away from Rolling Stone Lake. This effect is evident in Fig. A-29 (note the indentation in the cone of depression northeast of the lake). Not surprisingly Table A-18 indicates that mining will not divert any flow from segment EF which includes Rolling Stone Lake and the lower portion of Pickerel Creek (Fig. A.3-1). In fact, the simulation predicts that there will be a slight increase in discharge rate. In the real world, it would be expected that water levels in the wetland area would decline during dewatering if the cone of depression reaches this area.

THE WETLAND AREA SHOULD BE SIMULATED SIMILAR TO THE WAY RECOMMENDED FOR THE INTERNAL LAKES. SEE SECTION I-C.4 OF THIS REPORT.

VI. WATER BALANCE

A. DOCUMENTATION OF THE WATER BALANCE CALCULATION: According to the GEOFLOW user's manual (May 1983): "No subprogram evaluating the mass balance of the simulation system is presently included in GEOFLOW." During a meeting with EXXON on Jan. 11, 1984, it was stated that such a subprogram now exists. THE PROGRAM LISTING AND DETAILED DOCUMENTATION SHOULD BE PROVIDED TO DNR.

B. ACCURACY OF THE WATER BALANCE CHECK: The results of a water balance check for the application of GEOFLOW to the Crandon Site is given in the Supplement to Appendix 4.1A. According to information on p. 7 of the supplement, the percent error in the water balance for the horizontal flow model for the steady state simulation (no mine inflow) is 14.5%. This is quite a large error for a flow model. The USGS two-dimensional model routinely has less than 1% error. During the Jan. 11th meeting with EXXON, it was indicated that an error in accounting for outflow from the model had been detected in the water balance calculation. THE NEW MASS BALANCE RESULTS FOR THE STEADY STATE CALIBRATION AS WELL AS FOR THE TRANSIENT SIMULATION REPORTED IN THE EIR SHOULD BE PROVIDED TO DNR.

C. "CREATION" OF WATER DURING THE DEWATERING SIMULATION: Because of the way in which the model treats elements that go dry, the error in the water balance could be higher for the simulations that involve mine dewatering. If the model predicts that the aquifer has a saturated thickness less than 0.457 m in response to mine dewatering, the model is directed to re-set the saturated thickness in that element to 0.457 m. This is necessary because if the heads were not re-set, the element would have zero transmissivity and soon the area around the mine would be surrounded by a zone of zero transmissivity and no water could reach the mine. This is clearly unrealistic. Therefore, it is necessary to maintain some transmissivity in the elements around the mine by re-setting the saturated thickness periodically and allowing the model to "create" water at these elements.

Elements go dry fairly quickly. During the first four years of the simulation, the saturated thicknesses in four elements (#367, 397, 430, 431) are re-set to 0.457 m (Printout 2.1), causing the "creation" of approximately 60,000 cubic meters (gal) of water in the first four years of the simulation. Of the four elements that are re-set, only one is directly over the mine area (#430). The other three are north of the mine area (see Fig. A-18). In the simulation for years 32- 33, twelve nodes are re-set (Printout 2.12) and of these only three are over the mine area; the other nine are north of the mine.

These adjustments are necessary because a two-dimensional model is being used to represent a three-dimensional flow system. It is difficult to assess the amount of error caused by manipulating the model in this way. The amount of water "created" during the simulation may be insignificant in relative terms. If so, results of a water budget analysis for the transient simulation (see, Section B above) will be helpful in evaluating the errors introduced by these head manipulations.

Another concern is that the model as constructed does not accurately reflect the flow regime. For example, in the field the glacial aquifer north of the mine site could de-saturate and water might flow from the glacial aquifer through fractures in the surrounding bedrock and then laterally through the sides of the orebody to the mine. (See discussion on this subject in my report on Prickett's mine inflow model.) IN ORDER TO ADDRESS THE POTENTIAL FOR THE CREATION OF THIS TYPE OF FLOW SYSTEM, MORE INFORMATION ABOUT THE CURRENT THREE-DIMENSIONAL FLOW SYSTEM THAT INCLUDES THE GLACIAL AQUIFER, THE OREBODY AND THE SURROUNDING BEDROCK IS NEEDED. This issue is best addressed through compilation and analysis of existing field data on hydraulic conductivities and heads in the orebody as well as additional simulations using the Prickett mine inflow model.

VII. SUMMARY

In my opinion a number of assumptions used in the simulation of the Crandon site are questionable, including the treatment of Little Sand, Oak, Deep Hole and Duck Lakes, the use of specified head boundary conditions in the northern half of the modeled area, and the creation of water in elements that go dry during the simulation. In addition, a detailed sensitivity analysis is needed in order to determine the effects of uncertainties in the model parameters.

1. The lakes should be treated as source bed aquifers so that variable seepage rates from the lake are automatically calculated by the model. In this way, seepage rates will accurately reflect the variable head distribution beneath the lake. The model will then be capable of accounting for spatial variations in thickness and hydraulic conductivity of the lakebed sediments. Furthermore, a priori assumptions about the magnitude of lake seepage during dewatering will be avoided.

2. No flow boundary conditions should be imposed along segments of Swamp Creek and possibly Hemlock Creek, in successive runs of the transient model in order to determine the sensitivity of the impact predictions to assumed boundary conditions. The wetland NE of Rolling Stone Lake should be treated as in #1, above.

3. Detailed water budget analyses should be provided for each run of the model. These analyses should include documentation of the way in which the budget was calculated as well as the calculations and final results. A careful accounting of the volume of water "created" at nodes that go dry during the dewatering simulation should also be provided.

4. Detailed documentation of the results of a sensitivity analysis should be prepared. The sensitivity analysis should address the sensitivity of the model's impact predictions to changes in:

   (a) recharge rate;
   (b) hydraulic conductivity in zones 1, 2, and 3, with special attention to zones 2 and 3;
   (c) leakance of the lakebed sediments, where leakance is defined to equal the ratio of hydraulic conductivity to thickness;
   (d) storage coefficient with special attention to the effect of storage coefficient on the time needed to reach steady state conditions.

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