Report

Assessment of the Influence of Dewatering at Bailly N-1

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D'APPOLONIA

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1.0 INTRODUCTION

Northern Indiana Public Service Company (NIPSCO) has retained D'Appolonia Consulting Engineers, Inc. (D'Appolonia) to assess the influence of construction dewatering at NIPSCO's Bailly Generating Station, Nuclear 1 (Bailly N-1) on groundwater levels in the vicinity of Cowles Bog which is located within Indiana Dunes National Lakeshore (IDNL) (Figure 1).

D'Appolonia has provided services as a geotechnical consultant in and around the Indiana Dunes area since 1959 at the site of Midwest Steel Company, since 1963 at the site of Bethlehem Steel Corporation (BSCO) and since 1966 at the site of the Port of Indiana. A part of D'Appolonia's responsibility has been large scale subsurface investigations and construction dewatering using deepwell and wellpoint systems.

The U.S. Geological Survey (USGS) in cooperation with the National Park Service (NPS), has published two reports; 78-138 and 80-1105 (References 1 and 2 respectively) relative to effects of construction dewatering on groundwater levels within IDNL.

Reference 1, issued in January 1979, summarizes a two year study of soil and groundwater conditions within a study area located north of U.S. 12, between the Port of Indiana and Mineral Springs Road in Porter County, Indiana. The study area is outlined in blue on Figure 2. A portion of IDNL is adjacent to NIPSCO's Bailly Generating Station where two fossil fuel plants are operating and a nuclear generating unit is under construction. The principal objective of the USGS study was to investigate the effects of construction dewatering on the groundwater levels within IDNL. The USGS constructed a digital model of the groundwater regime for this purpose. The finite-difference model (Trescott 1975) was used to simulate and predict changes of groundwater flow in three dimensions throughout the study area.

At a meeting on January 31, 1980 NPS informed NIPSCO that the USGS, using the model, had predicted groundwater changes of up to 0.5 feet at Cowles Bog (over 8000 feet away) resulting from NIPSCO's pressure relief system. Because this prediction is inconsistent with observed data in the area, NIPSCO requested that D'Appolonia review the soil parameters used in the USGS report. The results of this review were submitted in Reference 3.

Reference 2, issued in September 1980, is a supplement to Reference 1 directed specifically toward determining the effect of Bailly N-1 construction dewatering at Cowles Bog.

This report encompasses a study of References (1), (2), soil data, pumping tests and observations during construction in the Indiana Dunes area since 1959. Based on our analysis of all available data, it is our view that the pressure relief system proposed for Bailly N-1 dewatering will not affect the water level at Cowles Bog.

2.0 SITE CONDITIONS AND SOIL PARAMETERS

The study area consists of land owned principally by Bethlehem Steel Corporation (BSCO), NIPSCO and NPS. Throughout the BSCO site (Burns Harbor Plant) over 800 borings were drilled, five of which were drilled within the IDNL. Over 120 soil borings were drilled on the NIPSCO property (Bailly Generating Station). Over 400 observation wells and over 70 dewatering wells were installed within the study area. Two field pumping tests were conducted to obtain in situ permeability; one in 1963 at the BSCO site and another in 1979 at Bailly N-1 site.

Reference 1 describes the study area as approximately 80% industrialized land and 20% national lakeshore. Surficial physical features include the interdunal ponds (Pond Nos. 1, 2, 3 and 7), the fly-ash settling ponds (Pond Nos. 10, 11, 12 and 13) and the Great Marsh which contains an area known as Cowles Bog, designated as a National Landmark.

Reference 1 divides the soils into four units. The following descriptions of these units are extracted from Reference 1.

- Unit 1, unconfined aquifer, consists primarily of fine sand with lateral hydraulic conductivity of 167 ft/day. The saturated thickness ranges from 0 to 35 feet.

- Unit 2, confining layer, consists chiefly of clay with a thickness ranging from 0 to 80 feet.

- Unit 3, confined aquifer, consists chiefly of fine to medium sand with lateral hydraulic conductivity equal to that of Unit 1. The thickness of the unit ranges from 0 to 80 feet.

- Unit 4, primarily silt and clay with a thickness ranging from 60 to 140 feet. The characteristics of Unit 4 are not considered in this report.

Relying upon numerous borings, pumping tests and knowledge gained through 21 years of experience in the area, soil conditions and layering can be reliably defined at the BSCO and NIPSCO sites. This is not true for the IDNL portion of the study area since logs of only five borings and one water supply well (W1) are available for analysis. Although USGS installed over 30 observation wells within IDNL, adjacent to Bailly N-1, soil sampling was conducted in only one of these. The remaining were installed by driving or jetting. However, these data are sufficient to identify some of the contradictions in the data between Reference 1 and several logs which are selected from the above mentioned logs. The contradictions are discussed in detail in section 3.3 of this report.

D'Appolonia's review of all available data indicates that the permeable soils (Units 1 and 3) within the study area should not be modeled as two aquifers (unconfined and confined) separated by a practically impervious layer (Figures 3 and 4). Generally there is one aquifer which is partly unconfined and partly confined because the confining layer is absent in many locations. The sands of Unit 1 and Unit 3 are directly connected not only through many large openings in the confining layer (Unit 2) but also to Lake Michigan as a line source. A detailed description of the confining layer is presented in Reference 3. The simplifying assumption used in modeling is inconsistent with the actual statigraphy in the study area.

During review several discrepancies were discovered between the actual conditions and the conditions presented in Reference 1 relating to BSCO dewatering wells. These differences introduce serious errors which preclude reliable model results.

The major points from Reference 3 can be summarized as follows:

1. A large body of field data relative to soil parameters within the study area has been collected over a 20-year period; the USGS reports ignored or misused much of this data.

2. There are significant discrepancies between the actual field data and the data and assumptions used by the USGS. For example:

    a. The wrong permeabilities were used for Units 1 and 3.

    b. The USGS study incorrectly modeled the top elevations of Unit 2.

    c. Unit 3 is connected to the sands that lie above Unit 2 through many large openings and it is also connected to Lake Michigan. Unit 2 is not continuous as the USGS assumed.

    d. Units 1, 2 and 3 are different in shape and in thickness from those used in the model.

    e. There are major differences between actual ground water levels and those assumed by the USGS.

    f. Two different aquifers (unconfined and confined) do not exist throughout the study area as modeled by the USGS; in many areas they are connected and act as one.

3. The radius of influence (the limit of lateral extension of a cone of depression) for the pressure relief system was calculated using actual permeabilities obtained from pumping test results and found to be less than 950 feet. Accordingly, the system cannot have any effect on Cowles Bog which is located over 8,000 feet from the Bailly N-1 site.

4. The radius of influence from the pressure relief system will not reach the bog area even if it is assumed that Unit 2 is continuous throughout the study area with an opening ("window") only under the bog.

5. For these reasons it is concluded that the model, as presently constructed, does not accurately predict groundwater fluctuations and cannot be used to support the conclusion that the pressure relief system will affect the Cowles Bog area. One may safely argue, a posteriori, that a model reflecting a drawdown at 8000 feet under these circumstances contains inherent error because the result is manifestly wrong.

3.0 REVIEW OF USGS REPORTS

D'Appolonia's initial review was limited to soil parameters used in the USGS Report 78-138. After the USGS Report 80-1105 was released, at NIPSCO's request, D'Appolonia performed a review of both USGS reports. The following is an analysis of pertinent issues addressed in both USGS reports.

3.1 USGS REPORT 78-138 (Reference 1)

3.1.1. "Unit 3 consists chiefly of a gray, fine to medium sand but contains thin lenses of sandy clay, clay, and sand and gravel. Thickness of unit 3 ranges from 0 to 80 ft (fig. 9). The unit is thickest beneath the central and south-central parts of the study area. Where unit 3 is absent, unit 4 merges with unit 2." (p. 14, Par. 3)

In the 5000 by 8000 foot area between NIPSCO's east property line and Cowles Bog, no boring has been drilled deep enough to determine the thickness of Unit 3. Accordingly, Figure 9 showing "thickness of unit 3" in that area is speculative. This figure is included in Appendix B.

3.1.2 "..average lateral hydraulic conductivity of 167 ft/day * for unit 1. This value is at the upper end of the range of lateral hydraulic-conductivity values reported for this unit in Porter and LaPorte counties . . ." (p. 15, Par. 1)

The site is not in LaPorte County. On site and near site values of permeability are available. Permeability calculated by the authors is "at upper end of reported values" but was used as a representative average value.

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* 589 x 10^{-4} cm/sec

The most reliable procedure for determining the average in situ permeability of a water-bearing formation is a field pumping test (Reference 4). In 1963 a field pumping test was conducted at the BSCO site prior to any deep well dewatering activity. The average in situ permeability of the sands was calculated to be 250 x 10^{-4} cm/sec or 71 ft/day. Extensive dewatering throughout more than 1000 acres regularly confirmed this as a representative value of average permeability.

In 1979 a field pumping test was conducted in Unit 3 at the site of Bailly N-1 (Reference 7). Using 80 feet as the thickness of Unit 3 and an average transmissivity of 12,000 GPD/ft, it was found that the resulting average permeability is 70 x 10^{-4} cm/sec or 20 ft/day.

The permeability used in the model for Unit 1 and Unit 3 is two to eight times higher than the average permeability obtained from these field pumping tests.

A permeability of 1 x 10^{-4} cm/sec for "fine silty sand with clay" (a part of Unit 3) was determined by D'Appolonia using the USGS log of observation well 107 (Appendix C). The permeability of 589 x 10^{-4} cm/sec used in the model is about 600 times higher than actual permeability at observation well 107. Additional details regarding permeability within the study area are contained in Section 4.0 of Reference 3 and Section 3.3 of this report.

Based on the above it is concluded that the permeabilities used in the model do not reflect site conditions. Differences in actual permeabilities vary too much to be used as a constant throughout the study area. Further, the value of a finite difference model lies precisely in the ability of introducing a large number of variables.

3.1.3 "Lines of equal transmissivity for units 1 and 3 were obtained by multiplying the average hydraulic-conductivity value by thickness, as determined from the thickness maps for each unit. The distributions of transmissivity for units 1 and 3 are shown in figures 11 and 12, respectively. Although the preceding technique can lead to a systematic estimate of transmissivity either too high or too low, these maps (figs. 11 and 12) did not require adjustment during model analysis." (p. 15, Par. 3)

Because the coefficients of permeability used by the authors are incorrect and the absence of information from deep borings in the area between NIPSCO's east property line and Cowles Bog, the estimate of transmissivity as shown in Figures 11 and 12 (Reference 1) is invalid. Any transmissivity lines drawn between NIPSCO's east property line and Cowles Bog are speculative. Figures 11 and 12 from Reference 1 are included in Appendix B.

3.1.4 "A map (fig. 16) showing the approximate configuration of the October 26, 1976, potentiometric surface of unit 3 provides a base map for the unit before dewatering at the nuclear excavation site or pumping at the coal-fired plant. Pumping at the plant began in January 1977, and dewatering at the nuclear excavation site began in March 1977." (p. 31, Par. 3)

On Figure 16 of Reference 1, the Unit 3 potentiometric contour north of Bailly N-1 near the lake is shown at elevation 600. The ground surface elevation in this area is between 580 to 585 feet. Using this elevation implies that Unit 3 is a free-flowing artesian aquifer which is not the case, as no artesian head was encountered during drilling operations in the area. The USGS report does not recognize that Unit 3 is not, in fact, a confined aquifer and the contour variation should have alerted the USGS to a flaw in its application of the model.

> 3.1.5 "Constructing the map of the potentiometric surface of unit 3 involved adjusting the water levels in Bethlehem Steel Corp. wells in unit 3 in a manner similar to that done for wells in unit 1. A decrease in water levels in Bethlehem Steel Corp. observation wells from September 1976 to January 1977 ranged from 0.60 to 4.4 ft. Water levels for the Geological Survey wells in unit 3 for October 26, 1976, were estimated by following the trends of the water level in the unit in Bethlehem Steel Corp. wells from September 1976 to April 1977, when water levels were available for all the Geological Survey wells. The adjustment required was an increase of 2.0 ft. over April water levels. The potentiometric surface of unit 3 on October 26, 1976, constructed by the preceding method, is shown in figure 16. Although not based on data for this date, the map of this surface for October 26 represents an approximation that is probably accurate within the contour interval of the map and should allow a reasonable interpretation of the flow direction in unit 3 on this date." (p. 31, Par. 5)

The model was calibrated using these estimated water levels which are "probably" accurate within the contour interval. The contour interval is 5 feet and there is only one data point in the northern half of the study area and no data points in the vicinity of Cowels Bog (Figure 6) indicating that model calibrations were not performed with an accuracy sufficient to predict water level changes as small as a tenth of a foot.

> 3.1.6 ". .At present (1977) it [BSCO] is pumping 5 wells, althou . it has pumped more than 70 wells at different times. Information on well locations, well construction, historic water levels, and specific-capacity tests for the major wells constructed during the last 5 years was made available to the Geological Survey by Bethlehem Steel Corp. during the study. . " (p. 49, Par. 1)

In Reference 1, Figures 13 and 25 show only one well while Figures 16 and 26 show three wells (See Figures 5 and 6, this report). All these figures are for water levels on October 26, 1976. Table I (Page 49, Reference 1) shows four wells to be active on that date. The USGS is aware that all of these wells are fully gravel-packed (Pages 15 and 49, Reference 1). Therefore, all the wells are pumping from both Unit 1 and Unit 3, yet in Table I the USGS lists wells 6 and 73 as pumping only from Unit 3. Accordingly, the model derived water levels as presented in Figures 25 and 26 are incorrect, as the well data has been incorrectly incorporated into the study.

3.1.7 "Water is pumped for domestic use in Dune Acres and in the southeast part of the study area, but this pumpage is minimal and has only a very localized effect on ground-water levels." (p. 52, Par. 5)

This may be relevant to the study objectives of Reference 1. It is not true for Reference 2 in which the study objective is to assess the influence of construction dewatering at Bailly N-1 on Cowles Bog (Figure 1) over 8,000 feet away. Using the model, the USGS predicted groundwater level changes as far as the Cowles Bog area. If this is correct, all wells within a radius of approximately 10,000 feet from Cowles Bog should be incorporated into the model particularly when the study is attempting to determine water level changes as small as one tenth of a foot.

3.1.8 Figure 11, Reference 1, "Transmissivity of Unit 1, October 26, 1976."

Figure 11 (Reference 1) is included in Appendix B and shows that Unit 1 is absent in the southeast corner of the study area.

Figures 13 and 25 (Reference 1) then show groundwater levels for Unit 1 in the area where Unit 1 is supposedly absent. Obviously this is incorrect (Figure 5 of this report).

3.1.9 Figure 16, Reference 1, "Potentiometric surface of Unit 3, October 26, 1976".
Figure 26, Reference 1, "Model-derived steady state potentiometric surface of Unit 3".

Figure 16 shows observed water levels in Unit 3 (see Section 3.1.5) for October 26, 1976, and Figure 26 shows the model derived water levels for the same time. Data from these two figures is summarized and presented in Figure 6 of this report. It can be seen that water levels in Unit 3 are not in good agreement particularly for model calibration and that groundwater levels for Unit 3 are shown in the area where Unit 3 is absent north of Bailly N-1.

3.2 USGS REPORT 80-1105 (Reference 2)

3.2.1 'A variation or "discontinuity" in the hydraulic characteristics of the confining unit (unit 2) beneath Cowles Bog would intensify water-level declines in unit 1 in the vicinity of Cowles Bog resulting from construction dewatering. With the "discontinuity", a simulation of simultaneous decline of the seepage mound and the second phase of dewatering indicates that water levels in unit 1 in Cowles Bog would be below "reference water levels" (water levels, as simulated in the model, that would have been present in unit 1 on October 26, 1976, if there had been no seepage from the fly-ash ponds) after 18 months. For a comparable simulation without the "discontinuity," water levels did not decline below the

> "reference levels." Model results with the "discontinuity" present also indicate that the artificial recharging of unit 1 near the excavation cannot completely make up water-level declines below "reference levels" within the area of Cowles Bog after 18 months of simultaneous decline of the seepage mound and the second phase of dewatering...' (p. 1, Par. 4)

The accuracy of "reference water level" is commented upon in Reference 1, Page 31 and is reproduced below:

> "Constructing the map of the potentiometric surface of unit 3 involved adjusting the water levels in Bethlehem Steel Corp. wells in unit 3 in a manner similar to that done for wells in unit 1. A decrease in water levels in Bethlehem Steel Corp. observation wells from September 1976 to January 1977 ranged from 0.60 to 4.4 feet. Water levels for the Geological Survey wells in unit 3 for October 26, 1976, were estimated by following the trends of the water level in the unit in Bethlehem Steel Corp. wells from September 1976 to April 1977, when water levels were available for all the Geological Survey wells. The adjustment required was an increase of 2.0 feet over April water levels. The potentiometric surface of unit 3 on October 26, 1976, constructed by the preceeding method, is shown in figure 16. Although not based on data for this date, the map of this surface for October 26 represents an approximation that is probably accurate within the contour interval of the map and should allow a reasonable interpretation of the flow direction in unit 3 on this date." (underlining added for emphasis)

The map of the water surface has an accuracy of 5 feet, and yet it is used as "reference water levels". These were used throughout Reference 1 and 2 studies to predict drawdown, which will introduce error.

3.2.2 '. . .Because of the close proximity of the model boundary to the bog, model simulation can only yield maximum and minimum estimates of the impact of the seepage-mound decline and construction dewatering for simulations of the "discontinuity" beneath Cowles Bog. The maximum and minimum estimates of impact are derived by simulating a constant-flux boundary and a constant-head boundary, respectively, at the east edge of the model. The difference between the maximum and minimum impacts is significant, particularly for simulation of seepage-mound decline, but the model cannot be used to determine which boundary condition best simulates the aquifer system. A new expanded model, which places the east boundary farther away from Cowles Bog to eliminate the effects of that boundary on water levels near the bog, would be needed to refine the estimates of the impact of construction dewatering and seepage-mound decline on water levels in the vicinity of the bog. Also, if possible, the storage properties of the marsh, which are not incorporated in the present model, could be included.' (p. 2, Par. 1)

Moving the east boundary farther to the east (away from the bog area) will not "refine" the predicted drawdown in the bog area but simply force the predicted drawdown to become greater. There are unlimited locations of the east boundary and correspondingly unlimited predicted drawdowns in the bog area for this computer model. The modeling error is endless unless the radius of influence of the dewatering wells is taken into consideration when establishing the model boundary.

The storage properties of the marsh cannot be excluded from the model as it is a year round wetland and virtually eliminates any predicted drawdown.

3.2.3 'The USGS and the NPS have collected new hydrologic data in the vicinity of Cowles Bog. These data suggest that (1) the confining unit (unit 2), normally present between the unconfined aquifer (unit 1) and the confined aquifer (unit 3), <u>may</u> be thin or absent; (2) the vertical hydraulic conductivity of unit 2 <u>may</u> be greater than it is elsewhere; or (3) a combination of items (1) and (2) <u>may</u> exist in the area of the bog. This "discontinuity" in the confining unit would greatly enhance the hydraulic connection between the unconfined and confined aquifers and <u>could</u> intensify the impact of construction dewatering on water levels at Cowles Bog, particularly <u>if</u> a large part of the water pumped from the excavation came from unit 3.' (underlining added) (p. 3, Par. 3)

Item (1) states that the confining unit <u>may</u> be thin or absent. There are many locations within the study area where unit 2 is absent or is very thin (References 1, 2 and 3).

Item (2) above states that the vertical hydraulic conductivity <u>may</u> be greater. This condition exists in all locations where unit 2 is absent. Conclusions based on the "new data" are speculative. The expression "may be" is hypothetical and generates hypothetical results. There are no deep soil borings within the bog area and its surroundings. To speculate as to the characteristics of Unit 3 using hypothetical data to define the soil strata results in an unrealistic assessment of the effect of construction dewatering on Cowles Bog.

3.2.4 ". . The objectives [illegible] the study were to (1) review all significant hydrolog[illegible] collected at the NIPSCO Bailly site since the study by Meyer and Tucci (1979) and determine whether the data could be used to refine their estimates of effects of construction dewatering on ground-water levels in the Lakeshore, . ." (p. 3, Par. 4)

The study did not "review all significant hydrologic data", or if it did, it failed to incorporate these into its analyses. Reference 2 ignores the permeability determined from a key pumping test conducted by NIPSCO. The resulting value of 70 x 10^{-4} cm/sec (Reference 7) is more than eight times smaller than the permeability 167 ft/day or 589 x 10^{-4} cm/sec used by the USGS in its computer model. Further, the NIPSCO pumping test yielded a radius of influence of only 600 feet. This is confirmed by other tests and observations in the area.

> 3.2.5 ". .In the south one-third of the excavation, the water levels in both units 1 and 3 have declined about 11 feet. The nearly equal water-level decline in the two units also suggests that the hydraulic connection between the two aquifers is good in that area, especially because little water has been removed directly from unit 3. The significance of this hydraulic connection was investigated further by examining the results of phase 1 dewatering for model experiments K through Z of Meyer and Tucci (1979)." (p. 4, Par. 2)

The above discussion identifies a "good" hydraulic connection at only one location whereas there are many hydraulic connections throughout the study area which have not been considered (References 1, 2 and 3). In many cases Reference 2 relies on assumptions rather than data.

> 3.2.6 " Pumping directly from unit 3 for reduction of hydrostatic pressure in that unit was simulated in revised experiments S and U by assigning a constant head of 583.7 feet above NGVD to unit 3 at the model node representing the south one-third of the excavation and then holding it constant throughout the 18-month duration of phase 2 dewatering. Selection of this water level to represent the average requirement for reduction in hydrostatic pressure in unit 3 under the excavation was based on data presented in the report by Sargent and Lundy (1979)." (p. 15, Par. 3)

On November 7, 1979, the groundwater level in Unit 3 inside the slurry wall was 589.8 (Figure 5 of Reference 2). Experiments S and U simulated drawdown to el. 583.7, creating 6.1 feet water level change in Unit 3. The calculated radius of influence (R) for this case, using the equation widely accepted (see Section 5.0), is:

$$R = 3\ (\Delta H)\sqrt{K} = 3 \times (6.1)\sqrt{589} = 444 \text{ feet.}$$

Where R= Radius of influence (feet)

ΔH= Drawdown at point of withdrawal (feet)

K= Permeability expressed in 10^{-4} cm/sec units

This calculated Radius of Influence is vastly less than the 8000 foot distance to Cowles Bog. Even allowing for considerable error in permeability, the radius of influence does not extend to Cowles Bog.

3.2.7 ". . .Simulated water-level declines in unit 1 for revised experiment U are only slightly greater than those produced by experiment U of Meyer and Tucci (1979). This near agreement indicates that simulation of an extended phase 1 dewatering, a lower maintenance of the water level in the excavation for phase 2 dewatering, and direct pumping from unit 3 produce an estimated impact on water levels within the Lakeshore that differs little from those estimated by Meyer and Tucci (1979). The model-calculated rate of pumping from the excavation at the end of revised experiment U was 819 gal/min of which 816 gal/min is from unit 3 and 3 gal/min from unit 1. The total rate compares fairly closely with the 710 gal/min for experiment U of Meyer and Tucci (1979, table 4)." (p. 15, Par. 4)

Units 1 and 3 are connected inside and outside the slurry wall. Pumping rates of 816 gpm from Unit 3 and 3 gpm from Unit 1 are unrealistic. It is reasonable to expect that more than 3 gpm will come directly from Unit 1 through the steel sheet piling at northeast corner of the excavation, and indirectly via Unit 3 which is connected to Unit 1 outside the slurry wall.

3.2.8 Figure 9, Reference 2, "Model-simulated water-level declines in Unit 3 after 18 months of phase 2 construction dewatering (revised experiment U)"

Figure 9 shows 2 feet of water level decline in Unit 3 north of Bailly N-1 excavation site. According to the USGS reports, unit 3 does not exist in this area. The drawdown is incorrect and illustrates that the model simulation is inapplicable.

3.2.9 ". . .Whether the actual ground-water system will behave in the same manner as the model simulation depends on how well the model simulates the physical properties of the ground-water system and the artificial recharge of water for mitigation. Therefore, these model simulations should not be viewed as precise predictions of what will occur in the field, but rather as an estimation of what may occur." (p. 27, Par. 1)

This is true for all models. The USGS model does not simulate actual physical site properties. More importantly, the model is incorrectly used to predict drawdown beyond the radius of influence, a contradiction the USGS reports fail to address.

3.2.10 'The ground-water mound in unit 1 at Cowles Bog is probably due to a thinning or absence of the confining unit (unit 2) beneath the center of the bog that normally separates units

> 1 and 3, or a greater value of the vertical hydraulic conductivity of unit 2 beneath the center of the bog than elsewhere, or a combination of both factors. The variation in one or both of the characteristics of the confining unit, hereafter termed a "discontinuity," results in a better connection between the two aquifers (units 1 and 3) than elsewhere. Upward flow from unit 3 to unit 1 through the confining unit (unit 2) is well documented in the study area and throughout the Lakeshore. For example, upward flow is evident at well 108, about 2,000 feet northeast of Cowles Bog and east of Mineral Springs Road (fig. 14), where the water level in unit 3 was about 2.2 feet higher than the level in unit 1 in February 1980. The better hydraulic connection beneath Cowles Bog apparently allows greater quantities of ground water to discharge upward from unit 3 into unit 1 through the "discontinuity" than where the confining unit is present and thus to produce the mound in unit 1 at the bog. Other documented "discontinuities" in the confining unit include one at the west end of pond 1 and another in the south part of the study area (Meyer and Tucci, 1979, fig. 7). There also may be a "discontinuity" under the south part of the excavation.' (p. 27, Par. 4)

Flow from Unit 3 to Unit 1 is not documented. In many areas it has been documented that the flow is from Unit 1 to Unit 3. At the Bethlehem Steel Corp. plant site, shallow piezometers showed higher groundwater levels than the deep piezometers prior to the plant dewatering in 1963. The USGS piezometers 103 and 104 (Figure 2) show the same water level; the USGS piezometer G6 shows a water level in unit 1 higher than piezometer 102 in Unit 3. The USGS piezometers 107 (in Unit 3) and 108 (in Unit 1) cannot be used for comparison because 107 is screened in a layer of silty sand with clay and it is out of order. According to the data, it is doubtful if 107 was working properly from the time of installation. The USGS statement ". . Upward flow is evident at Well 108 . ." is incorrect because the screen of Well 108 is located in Unit 1 and Unit 2 is present at that location, therefore, it cannot record water levels in Unit 3.

3.2.11 'Although the hypothesis of the "discontinuity" in the confining unit at Cowles Bog has not been proven with direct evidence such as test borings and corings, the mound in unit 1 indirectly supports it. The USGS and NPS will continue to gather data that will expand and refine the present understanding of the hydrology of Cowles Bog. For now, the hypothesis that a "discontinuity" exists in the confining unit underlying Cowles Bog is assumed, and the model simulations that follow incorporate this "discontinuity".' (p. 33, Par. 2)

Results derived from a hypothetical case are themselves hypothetical and inconclusive. They do not provide a reasonable engineering definition of the impact of the NIPSCO dewatering on Cowles Bog.

3.2.12 '. .Thus, for all model simulations involving the "discontinuity" in the confining unit at Cowles Bog, both constant-head and constant-flux boundary conditions were used in both units 1 and 3 along the east edge of the model. The two boundary conditions result in maximum and minimum effects on water levels at Cowles Bog caused by seepage-mound decline and construction dewatering. Although the storage properties of unit 1 were considered in the simulations, the storage properties of the Great Marsh were not. Standing water in the marsh and water in the organic mat could moderate water-level declines.' (p. 34, Par. 1)

The standing water in the marsh must be considered in the computer model because the marsh has an area of several hundred acres and the elevated portion of the bog has an area of 10 acres. This large body of available water would virtually eliminate the water level decline if indeed it were influenced by the NIPSCO dewatering.

> 3.2.13 "Evaluation of data collected at the NIPSCO Bailly site since December 1977 indicates that, of experiments K-Z by Meyer and Tucci (1979, tables 3 and 4), experiments S and U are the ones that best simulate field conditions. These two experiments assumed that the lateral hydraulic conductivity of the slurry wall around NIPSCO's excavation is equal to the design value 2.8 x 10^{-4} ft/day and that the vertical hydraulic connection between units 1 and 3 under the south one-third of the excavation is good. Model analysis indicates that the vertical hydraulic conductivity of the confining unit between units 1 and 3 under the excavation is a more sensitive parameter than the slurry-wall lateral hydraulic conductivity in the simulation of water levels near the excavation. Further, the good vertical hydraulic connection between units 1 and 3 yields results that are more consistent with field data regardless of what value of the lateral hydraulic conductivity of the slurry wall was used in the simulations." (p. 48, Par. 1)

Based on the above, Experiment S and U best simulate field conditions, but Figure 37 (Experiment S) of Reference 1 shows 5 feet of drawdown for the same experiments in Unit 3 north of Bailly N-1 where Unit 3 is absent. Also, Figure 9 (Revised Experiment U) Reference 2 shows 2 to 5 feet drawdown in Unit 3 where it is absent. This is a contradiction or inaccuracy of the "best" simulated experiments.

3.2.14 'Recently collected data indicate that a ground-water mound exists in unit 1 at Cowles Bog. The mound is probably produced by the upward discharge of ground water from unit 3 into unit 1 through a "discontinuity" in the confining unit that normally separates the two aquifers. A simulation of water-level decline due to phase 2 dewatering, including the "discontinuity," indicates that phase 2 is close to equilibrium after 18 months in the vicinity of the bog. Simulations also indicate that the "discontinuity" could cause intensified water-level declines in unit 1 at Cowles Bog during phase 2 construction dewatering and that water-level declines below the "reference level" at Cowles Bog cannot be eliminated completely by either the proposed mitigation plan or any remnant of the seepage mound present after 18 months of simultaneous phase 2 dewatering and seepage mound decline.' (p. 48, Par. 3)

The radius of influence from dewatering in Unit 3 at Bailly N-1 site will not reach the bog area (see Section 5.0). Even if it is assumed that it will reach the bog area, it will not cause intensified water level changes in Unit 1 near the bog area because the 10 acre elevated portion of the bog is encompassed by 240 acres of wetland. The wetland around Cowles Bog is also connected to another several hundred acres of wetland on the east side of Mineral Spring Road.

3.2.15 "Because the flow model has not been verified, it can only be used in a general way to evaluate the effect of construction dewatering and decline of the seepage mound on ground-water levels in and near the Lakeshore. Until the model-simulated estimates of water-level decline can be compared with measured declines, the accuracy of the simulated declines can not be determined.. ." (p. 48, Par. 4)

The flow model has not been verified, therefore, the accuracy of the simulated declines is unknown. However, as previously stated, because the model is predicting drawdowns beyond the radius of influence, it is safe to conclude that either the model or its application is incorrect.

> 3.2.16 ". . .A new expanded model, which places the east boundary farther away from Cowles Bog to eliminate the effects on water levels near the bog, would be needed to refine the estimates of the impact of construction dewatering and seepage-mound decline on water levels in the vicinity of the bog. More field data, detailing the stratigraphy and hydrology of the area, would need to be collected to further refine, calibrate, and verify the model." (p. 49, Par. 1)

Ideally the boundary should be established at the radius of influence of the pumped well (or wells). Arbitrarily setting the boundary to include areas of interest while ignoring the radius of influence presupposes and in fact "forces" drawdown to occur in all areas included in the model simulation. That fact alone renders meaningless drawdown predictions between the radius of influence and the boundary where the boundary is arbitrarily extended beyond the radius of influence.

3.3 DISCUSSION OF SOIL DATA

D'Appolonia compared soil stratigraphy used by the USGS with the actual data at 13 locations. The comparisons of soil stratigraphy and permeabilities are illustrated on Figures C1 through C13 presented in Appendix C. The data used by the USGS in their model was taken from Figures 6, 7, 8, 9 and 10 of Reference 1 and are reproduced in Appendix B. Actual soil conditions are derived from USGS piezometer installation logs and soil boring logs by Sargent & Lundy, and D'Appolonia. Permeabilities assigned to the actual soil conditions are based on published correlations and pumping tests within the study area (see Appendix A). These comparisons have been limited only to those data points near Cowles Bog and those of major importance. The thirteen locations are shown on Figure 2.

Some of the differences revealed by the comparisons in Appendix C are outlined below:

1. The actual soil layers are substantially different than those used in the USGS model.

    a. Unit 2 is actually much thicker in the northeast area adjacent to Cowles Bog than assumed in the USGS model. As a result, the extent of impervious soils is greater than modeled by the USGS.

    b. Unit 3 in the east and south areas around Cowles Bog consists of silty sand with clay. These soils will exhibit a coefficient of permeability 30 to 600 times less than the value modeled by the USGS.

    c. There are no soil borings available for comparison west of the bog area except piezometer 102 which is located approximately 3000 feet away. This boring exhibits a clay layer sandwiched within Unit 3 which will greatly reduce groundwater flows.

    d. Because there are no soil borings in the Cowles Bog area and the large area surrounding the bog, little or no soil information is available for the computer program. The soil parameters for Units 1, 2 and 3 have been assumed by the USGS studies and those assumptions are inconsistent with the best data available.

2. From these boring logs the soils consist of many interbedded clay and sand layers. The clay layers vary from 3 to 5 feet in thickness and will drastically reduce the overall transmissivity of Unit 3. Accordingly, the radius of influence is diminished. The USGS did not account for the multi-layering system in modeling the groundwater regime.

4.0 REVIEW OF USGS MODEL

The NPS retained the USGS to assess the effect of Bailly N-1 construction dewatering on water levels within the IDNL boundary including the Cowles Bog area. This assessment has been conducted by simulating the subsurface flow regime using a finite difference computer program developed by Trescott (Reference 9). The results of simulations are presented in References 1 and 2. As shown in this report, the USGS model results contradict hydrologic principles by indicating drawdowns, water levels and time to equilibrium values which are grossly inconsistent with previous experience, actual observations, calculations, and actual pumping tests in the area. A review of the modeling discloses several significant items that result in either meaningless or unreliable results. The modeling is discussed below.

D'Appolonia did not have access to all the computer input and output data while conducting this review. Therefore, input errors, truncation errors and errors in interpreting the output data are not addressed.

4.1 GRID SYSTEM

The grid system has two major faults, the close proximity of the model boundary to the bog and the increasing grid size between Bailly N-1 and the bog. The following instructions are set forth in the User's Manual for this computer program (Reference 9):

- Boundaries within the project area should be located accurately.

- Distant boundaries can be located approximately and with fewer nodes by expanding the grid.

- Place nodes closer together in areas of rapidly changing transmissivity in each layer.

The grid system was established for the study conducted in Reference 1 which was concerned with the western portion of the IDNL property and this area is modeled with a relatively fine grid. However, in the second study, Reference 2, Cowles Bog is the area of major concern; yet it is represented by some of the coarsest grids in the mo Certainly, a "discontinuity in Unit 2" would represent an "area of rapidly changing transmissivity", and Figure 14, of Reference 2, shows that water levels near Cowles Bog vary considerably within relatively small lateral distances. Yet this assumed discontinuity is represented by only one node. The Cowles Bog area study should not have been performed using a grid designed for the study in Reference 1.

4.2 INPUT DATA

Key input parameters used in the model are incorrect, the most reliable data (that obtained from pumping tests) was not used at all, and some of the data used was improperly interpreted.

Omission of the storage properties of the Great Marsh is significant. There is over 200 acres of standing water contiguous to Cowles Bog. There is an additional several hundred acres of standing water east of Mineral Springs Road, which is directly connected to Cowles Bog through a culvert and Unit 1. As mentioned on page 34 of Reference 2, "standing water in the marsh and water in the organic mat could moderate water level declines" (underlining added). It is our view that several hundred acres of standing water immediately available to the Cowles Bog area will offset any hypothetical water level declines.

Inaccurate representation of site conditions is discussed in detail in Sections 2.0 and 3.0 of this report and is summarized below for convenience.

- Units 1 and 3, particularly in the western portions of the study area, are connected and they constitute a single unconfined aquifer.

- Observed water level readings at Units 1 and 3 are different than those used by USGS.

- The actual hydraulic conductivities, hence transmissivity used for Units 1 and 3, are different than shown in both USGS reports.

- The dewatering wells at the BSCO plant were improperly modeled.

In addition, permeabilities of Units 1 and 3 are not constant as assumed in the analyses. Therefore, the resulting transmissivities are incorrect (Figures 11 and 12 Reference 1, which are included in Appendix B). It is difficult to understand the purpose of using an intensive finite difference modeling procedure, and then assume the same permeabilities in Unit 1 and Unit 3 throughout the entire study area. This is particularly true when the available data indicates permeability variations of up to 600 times less than the values used in the model. Using more realistic permeability values will greatly reduce drawdowns within the IDNL property.

There is a critical lack of stratigraphic data, particularly in the northeastern portion of the study area (the Cowles Bog and the Great Marsh area). This was not adequately considered in discussing the accuracy of the model results. On page 33 of Reference 2 the USGS states:

> "However, the lower vertical hydraulic conductivity of the confining unit used in Experiments S and Revised S produced a better simulation of the observed difference between water levels in Units 1 and 3 in Cowles Bog than Experiments U and Revised U".

The nearest observation well to Cowles Bog, which measured water levels in Unit 3, is over 2000 feet away. Yet differences in water levels between Unit 1 and Unit 3 at Cowles Bog are presented and predicted to the nearest 0.1 foot (Table 3, Reference 2). Accuracy of 0.1 feet at a distance of 8000 feet is precluded by errors and oversimplifications in the input data. In fact, the distance alone precludes that level of accuracy.

4.3 MODEL LIMITATIONS

In the User's Manual (Reference 9, page II-14) it is stated that some features such as the necessary logic to permit an aquifer to change from artesian to water table conditions can be added to the three dimensional models with changes in the code. Also, Reference 1, Page 53 states:

> "The finite difference model of Trescott (1975) for simulation of unsteady or steady, confined or unconfined, groundwater flow in three dimensions was used to simulate the movement of groundwater in the unconsolidated rocks underlying the study area".(underlining added).

We interpret these statements to mean that the program as used by the USGS, does not permit an aquifer to change from artesian (confined) to water table (unconfined) conditions. This represents a major breach in the model logic, considering that a change from confined to unconfined conditions does in fact occur in several areas. Such a condition would occur at the assumed discontinuity under Cowles Bog where the drawdown is predicted to one tenth of a foot.

4.4 MODEL CALIBRATION

Calibration of the model is not sufficiently accurate to predict drawdowns to the nearest foot, and certainly not to one tenth of a foot. Comparison of Figures 4, 5, and 6 of Reference 2 show water level drawdown variations in excess of 2 feet in close proximity to the NIPSCO excavation where input data is relatively plentiful Reference 1, Page 34 recognizes this.

> "Although not based on data for this date, the map of this surface for October 26 represents an approximation that is probably accurate within the contour interval of the map and should allow reasonable interpretation of the flow direction in Unit 3 on this date" (underlining added).

This refers to Figure 16 (Reference 1) which has a contour interval of 5 feet. Other water level inconsistencies include:

- Water levels are shown to exist in Unit 3 where Unit 3 does not exist, north of Bailly N-1.
- The 605 contour is drawn through the northeastern portion of the study site without a data point on which to base the location of this interval.

At Cowles Bog the measured water levels vary between elevations 604 and 608, as shown in Figure 14, Reference 2. Yet in the model both Unit 1 and Unit 3 water levels are calibrated to elevation 605. While this may be the "best model experiment", it is certainly not sufficiently accurate to predict drawdowns to 0.1 feet, considering variations between the simulated and observed drawdown where observed data is available.

4.5 BOUNDARY CONDITIONS

The USGS has mentioned throughout Reference 2 that the finite difference model boundary was too close to Cowles Bog to obtain a good estimate of the drawdown values and that:

> "A new expanded model, which places the east boundary farther away from Cowles Bog to eliminate the effects on water levels near the bog, would be needed to refine the estimates of the

> impact of construction dewatering and seepage-mound decline on water levels in the vicinity of the bog" (Reference 2, Page 49).

A misconception exists with the premise that extending the boundary eastward will produce more accurate drawdown results at Cowles Bog. Inherent in models such as this, is the fact that if the eastern boundary were extended Detroit (over 200 miles to the east) the model would show drawdowns in South Bend, Indiana (about 50 miles to the east), and the model would correspondingly indicate greater drawdown in Cowles Bog. Conversely, if the boundary were placed west of Cowles Bog then the model would accurately show no drawdown at Cowles Bog. The concept of a radius of influence thus becomes essential to obtain reliable values from finite difference modeling. The eastern boundary of the study area at its present location, represents a radius of influence ten times greater than observations, experience, and calculations support.

4.6 OVERALL MODEL STRATEGY

In the paper "Groundwater Modeling: An Overview", (Reference 10), authors James Mercer and Charles Faust, experts in finite difference modeling, state:

> "Of course confidence in any predictive results must be based on (1) a thorough understanding of the model limitations, (2) the accuracy of the maps with observed historical behavior, and (3) knowledge of data reliability and aquifer characteristics."

As mentioned above, and elsewhere in the report, a model which cannot handle aquifers which may vary from artesian to water table conditions is used. Very little of the available historical data has been used, and none exists in the Cowles Bog area. And most importantly, there is a critical lack of subsurface stratigraphic data throughout the northeastern portion of the study area, and that which is known, has been incorrectly used in many cases. For these reasons, it is D'Appolonia's view that extended study (Reference 2) should not have been conducted without better input parameters.

Mercer and Faust also state:

> "Perhaps the worst possible misuse of a model is blind faith in model results. Calculations that contradict normal hydrologic intuition almost always are the result of data input mistakes, a 'bug' in the computer program, or misapplication of a model to a problem for which it was not designed. Proper application of a groundwater model requires an understanding of the specific aquifer. Without this conceptual understanding the whole exercise becomes a meaningless waste of time and money."(emphasis added)

5.0 DEWATERING AND RADIUS OF INFLUENCE

Construction dewatering at Bailly N-1 is designed to be conducted in two phases:

Phase I, Dewater within the slurry wall in Unit 1 to provide a dry excavation for the placement of footings. Phase I dewatering was activated on March 17, 1977 and is still in progress (Nov. 1, 1980). The average water levels in Unit 3 beneath the bottom of the excavation were at elevation 590.6 on August 14-16, 1978; at elevation 589.8 Nov. 7, 1979; and at elevation 589.2 Sept. 24, 1980. This indicates that water levels have reached steady state in Unit 3.

Phase II, The purpose of pumping from Unit 3 is to reduce the hydrostatic pressure in Unit 3 beneath the bottom of the excavation. The piezometric surface must be reduced to elevation 583.7 for construction. The average water level beneath the bottom of the excavation for the past two years has been 589.9. Accordingly, the additional required drawdown (from the present level) in Unit 3 beneath the bottom of the excavation for Bailly N-1 is 6.2 feet.

Reference 2 states that drawdown may occur at Cowles Bog over 8,000 feet away from the location of the Bailly N-1 pressure relief system. This presumes that the radius of influence (the limit of lateral extension of a cone of depression) must be in excess of 8,000 feet. To assume that the radius of influence of a wellpoint system in a fine sand media will extend over 8,000 feet is unrealistic, contrary to the engineering literature, pumping tests and observed data at the BSCO and NIPSCO sites.

The radius of influence was discussed in detail in Reference 3. The main points are repeated for emphasis because disregarding this constraint of the model precludes obtaining reliable drawdown data at Cowles Bog.

The radius of influence (R) for both artesian and gravity flows can be estimated from the following equation (Reference 4, p. 150):

$$R= C(H-h_w) \sqrt{K} \qquad \text{EQ. 1}$$

where R= Radius of influence, feet

$H-h_w$ = Drawdown in the well, feet

K= Permeability expressed in 10^{-4} cm/sec units

C= Dimensionless constant

C= 3 for artesian and gravity wells

C= 1.5 to 2.0 for a single line of wellpoints

Equation 1 was verified using pumping tests on wells in the Mississippi River Valley by the U.S. Army Corps of Engineers. It was also verified for a line of wellpoints by the Moretrench Corporation (Reference 5, p. 307). This equation was verified for dune sand at the BSCO site and on many other dewatering projects engineered by D'Appolonia.

For verification of Equation 1 at Bailly N-1, data from a NIPSCO pumping test conducted in 1979 was used (Section 4.0, Reference 3). Using a permeability of 70 x 10^{-4} cm/sec and a drawdown of 26 feet at the test well, the resulting value of the radius of influence is 653 feet. This value is in excellent agreement with the radius of influence of 600 feet observed at the end of the test.

Using Equation 1 and in the extreme case C=3 and the permeability from the pumping tests, the radius of influence can be calculated for a maximum groundwater change (from initial static water level) of 20 feet in Unit 3 at Bailly N-1. This results in a radius of influence of approximately 500 feet for the permeability of 70 x 10^{-4} cm/sec, that obtained from the pumping test at the NIPSCO site. Using the permeability obtained by the pumping test at the BSCO site, the radius of influence is approximately 950 feet.

Even if the USGS model permeability of 589 x 10^{-4} cm/sec is used (which has been shown to be excessively high and inconsistent with other data) with 20 feet of drawdown at Bailly N-1, the radius of influence is only approximately 1450 feet.

The following table is a summary of calculated radii of influence for different permeabilities.

Drawdown in Unit 3 at Bailly N-1 (feet)	Coefficient of Permeability (10^{-4} cm/sec.)	Data Source	Radius of Influence (feet)	Ratio to 8000 Feet
20	70	NIPSCO pumping test	500	16:1
20	250	BSCO pumping test	950	8:1
20	589	USGS assumed	1450	5:1

Based on the above, it is evident that Cowles Bog is beyond the influence of the pressure relief system at Bailly N-1. Accordingly, the groundwater level at Cowles Bog will not be altered as a result of construction dewatering at Bailly N-1.

6.0 GROUNDWATER DATA IN THE COWLES BOG AREA

Cowles Bog is located in the Great Marsh area which is a part of IDNL (Figure 2). Reference 1, Page 8, describes this area as:

> ". . .The Great Marsh occupies part of the northeastern quarter of the study area. The Great Marsh is wet during most of the year, when the water table is at or near the surface. Ditches that were dug years ago to help drain the marsh are still present. Two of these ditches cross the eastern boundary of the study area, but discharge through them is minimal. The marsh area also contains an area known as Cowles Bog, which was designated as a National Natural Landmark by Congress in 1965. There is some question as to the exact location of the bog and whether or not that particular part of the wetland is in fact a bog (William Hendrickson, National Park Service, oral commun., 1977)."

Reference 8 provides some of the details of the hydrological data in this area.

> "A 2-inch diameter stainless steel well, screened in the sand bottom, established that there is a positive hydrological pressure below the elevated mat. The pressure was sufficient to cause a flowing well which carried water a little more than 3 feet above the mat surface or 8 and a half feet above the level of the water which surrounds the elevated island. A pressurized source of ground water of significant dimension is thus shown to exist in Cowles Bog."

The following statement on Page 27, Reference 2 further describes the water level in the bog area as:

> ". . .Water levels in unit 1 within the mound are as much as 5 feet higher than in unit 1 beneath the surrounding marsh area. The mound

> apparently coincides with a topographic rise that is also as much as 5 feet higher than the land or open-water surface in the surrounding marsh."

Comparison of data quoted above from Reference 8 and Reference 2 leads to the conclusion that water levels within Cowles Bog are changing as much as 3.5 feet in a matter of months, indicating that even if changes of a few inches "predicted" by the USGS model were accurate, it would not make any difference, particularly in view of the fact that the bog is surrounded by a large recharge area of several hundred acre feet.

Water levels for 16 USGS piezometers (screened in Unit 1) are plotted on Figure 7. Eleven piezometers are inside the bog and five are in the marsh area surrounding it. The maximum difference between water levels measured in the bog is approximately six feet and in the marsh area, approximately five feet. In November 1979, the piezometers inside and outside the bog area show the lowest readings, and in March 1980 the highest. The changes are in the range of 1 to 2 feet. This apparently represents the seasonal change for that period and is typical for the area. The water level changes in piezometers (Figure 7) follow the same general trend and do not exhibit any anomalies inside or outside Cowles Bog. In turn, this indicates that changes in water level in the bog area are reflected in the marsh area. If it is assumed that the USGS computer model simulations are correct in predicting water level changes in Cowles Bog, the changes will be offset by recharge with marsh water before they can occur. It is unrealistic to predict any water level changes in the bog area without taking into account the surrounding marsh water.

Further, on Page 27, Reference 2 states:

> "The ground-water mound in unit 1 at Cowles Bog is probably due to a thinning or absence of the confining unit (unit 2) beneath the center of the bog that normally separates units 1 and 3, or

> a greater value of the vertical hydraulic conductivity of unit 2 beneath the center of the bog than elsewhere, or a combination of both factors. The variation in one or both of the characteristics of the confining unit, hereafter termed a "discontinuity," results in a better connection between the two aquifers (units 1 and 3) than elsewhere. Upward flow from unit 3 to unit 1 through the confining unit (unit 2) is well documented in the study area and throughout the Lakeshore."

Even assuming that the USGS hypothesis is correct regarding a "discontinuity" of Unit 2 at the bog, this would not be unique as Unit 2 is absent in many locations (as a small or large opening) throughout the study area (References 1, 2 and 3). Both USGS reports show Unit 2 as being absent in the southern half of the study area (Figure 7, Appendix B).

There are dunes located north and northwest of the elevated portion of Cowles Bog. These dunes have groundwater levels higher than the marsh (wetland) due to the recharge of the rainfall in the dunes area. At the bottom of the marsh areas semi-confining layers are sometimes formed which covers the Unit 1 sand. The high groundwater table in the dunes could produce some localized "artesian" flow in the lower marsh area. This phenomenen is explained in Reference 11, Page 47. This is the "upward flow" from Unit 1, not from Unit 3. (Upward flow from Unit 3 to Unit 1 is also discussed in Section 3.2.10)

7.0 CONCLUSIONS

Based on a review of USGS reports No. 78-138 (Reference 1) and 80-1105 (Reference 2) and all available field data, we have reached the following conclusions relative to the effects of construction dewatering at NIPSCO Bailly N-1 on the groundwater levels at Cowles Bog (IDNL).

- The radius of influence of NIPSCO's pressure relief system calculated through the use of actual field data and demonstrated permeabilities, is less than 950 feet. Furthermore,even when the erroneous coefficient of permeabilities assumed by the USGS is used, the radius of influence does not exceed 1450 feet. Therefore, the pressure relief system cannot have any effect on Cowles Bog which is located more than 8000 feet from the site of dewatering.

- The possible drawdown predicted by the USGS modeling exercise is wrong and unreliable; first, because a substantial body of actual field data available for the study area was ignored or misused in the model; secondly, because the assumptions used for the modeling bear little resemblance to actual field data; and finally, because of defects in application of the model itself.

The bog area is well beyond the calculated radius of influence of the proposed dewatering system. Accordingly, the system will not cause a groundwater level decline in the bog area. Further, analysis shows that the distance between the bog area and Bailly N-1 is so great that the calculated radius of influence would not reach the bog even if the permeabilities used in our calculations were in substantial error.

Simply stated, the radius of influence of NIPSCO's pressure relief system cannot be assumed to extend over 8000 feet to the Cowles Bog area under any reasonable application of hydrologic principles. Further studies of possible drawdown in the Cowles Bog area, suggested by the USGS, are not warranted.

Respectfully submitted,

RF Brissette

Richard F. Brissette

Stevo Dobrijevic

RFB/SD/lsb

Project No. MW79-720
November, 1980

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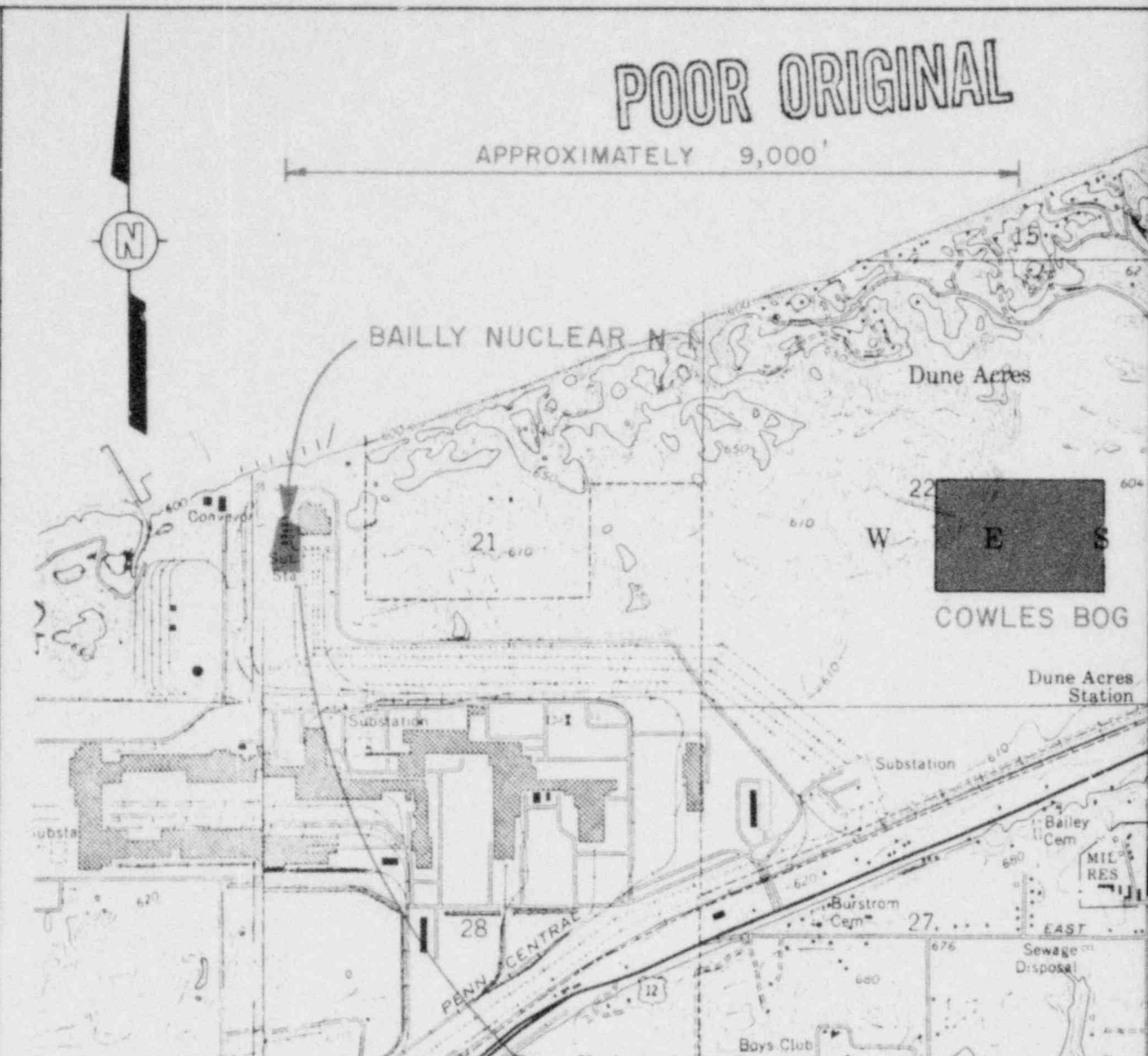
POOR ORIGINAL



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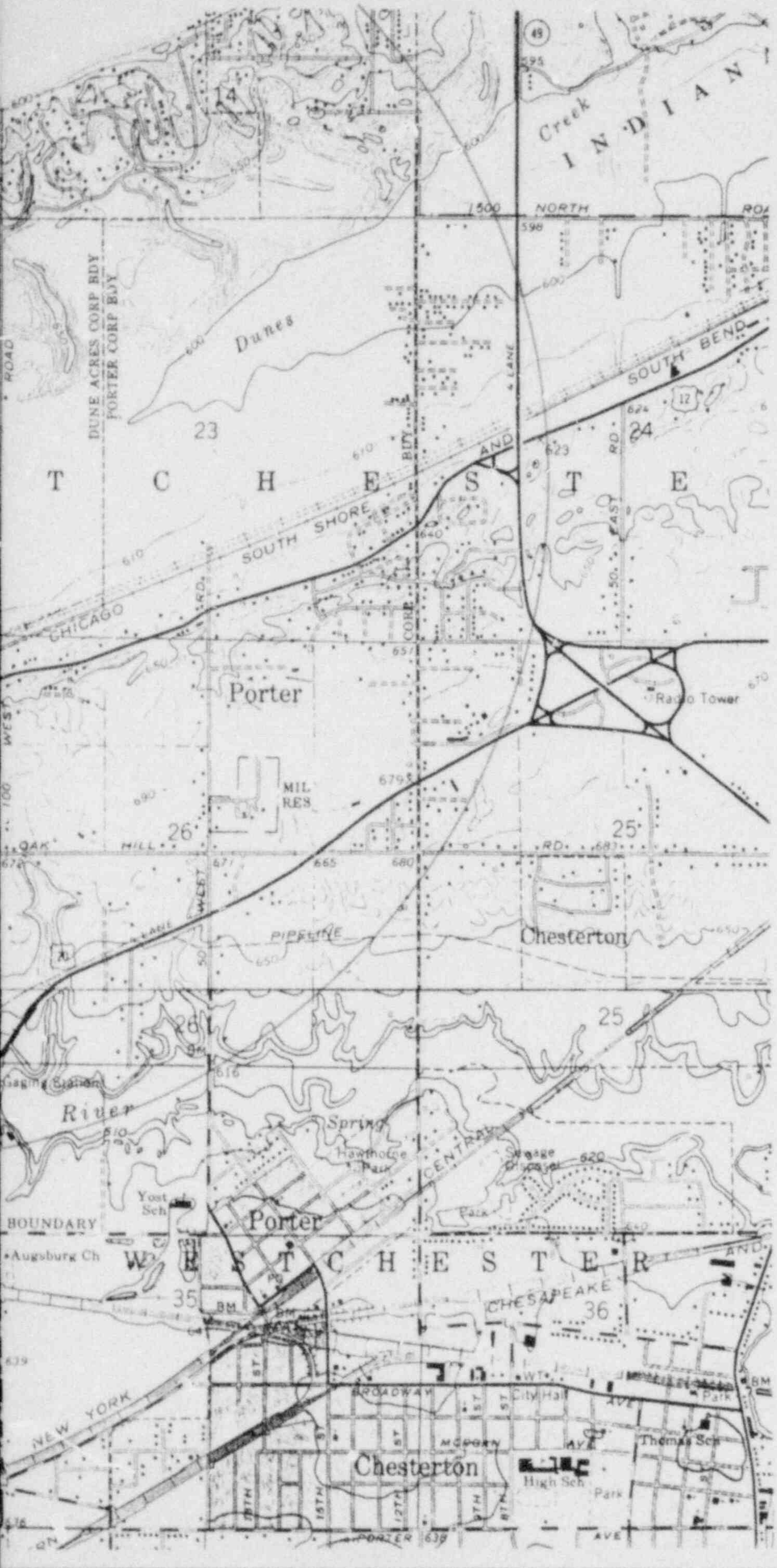


REFERENCE

USGS TOPOGRAPHIC MAPS
CHESTERTON, DUNE ACRES
AND PORTAGE QUADRANGLES,
1968 SERIES

POOR ORIGINAL

SCALE

2000 0 2000 feet

FIGURE 1

VICINITY MAP
BAILLY NUCLEAR 1
AND COWLES BOG
BAILLY GENERATING STATION
NUCLEAR 1

PREPARED FOR

NORTHERN INDIANA
PUBLIC SERVICE CO.

D'APPOLONIA

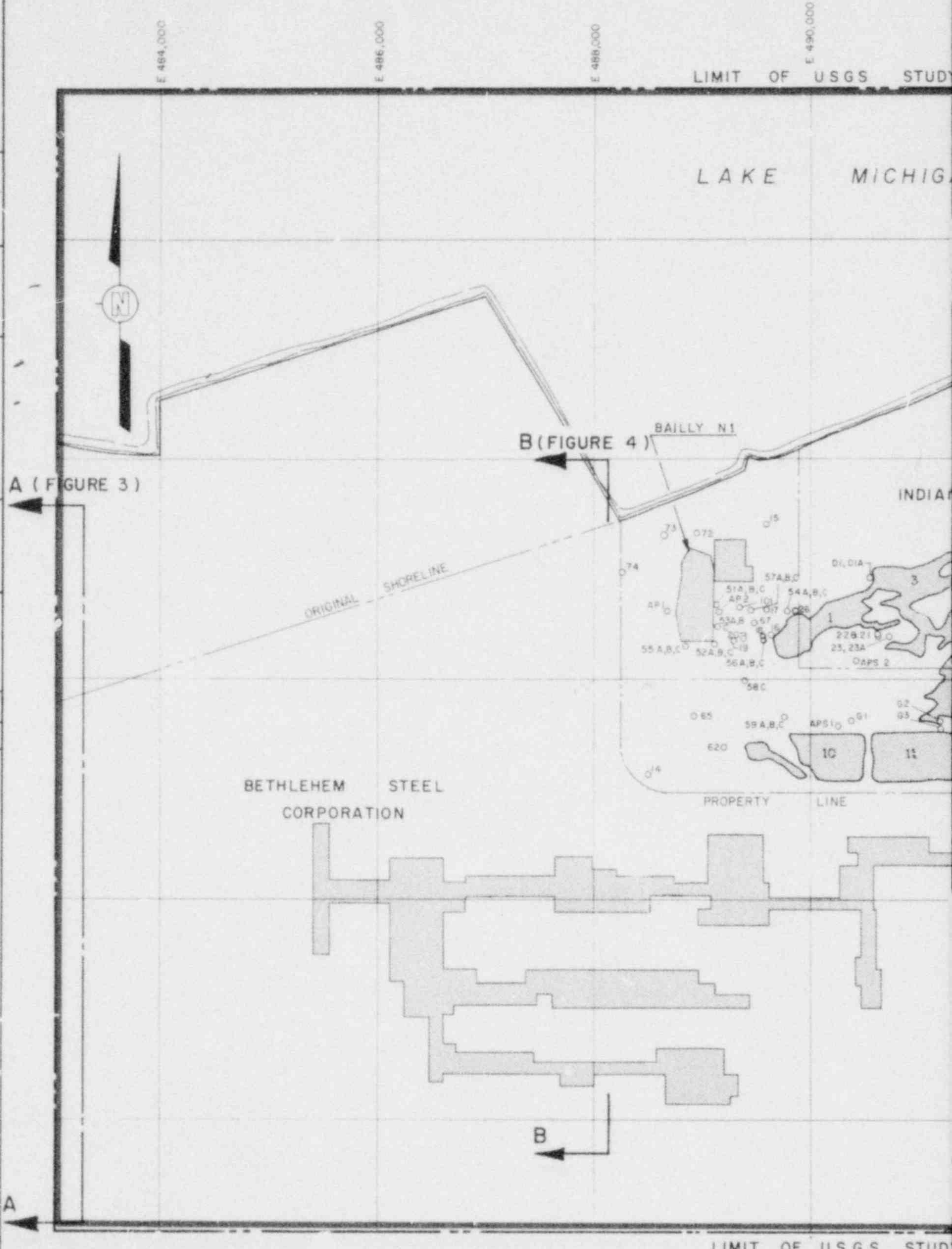
POOR ORIGINAL

DRAWN BY R. NEVERS 10-30-80

CHECKED BY

APPROVED BY

DRAWING NUMBER MW 79-720E11



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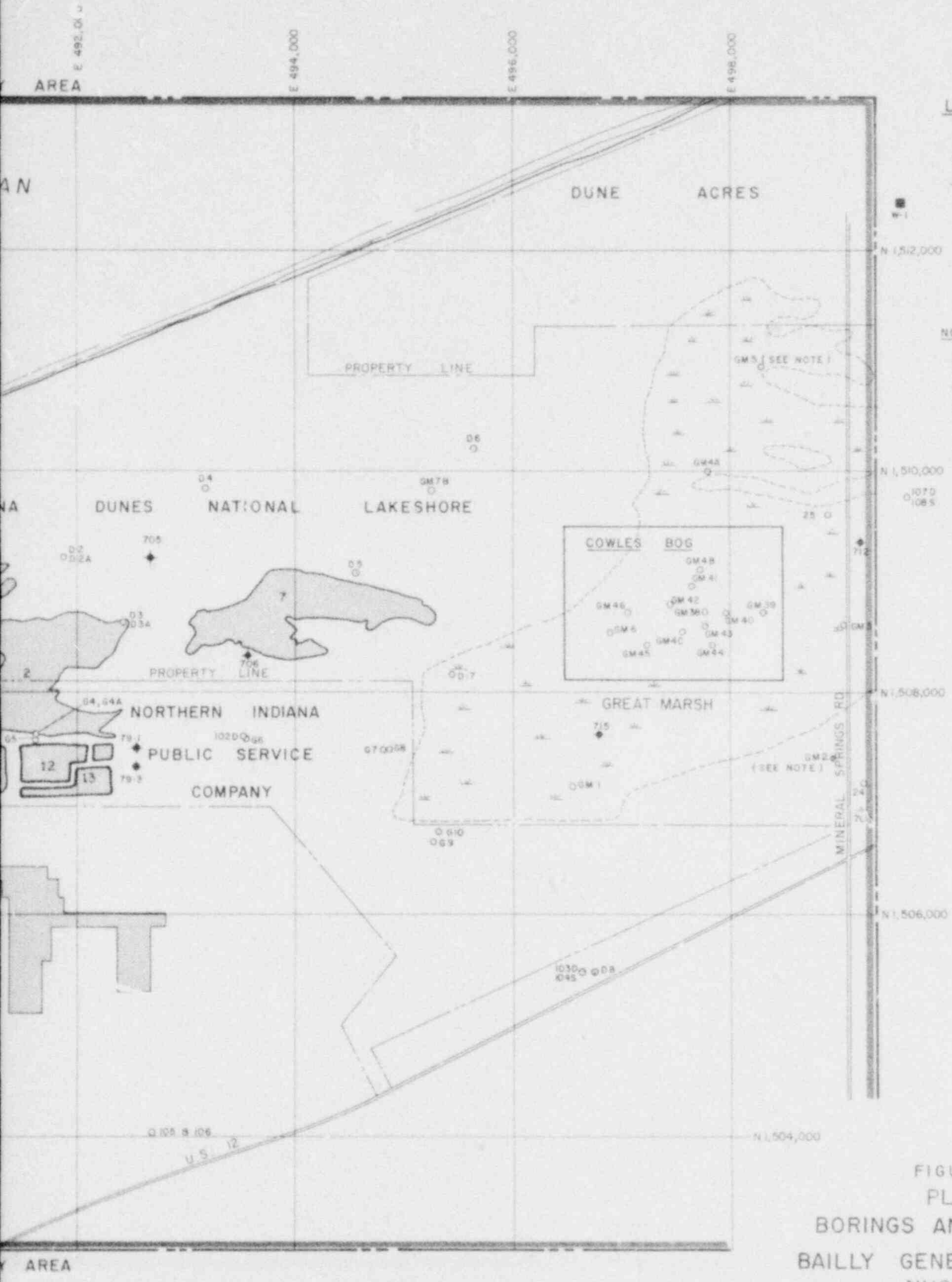
WATER-RESOURCES INVESTIGATIONS 78-138

SARGENT & LUNDY ENGINEERS
DRAWINGS M-500-H1 & M-501-L2

POOR ORIGINAL



LEGEND

- ○ PIEZOMETER
- ■ DUNE ACRES WELL
- ✦ BORING

NOTE:

LOCATION DISCREPENCIES FOR PIEZOMETER GM2 & GM5 EXIST BETWEEN COORDINATES, LEGAL DESCRIPTIONS, AND USGS INFORMATION. PLACEMENT ARRIVED AT BY USE OF U.S.G.S. INFORMATION AND LEGAL DESCRIPTIONS.

SCALE
0 600 1200 1800 FEET

FIGURE 2
PLAN
BORINGS AND PIEZOMETERS
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

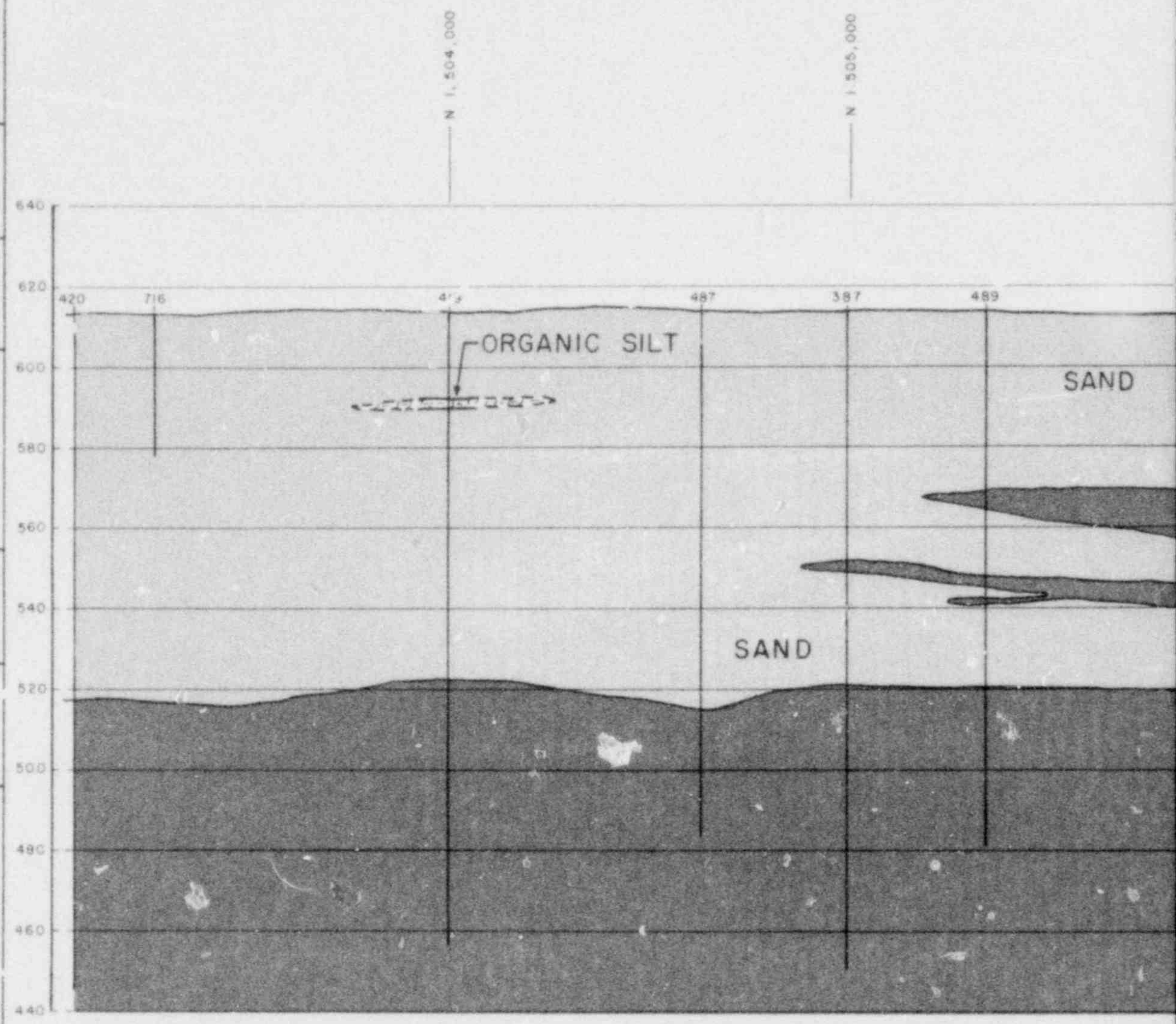
POOR ORIGINAL

DRAWN BY R.J.N. 4-7-80

CHECKED BY

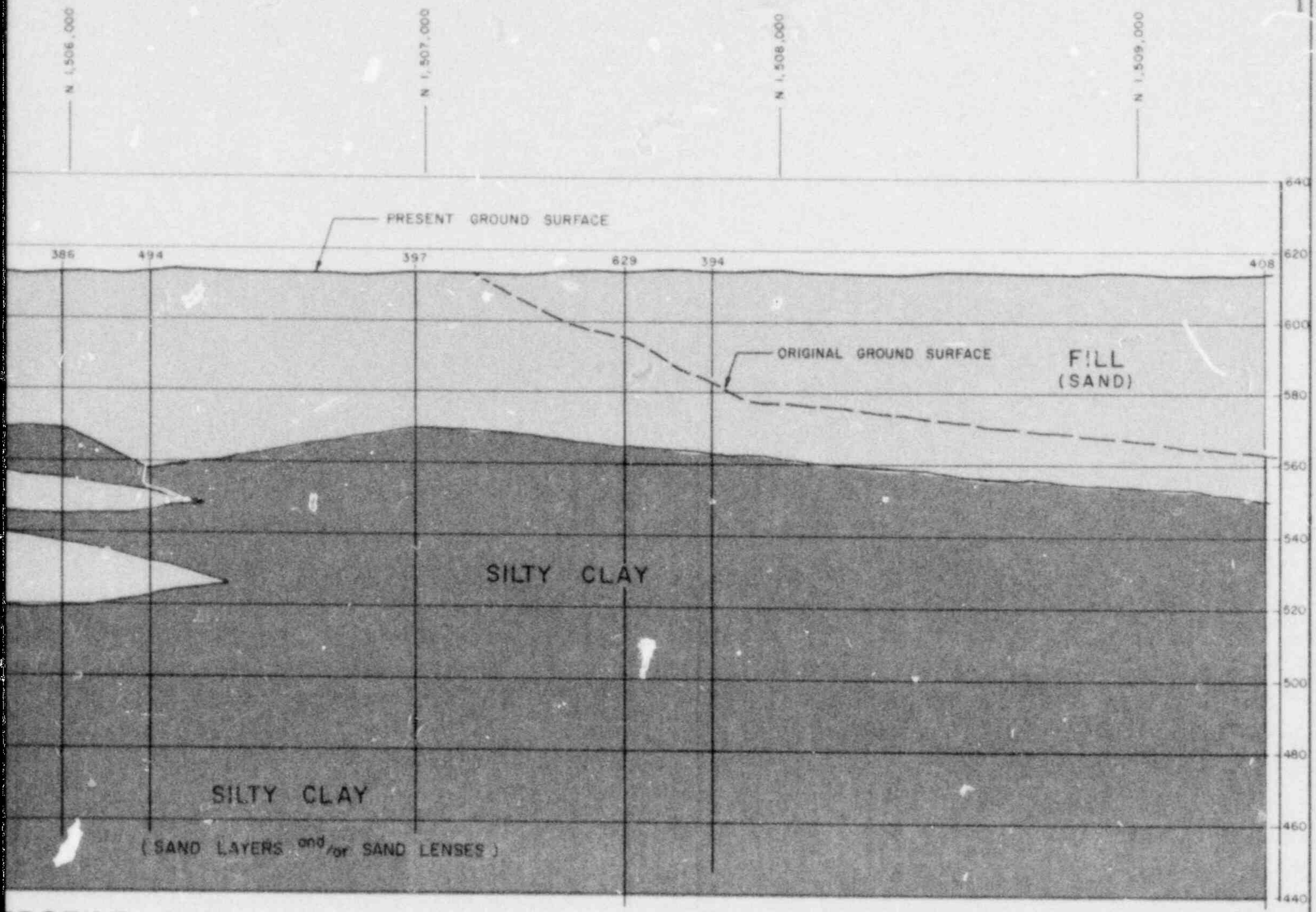
APPROVED BY

DRAWING NUMBER MW79-720 E6



NO

POOR ORIGINAL



PROFILE A-A

LOOKING WEST

TE

OR PROFILE LOCATION SEE
IGURE NO. 2.

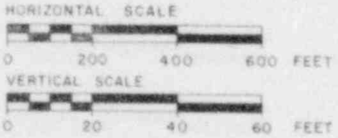


FIGURE 3

GENERALIZED SOIL PROFILE A-A
BAILLY GENERATING STATION
NUCLEAR 1

PREPARED FOR

NORTHERN INDIANA PUBLIC SERVICE CO.

D'APPOLONIA

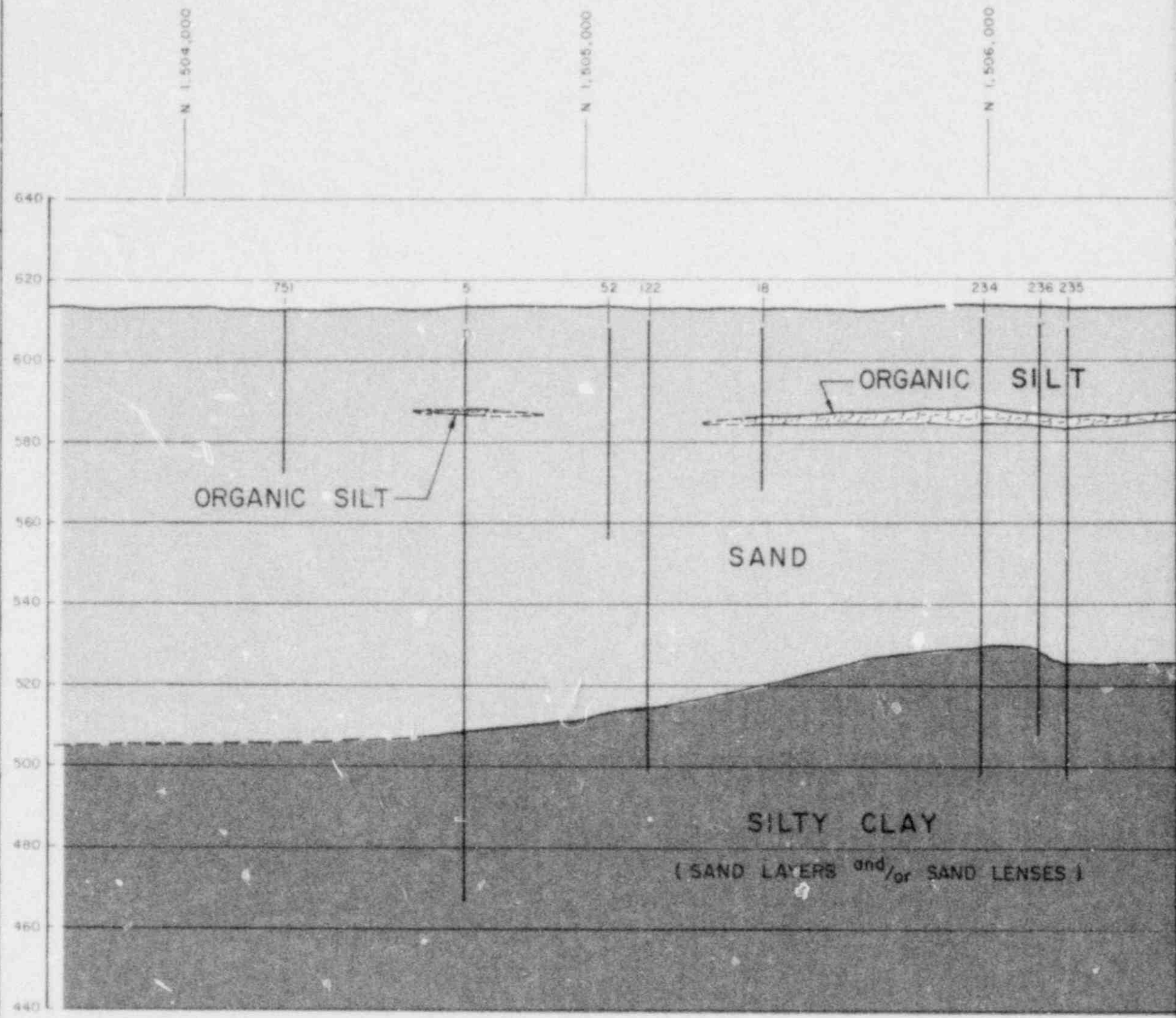
DRAWING NUMBER MW79-720 E7

DRAWN BY R.J.N. 4-10-80

CHECKED BY

APPROVED BY

POOR ORIGINAL

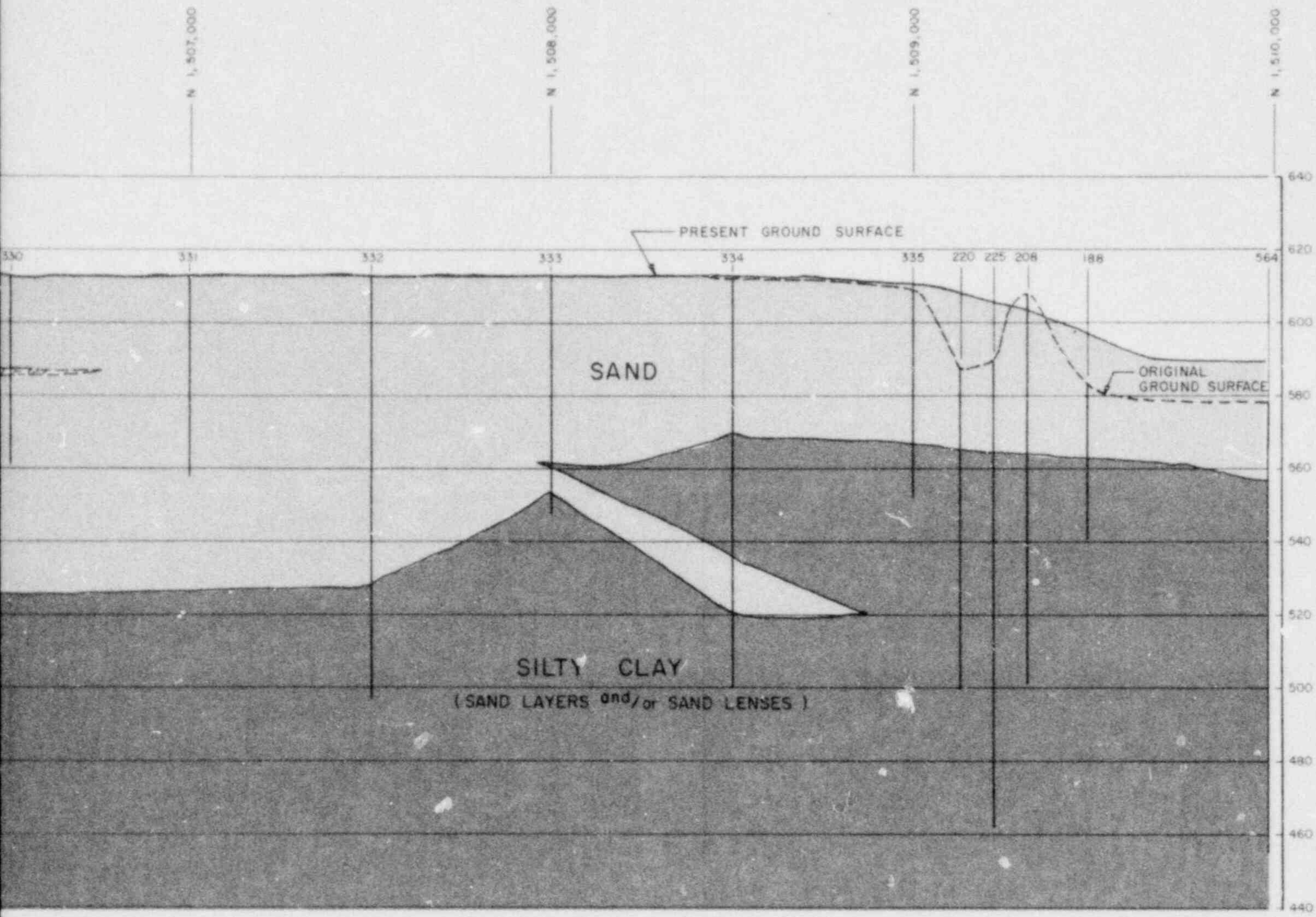


PRO

NOTE

- FOR
FIGUR

POOR ORIGINAL



OFILE B - B

LOOKING WEST

ES

PROFILE LOCATION SEE
E NO. 2

HORIZONTAL SCALE
0 200 400 600 FEET

VERTICAL SCALE
0 20 40 60 FEET

FIGURE 4

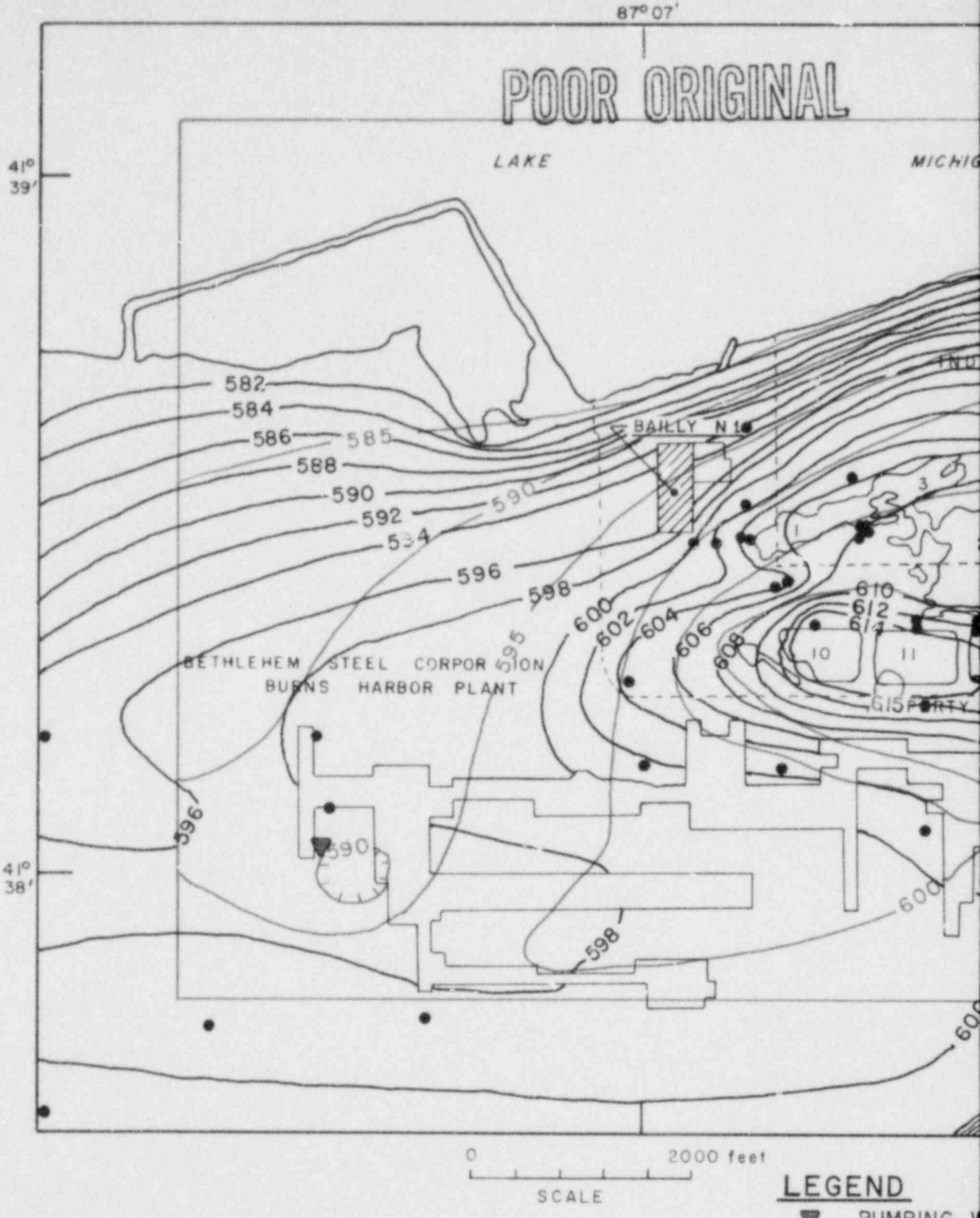
GENERALIZED SOIL PROFILE B-B
BAILLY GENERATING STATION
NUCLEAR 1

PREPARED FOR

NORTHERN INDIANA PUBLIC SERVICE CO.

D'APPOLONIA

DRAWN BY	WJ	11-1-80
CHECKED BY	RVK	11-3-80
APPROVED BY		11-3-80
DRAWING NUMBER	MW79-720B5	



LEGEND

▼ PUMPING W

● DATA POIN

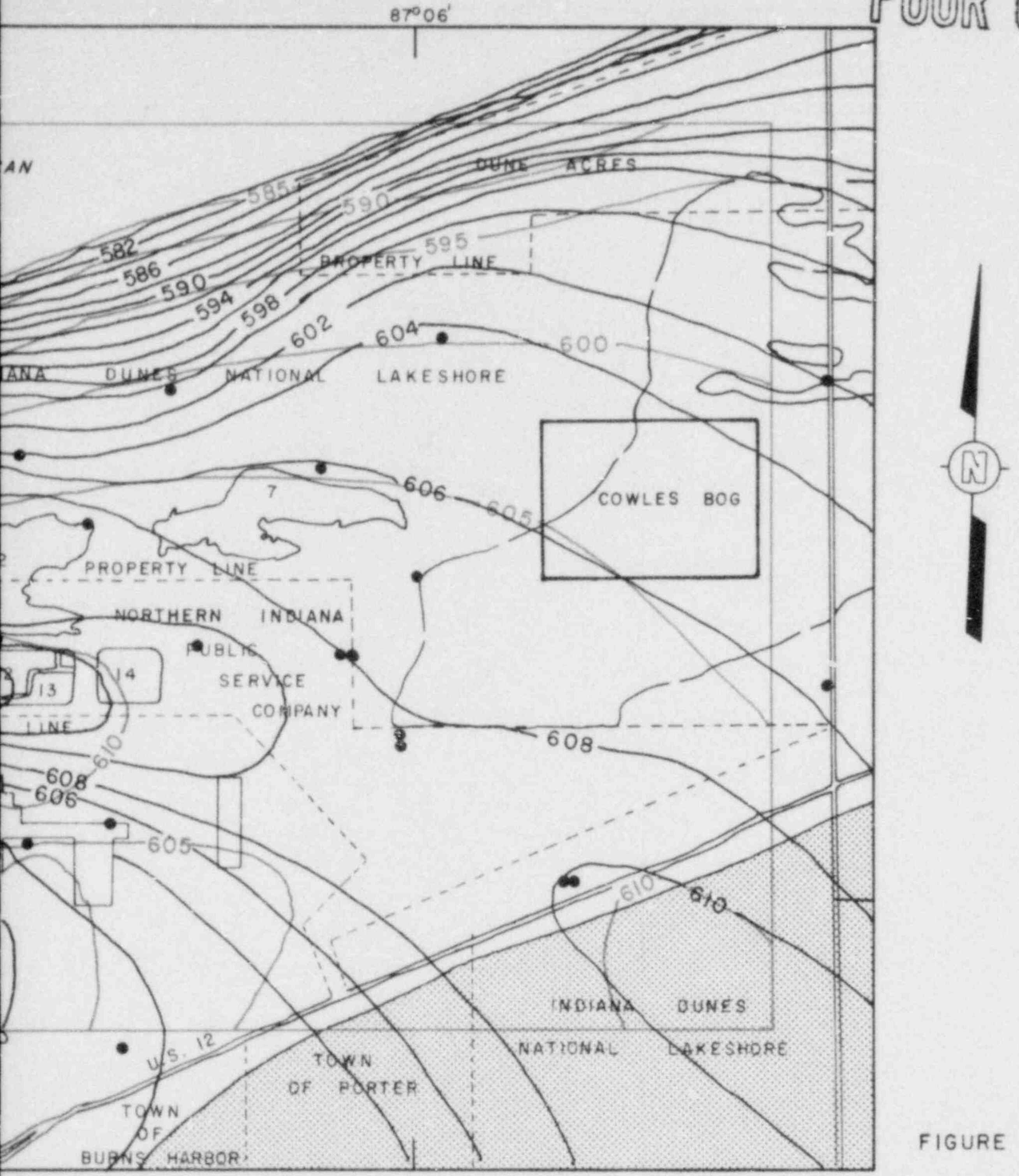
— 600 — OBSERVED UNCONFIN IN UNIT

— 590 — MODEL-DE LEVEL CO OCTOBER

▨ UNIT I AB

REFERENCE:

USGS REPORT 78-138, FIGURES 6, 13 & 25.



VELL

IT

AND/OR ESTIMATED
ED WATER LEVEL CONTOURS
, OCTOBER 26, 1976.

RIVED STEADY-STATE WATER
NTOURS IN UNIT I,
26, 1976.

SENT

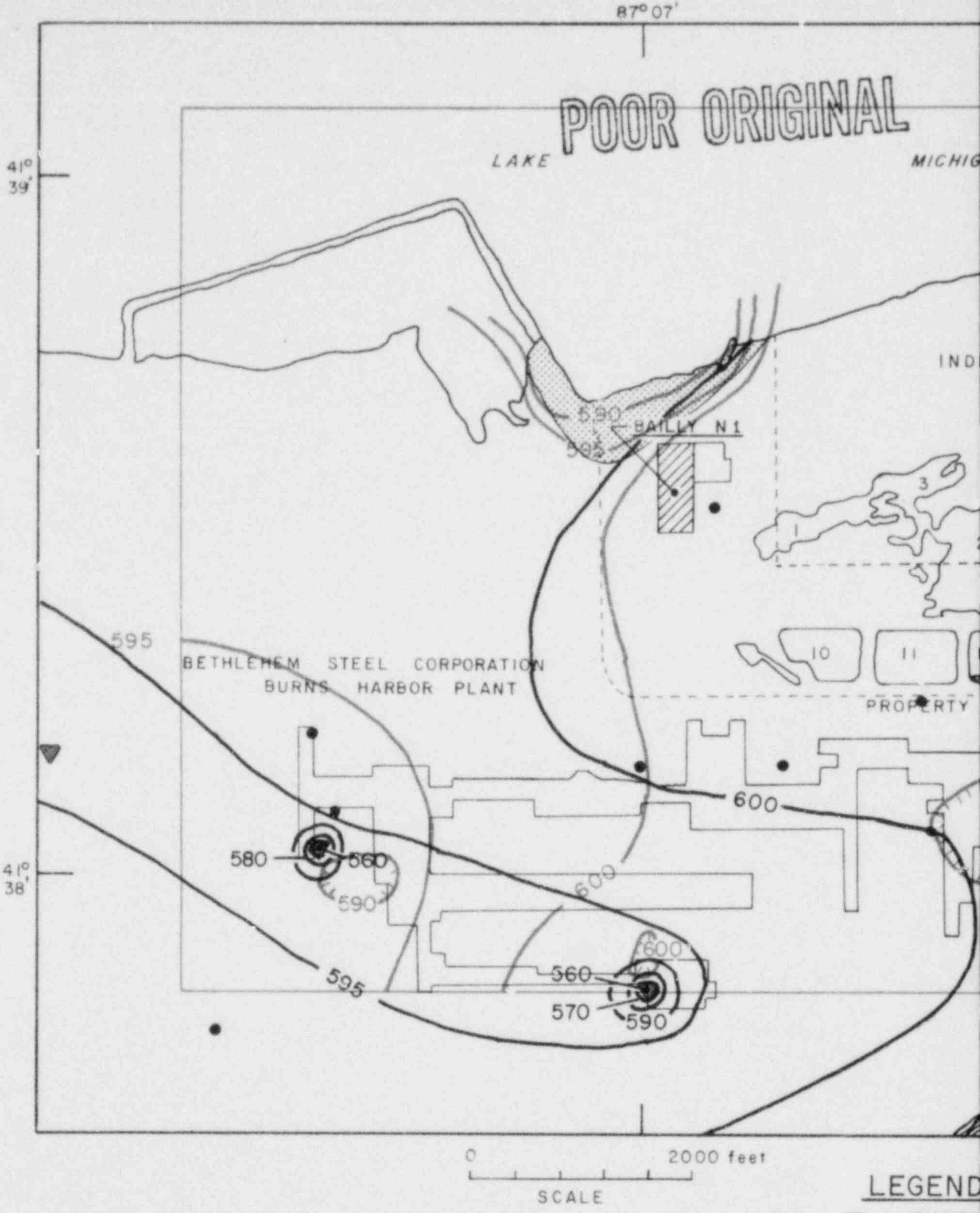
FIGURE 5

COMPARISON OF WATER LEVELS
IN UNIT I
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA
PUBLIC SERVICE CO.

D'APPOLONIA

DRAWN BY	RJN 11-1-80
CHECKED BY	WJ 11-3-80
APPROVED BY	SD 11-3-80
DRAWING NUMBER	MW79-720B6

POOR ORIGINAL



LEGEND

▼ PUMPI

● DATA

—605— POTEN UNIT

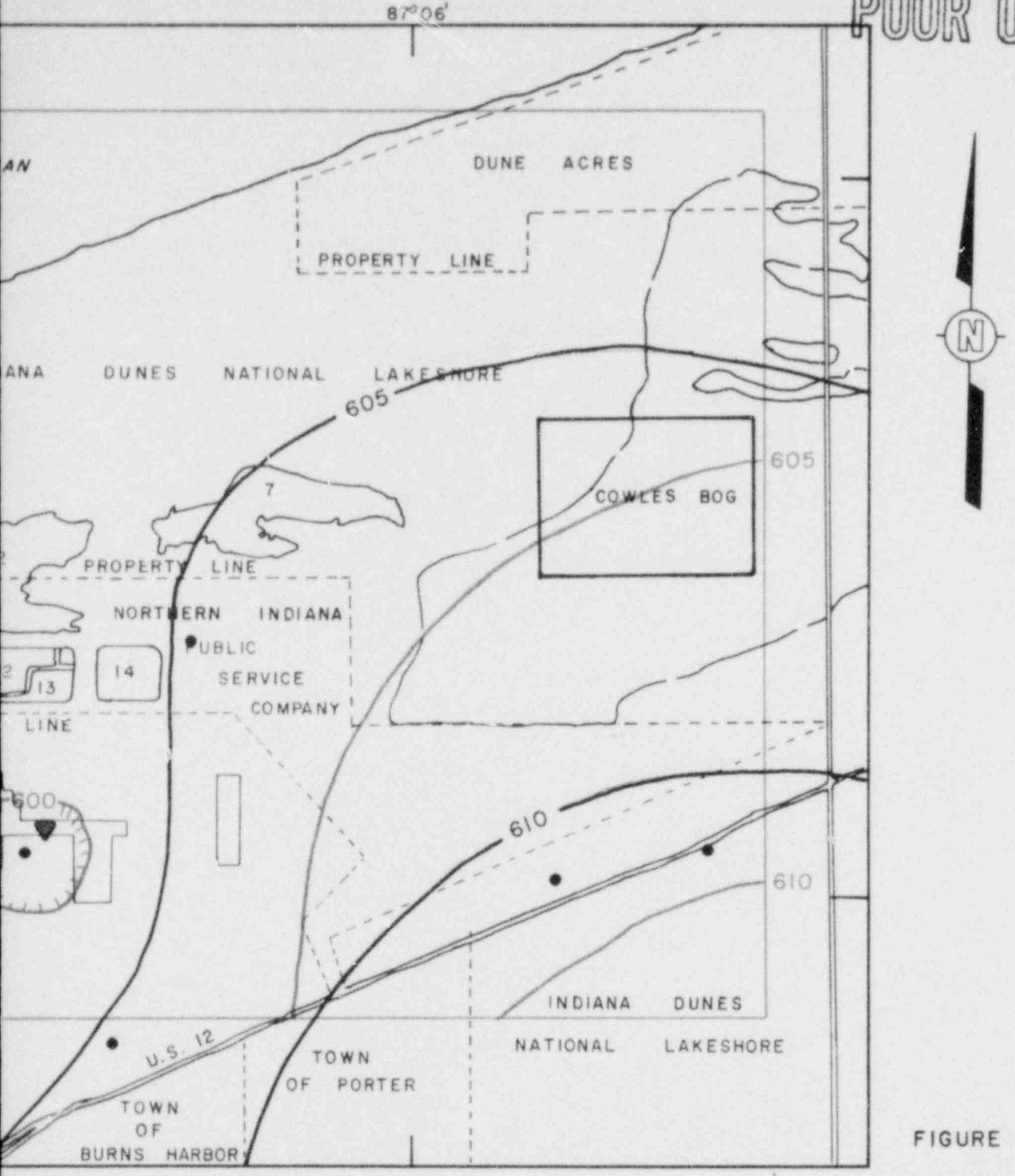
—600— MODEL POTEN UNIT

▨ UNIT

REFERENCE

USGS REPORT 78-138, FIGURES 7, 16 & 26.

POOR ORIGINAL



NG WELL

POINT

TIOMETRIC CONTOUR OF
3, OCTOBER 26, 1976.

L - DERIVED STEADY - STATE
TIOMETRIC CONTOUR OF
3, OCTOBER, 1976.

3 ABSENT

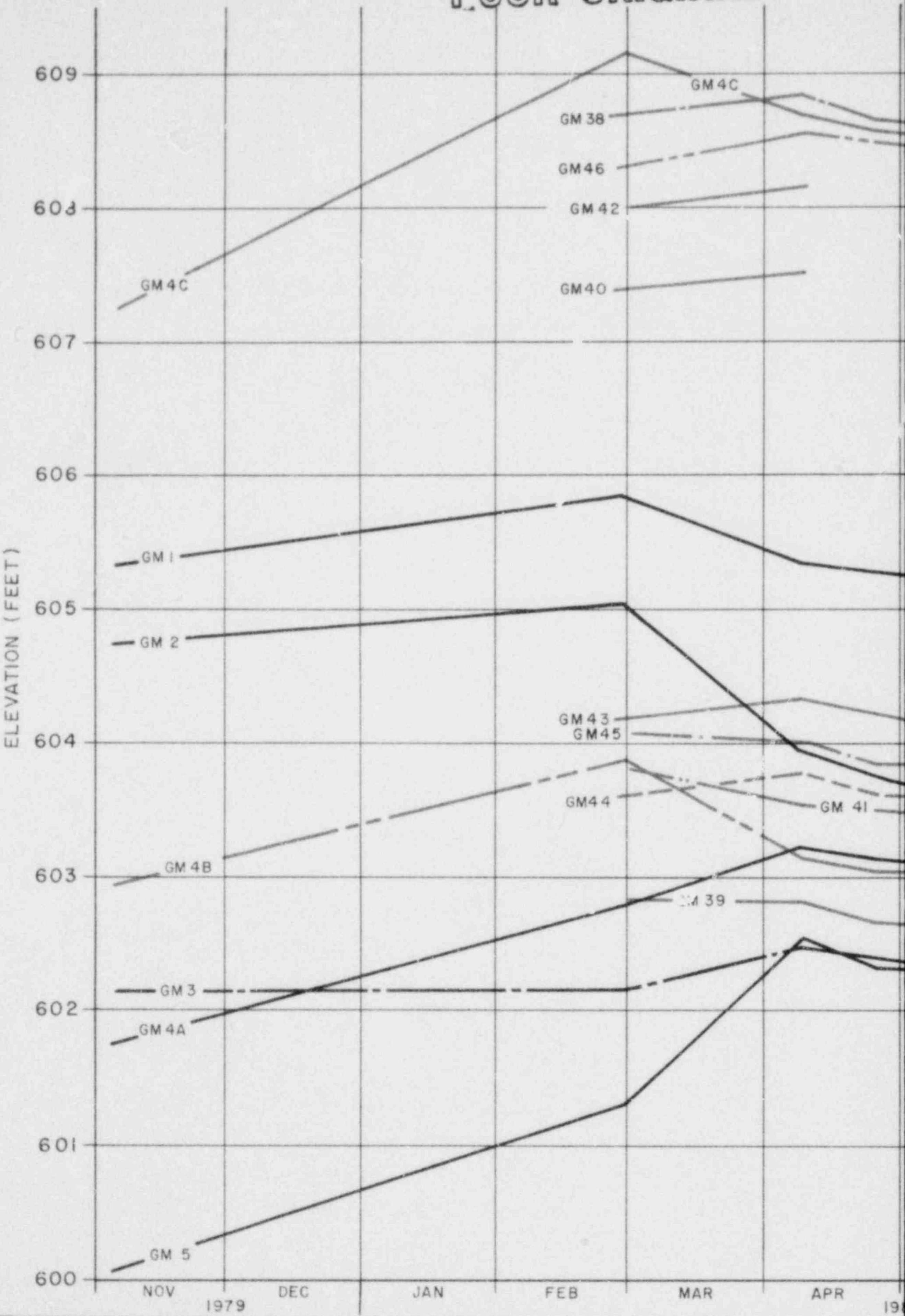
FIGURE 6

COMPARISON OF WATER LEVELS
IN UNIT 3
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA
PUBLIC SERVICE CO.

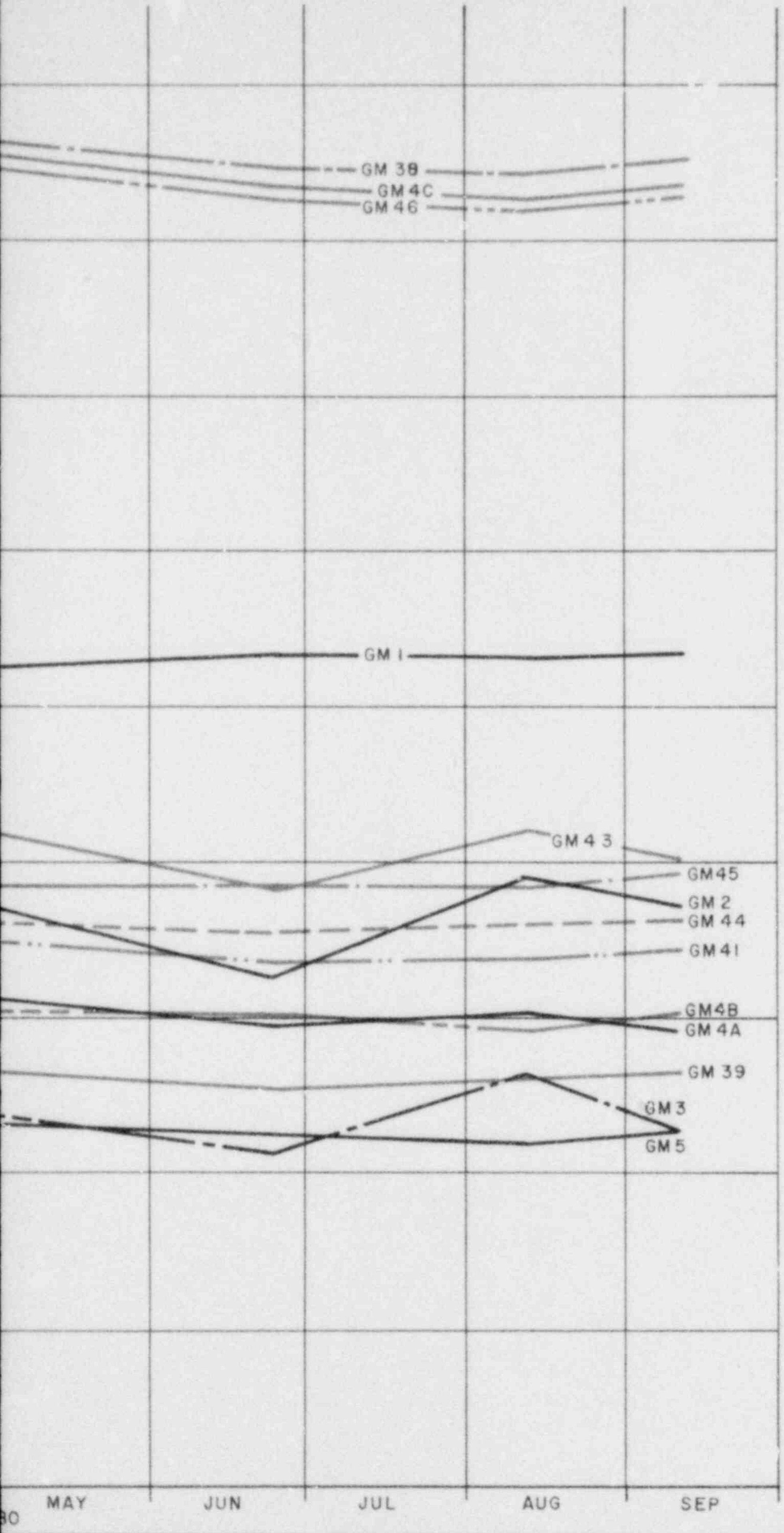
D'APPOLONIA

POOR ORIGINAL

DRAWN BY R.J.N. 11-2-80
CHECKED BY WJ 11-3-80
APPROVED BY RD 11-3-80
DRAWING NUMBER MW79-720 B 7



19 1253 HERCULENE, A&B SMITH CO., PGH., PA LT1530-1079



NOTE:

- WATER LEVELS PLOTTED IN ORANGE ARE RECORDED WITHIN THE COWLES BOG BOUNDARYS. THOSE PLOTTED IN BROWN ARE RECORDED IN THE "GREAT MARSH" AREA OUTSIDE THE COWLES BOG BOUNDARY.
- FOR PIEZOMETER LOCATIONS SEE FIGURE 2.

FIGURE 7

RECORDED WATER LEVELS
IN THE GREAT MARSH AREA
PIEZOMETERS
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR

NORTHERN INDIANA
PUBLIC SERVICE CO.

D'APPOLONIA

APPENDIX A

REPRESENTATIVE COEFFICENT OF PERMEABILITY OF SOILS IN 10^{-4}cm/sec UNITS

TYPE OF SOIL	COEFFICIENT OF PERMEABILITY			
	NAVFAC P-418 (Ref.4)	FOUNDATION ENGINEERING (Ref.5)	BASIC SOILS ENGINEERING (Ref.6)	USED FOR COMPARISON
Silty Clay			0.01	0.01
Silt			0.50	0.50
Sandy Silt	5-20			10
Silty Sand	20-50		1	20 (If clayey, use 1)
Silty Sand and Gravel			4	
Very Fine Sand	50-200	50		100
Fine Sand	200-500	200	40	200
Fine to Medium Sand	500-1000	500		500
Medium Sand	1000-1500	1000	1000	1000
Medium to Coarse Sand	1500-2000	1500		1500
Coarse Sand			4000	3000
Coarse Sand and Gravel	2000-5000	3000		

NOTE: Coefficient of Permeability by pumping test:

At BSCO site $K = 250 \times 10^{-4}$cm/sec

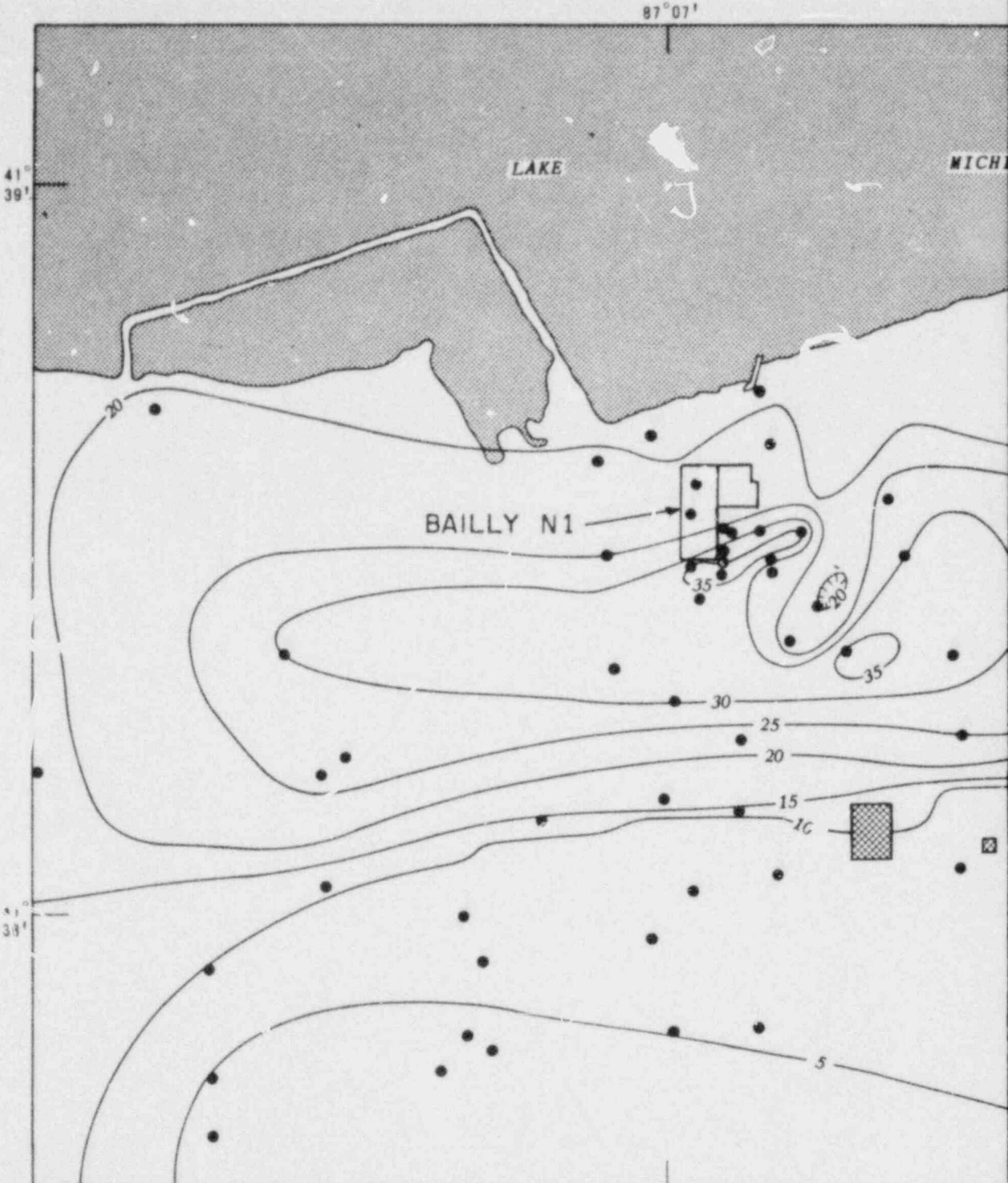
At NIPSCO site $K = 70 \times 10^{-4}$cm/sec

APPENDIX B

LIST OF FIGURES

*These figures are reproduced from and refer to the numbering system used in Reference 1, USGS Report 78-138.

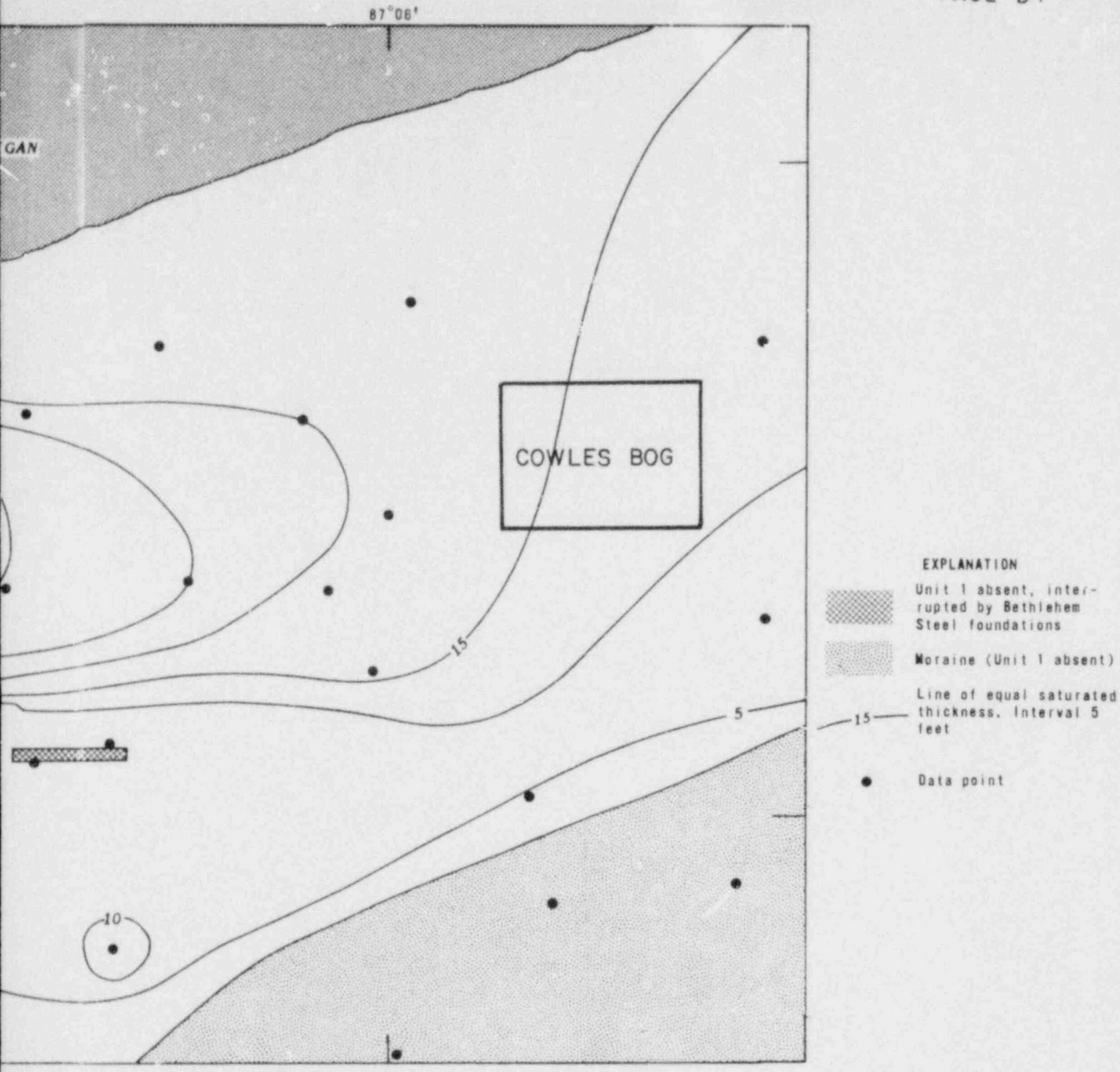
POOR ORIGINAL



Base from 1973 NIPSCO Map No. MS-150
by Sargent and Lundy

Figure 6.-- Saturated thickness of u

POOR ORIGINAL



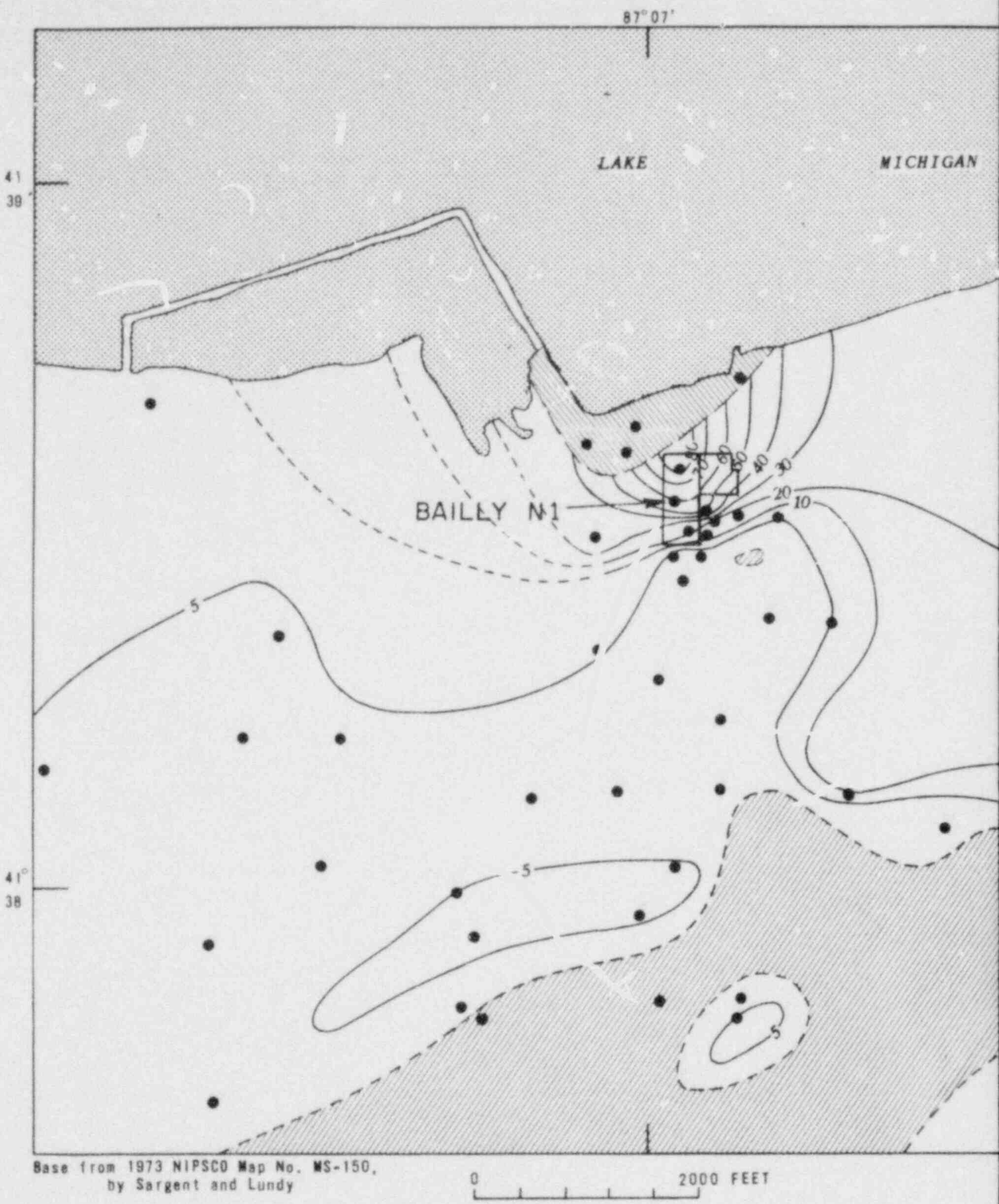
NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

nit 1, October 26, 1976.

FIGURE 6 REPRODUCED
FROM USGS REPORT 78-138

D'APPOLONIA

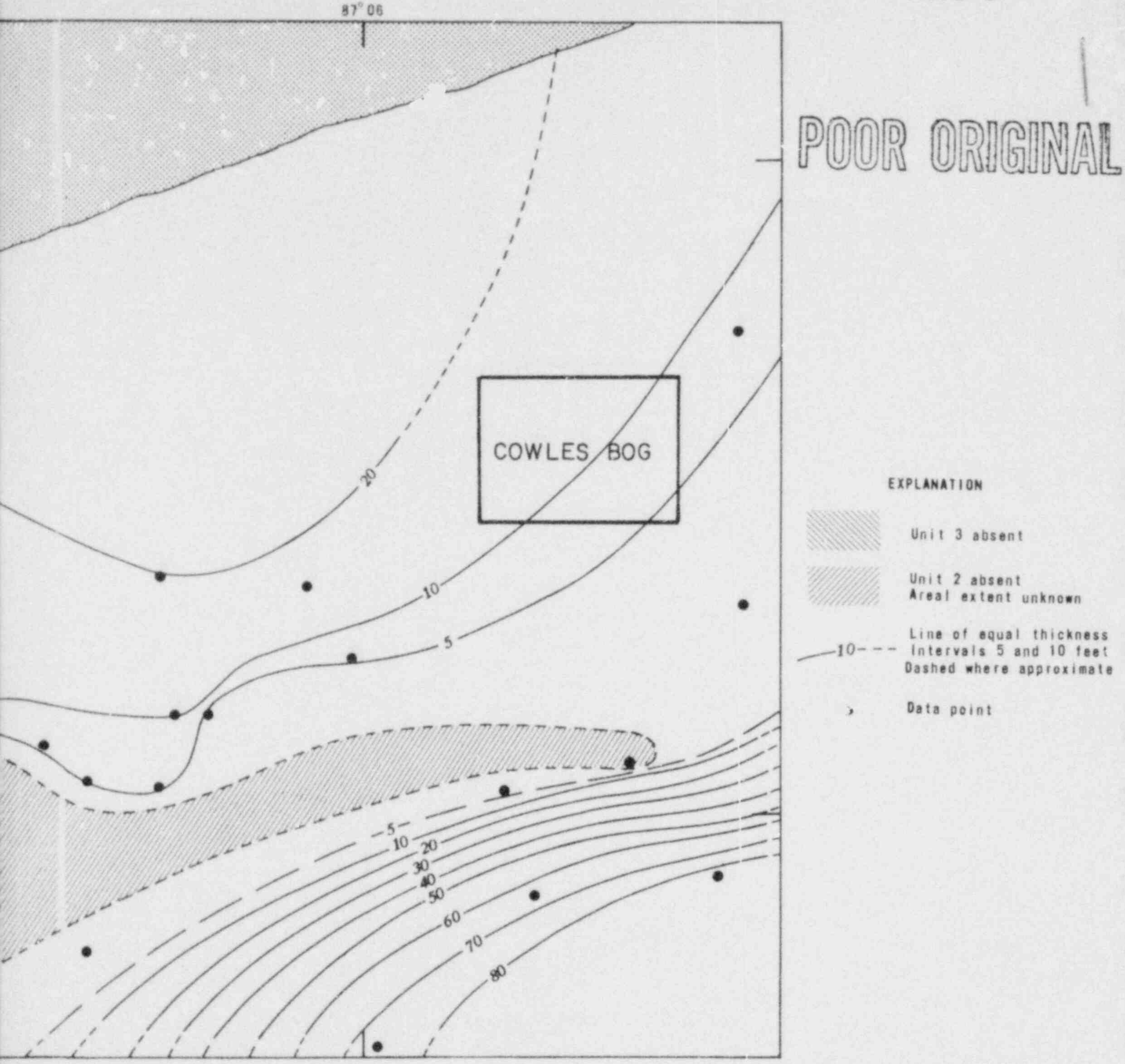
POOR ORIGINAL



Base from 1973 NIPSCO Map No. MS-150,
by Sargent and Lundy

Figure 7.--Thickness of unit

POOR ORIGINAL

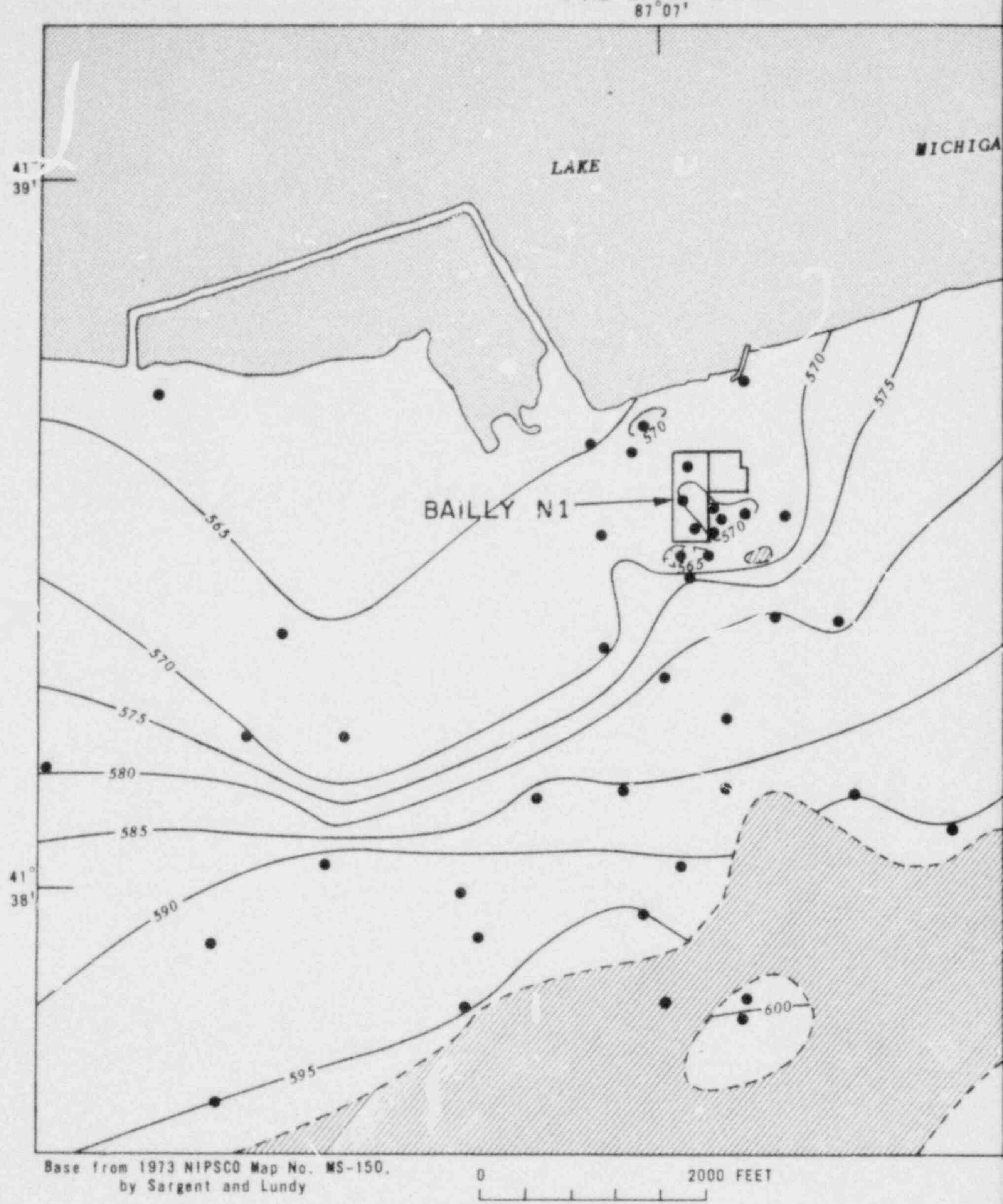


NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

2.

FIGURE 7 REPRODUCED
FROM USGS REPORT 78-138

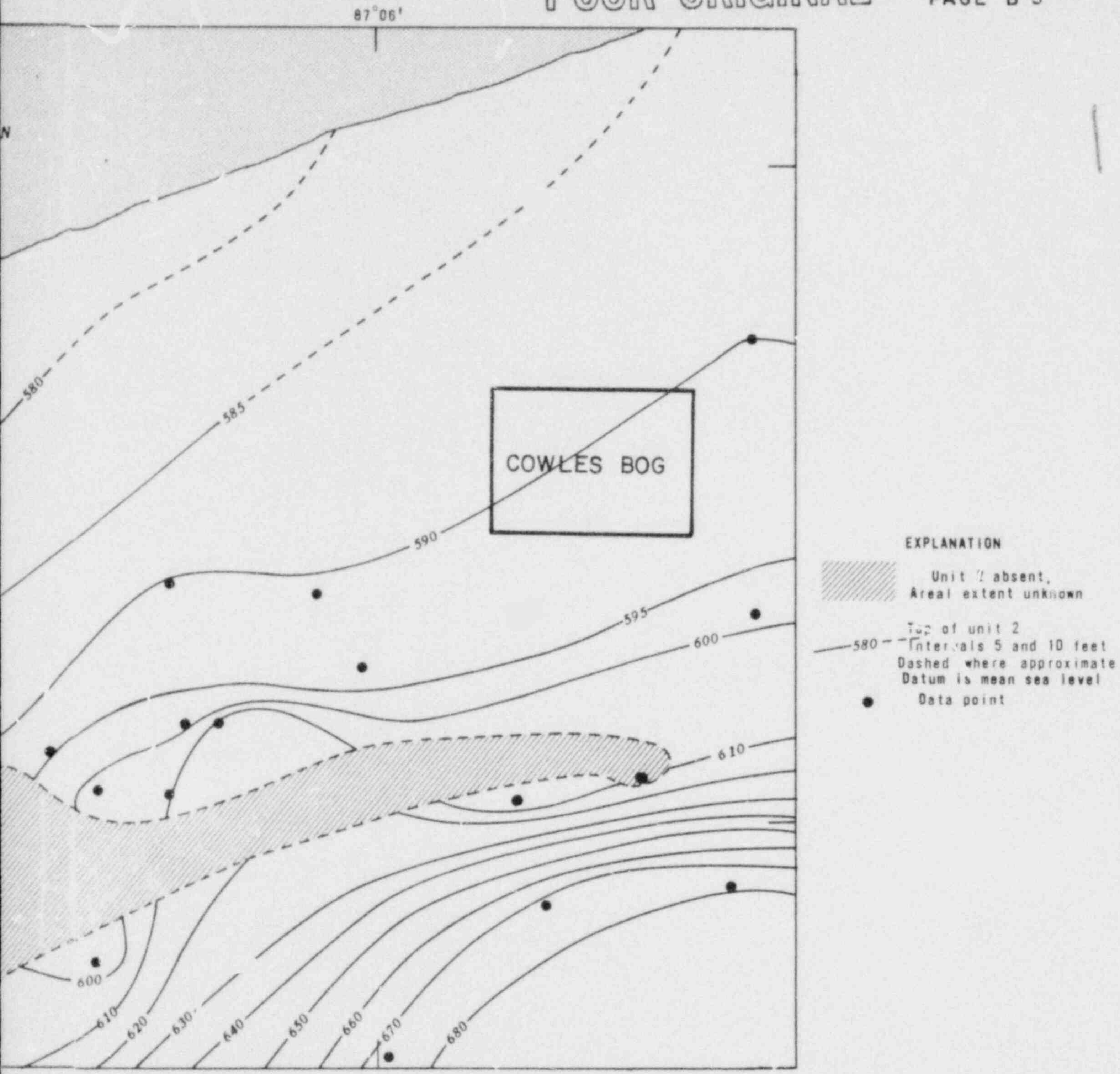
D'APPOLONIA



Base from 1973 NIPSCO Map No. MS-150, by Sargent and Lundy

Figure 8.-- Elevation of the surface of uni

POOR ORIGINAL



NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

2.

FIGURE 8 REPRODUCED
FROM USGS REPORT 78-138

D'APPOLONIA

POOR ORIGINAL

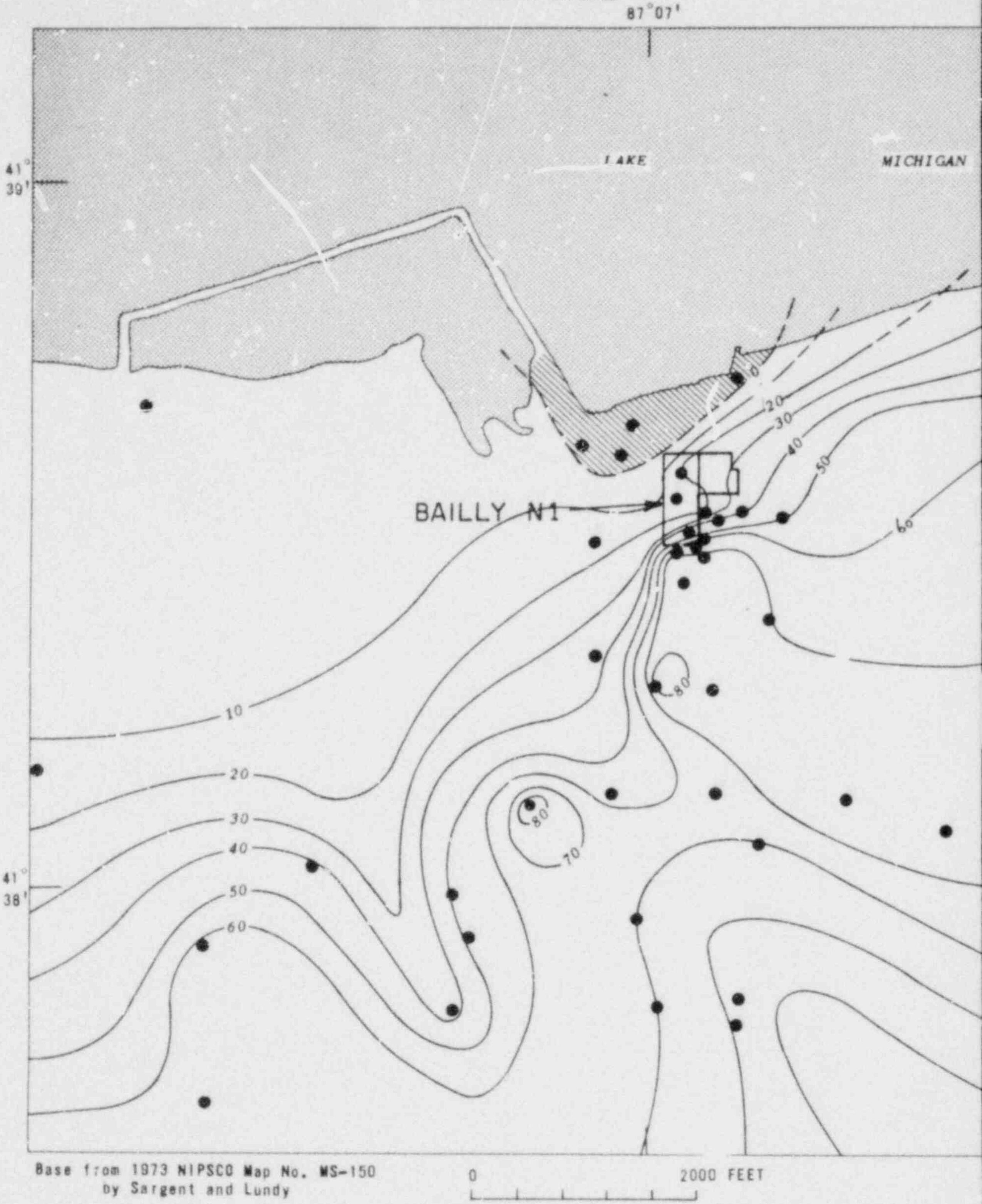
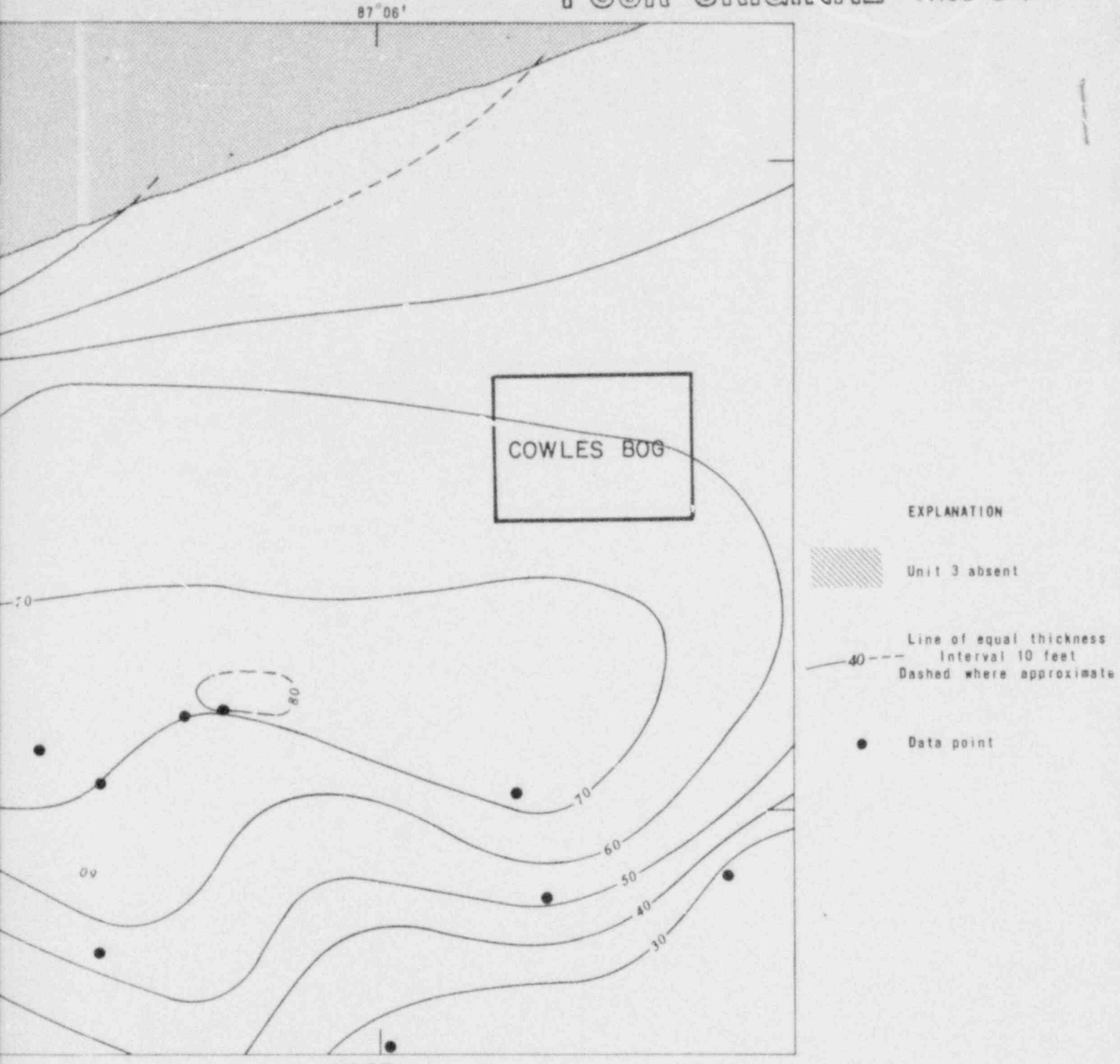


Figure 9.-- Thickness of un



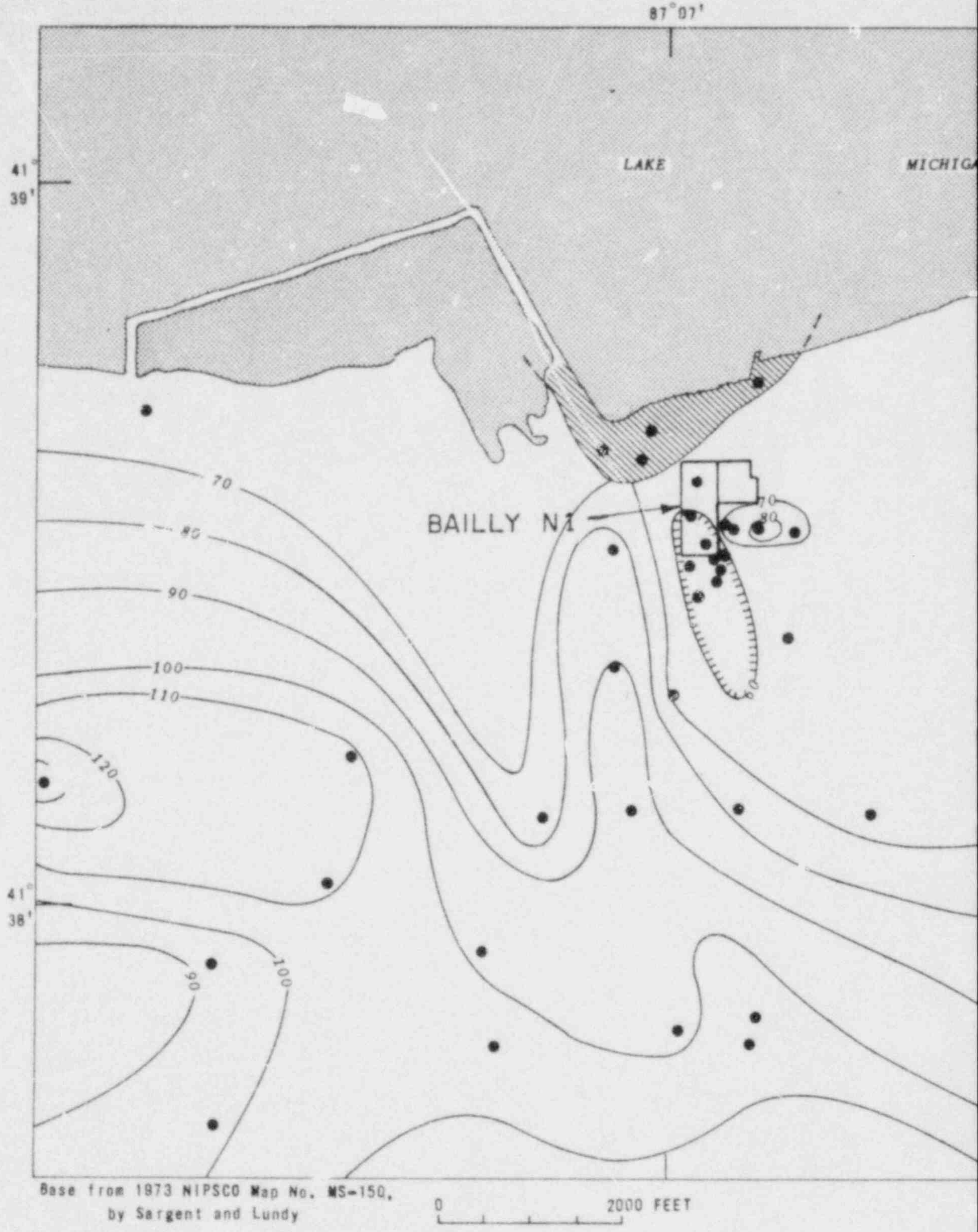
NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

t 3.

FIGURE 9 REPRODUCED
FROM USGS REPORT 78-138

D'APPOLONIA

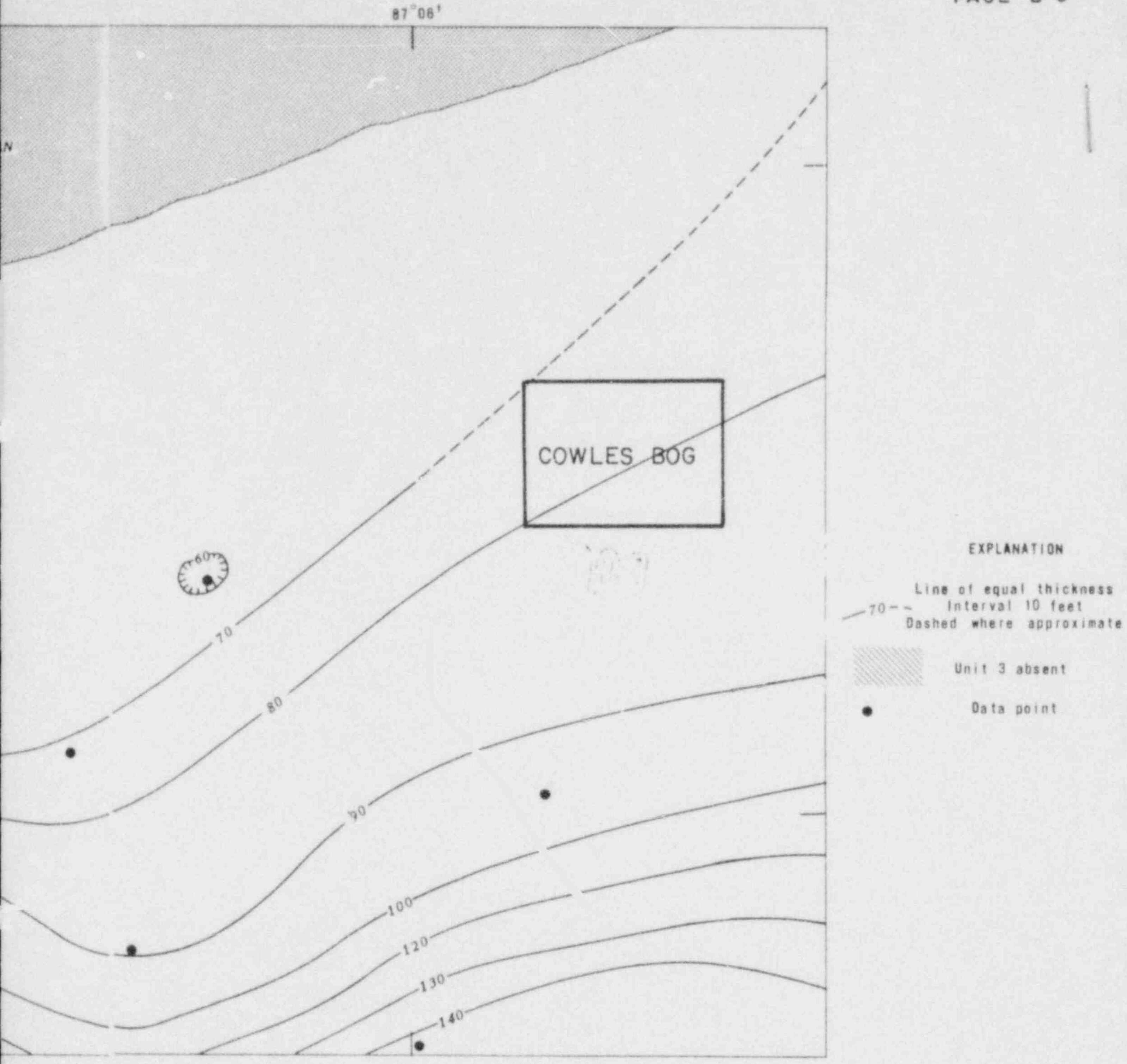
POOR ORIGINAL



Base from 1973 NIPSCO Map No. MS-150,
by Sargent and Lundy

Figure 10.-- Thickness of

POOR ORIGINAL

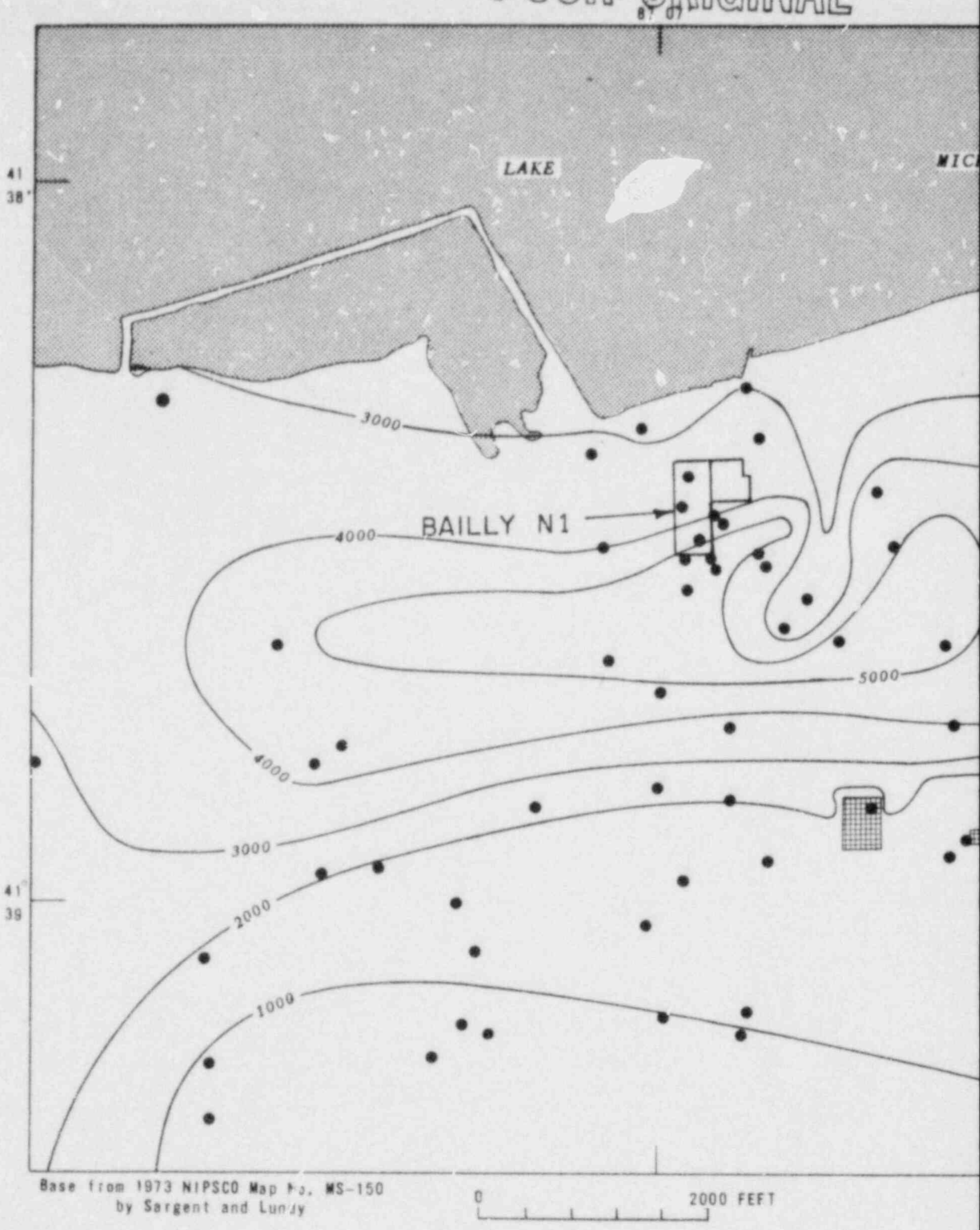


NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

unit 4.

FIGURE IO REPRODUCED
FROM USGS REPORT 78-138

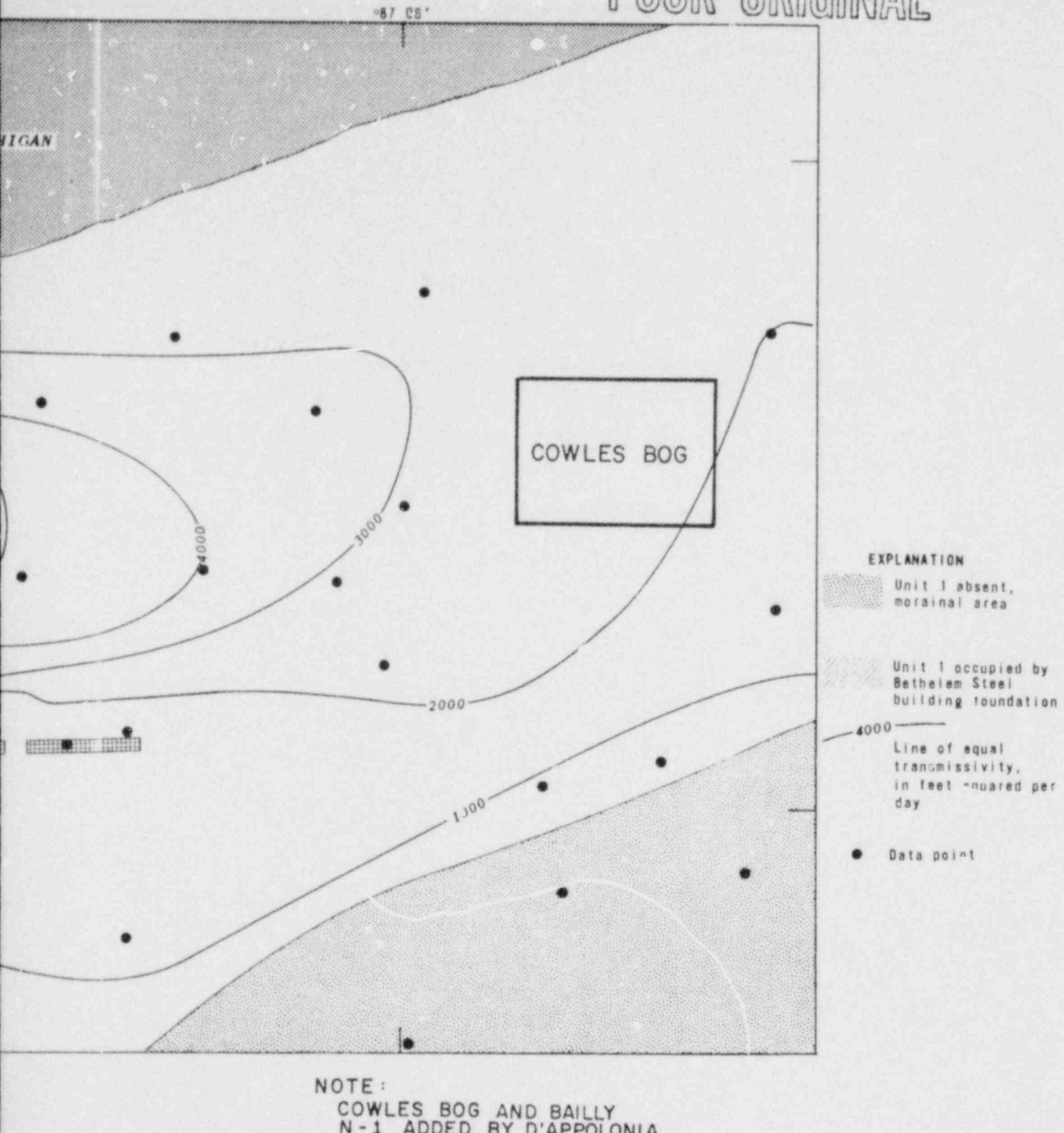
D'APPOLONIA



Base from 1973 NIPSCO Map No. MS-150
by Sargent and Lundy

Figure 11.--Transmissivity of unit

POOR ORIGINAL

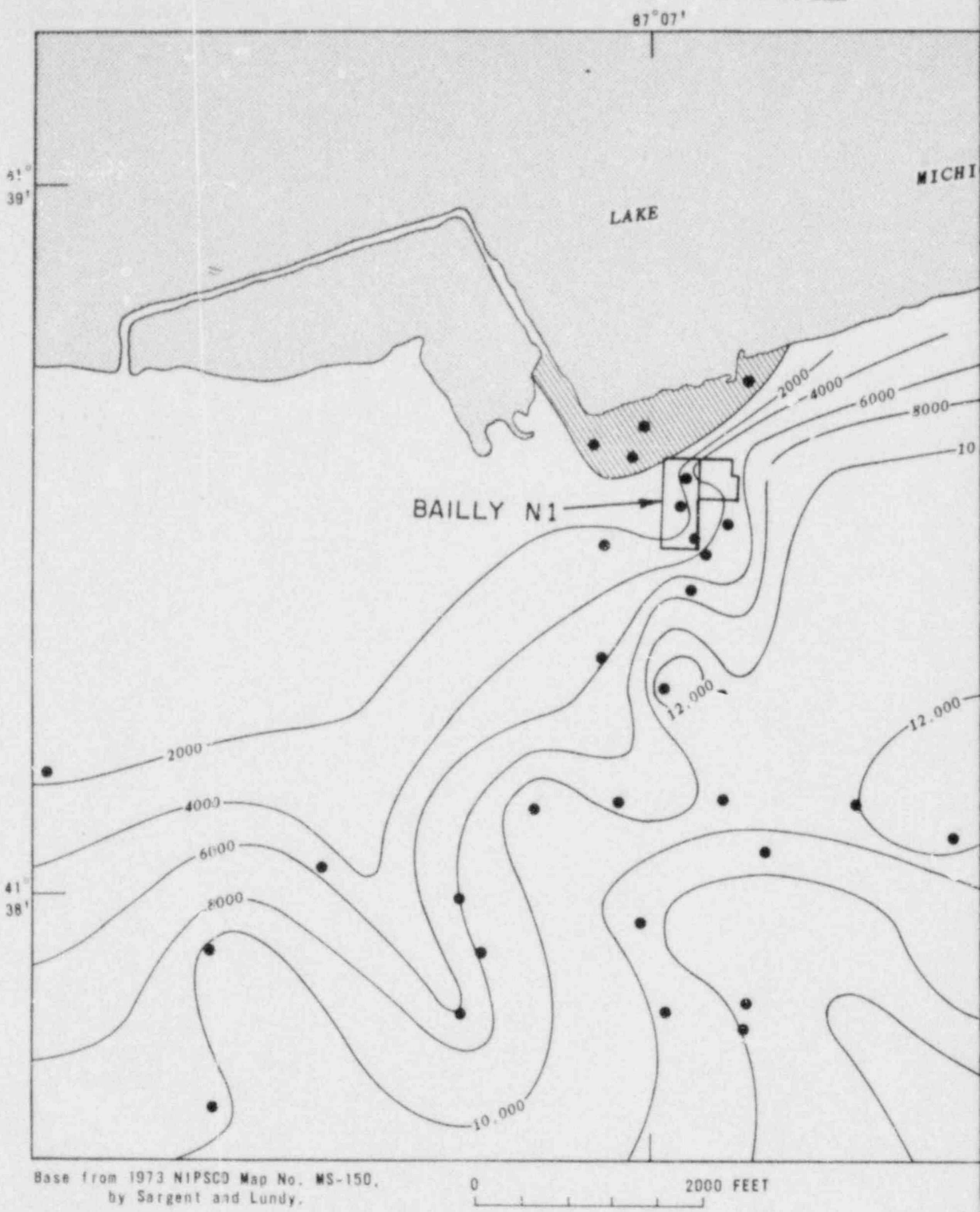


NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

1, October 26, 1976.

FIGURE 11 REPRODUCED
FROM USGS REPORT 78-138

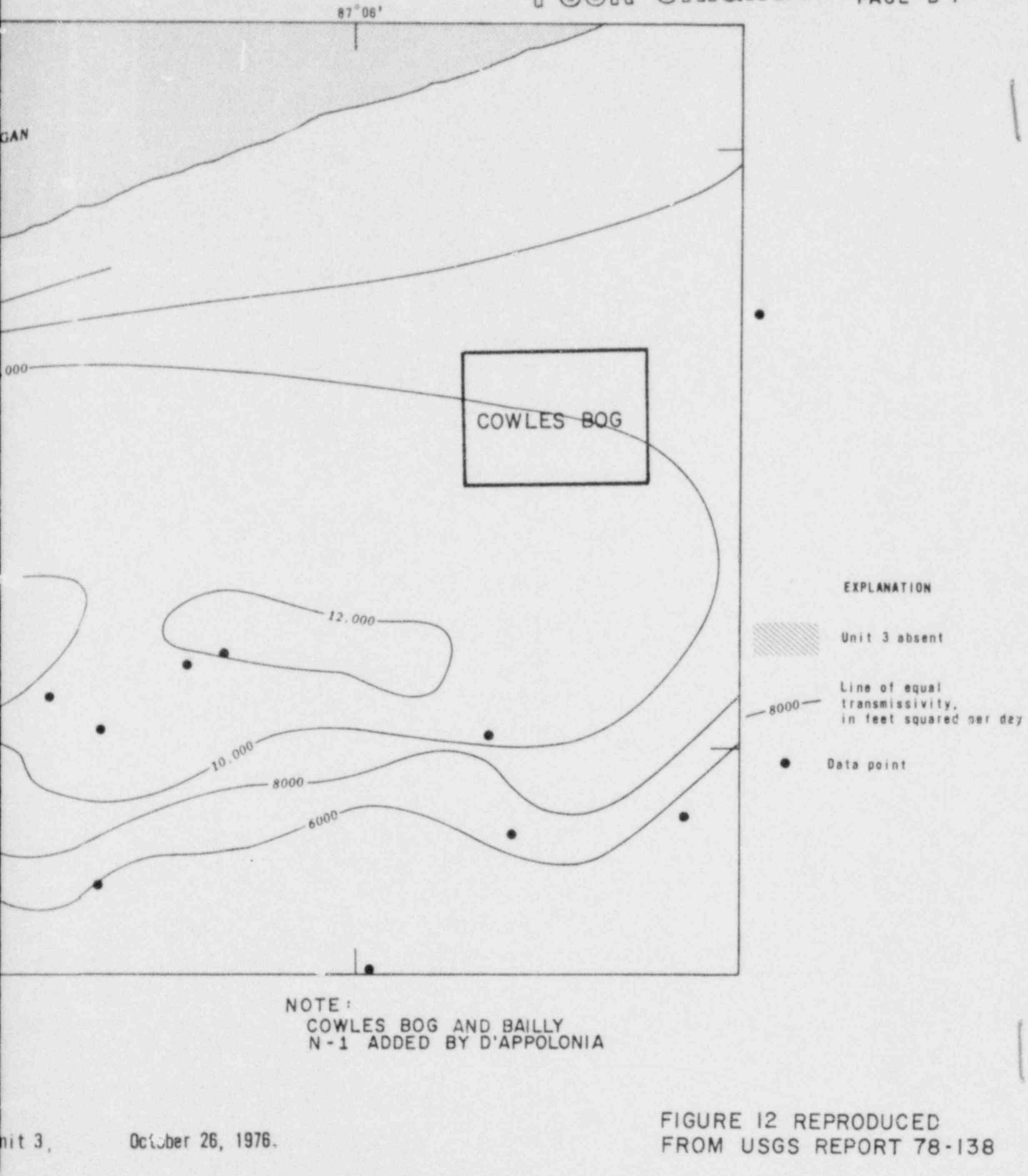
D'APPOLONIA



Base from 1973 NIPSCO Map No. MS-150, by Sargent and Lundy.

Figure 12.-- Transmissivity of U

POOR ORIGINAL



NOTE:
COWLES BOG AND BAILLY
N-1 ADDED BY D'APPOLONIA

nit 3, October 26, 1976.

FIGURE 12 REPRODUCED
FROM USGS REPORT 78-138

D'APPOLONIA

APPENDIX C

COMPARISON OF SOIL DATA

(For Explanation and Conclusions See Section 3.3)

Comparison of Soil Data at Dune Acres Well No. 1
Figure C1*

The actual thickness of Unit 2 clay encountered is approximately 55 feet, whereas the thickness used in the model is only 12 feet. The actual thickness of Unit 3 is approximately 12 feet instead of 45 feet used in modeling. The permeability of Unit 3 is about 1/3 of that used in modeling. The surface elevation of the Unit 3 sand is about 42 feet below the elevation used in the study. There are major differences in physical properties and limit the reliability of the modeling results.

Comparison of Soil Data at USGS Piezometer 101
Figure C2

Soil boring data indicates that Unit 2 is in fact two layers, one 19 feet thick and the other 9 feet. The model assumes an uninterrupted 40 foot thickness. The materials encountered at Unit 3 consist of clayey sands, clay, and sand. Permeabilities of these materials are 3 to 30 times lower than the value used in the study.

Comparison of Soil Data at USGS Piezometer 102
Figure C3

Unit 3 materials at this location vary from a coarse to fine sand with permeabilities varying from 3 times lower to 3 times higher than the value used in modeling. The actual stratigraphy shows a clay layer embedded between sand so that vertical flows will be affected within the aquifer.

---

* Figures C1 through C13 are included in this Appendix.

Comparison of Soil Data at USGS Piezometer 103
Figure C4

Unit 2 was not encountered at this location, however, the model assumes a fifteen foot thickness for Unit 2. The Unit 3 sands encountered are approximately 92 feet thick not 70 foot thick as modeled. Permeabilities of the actual sand vary from 2 times more to 600 times less than the value used in the study. Lack of Unit 2 in this boring is significant as the actual case indicates an unconfined aquifer whereas it was modeled as a confined aquifer. The groundwater level was modeled about 5 feet above the existing ground surface.

Comparison of Soil Data at USGS Piezometer 105
Figure C5

The actual Unit 3 sands have variable amounts of silt with permeabilities up to 600 times smaller than the value used in the study. Also, the actual thickness of the Unit 3 soils is about 77 feet, not the 55 feet that was modeled.

Comparison of Soil Data at USGS Piezometer 107
Figure C6

The thickness of Unit 2 material is about 2 feet, whereas it was modeled as 5 feet. The actual Unit 3 sands are silty with clay and about 600 times less permeable than that used in the study.

Comparison of Soil Data at Boring 705
Figure C7

Although this boring is shallow, it represents the only data available at this location. Permeabilities of the upper Unit 1 sands are similar to the values used in the model. Information is lacking for Units 2 and 3.

Comparison of Soil Data at Boring 706
Figure C8

This boring shows that the upper Unit 1 sands are about 3 times less permeable than the values used in the model.

Comparison of Soil Data at Boring 709
Figure C9

The Unit 1 sands have permeabilities of about 3 times less than that modeled. Also, the Unit 3 sands encountered are only about 18 feet thick not 55 feet as was modeled. The actual permeabilities of Unit 3 are 3 times less than the value used in the study. Unit 2 was encountered at an elevation about 12 feet below that used in the model study and the surface elevation of the Unit 3 sands is about 17 feet below the elevation modeled.

Comparison of Soil Data at Boring 712
Figure C10

The Unit 1 sands have permeabilities 3 to 30 times less than the value used in the study. The actual thickness of the Unit 2 clays is more than 44 feet and not the 5 feet used in the model resulting in more than a 39-foot difference in elevation of Unit 3.

Comparison of Soil Data at Boring 715
Figure C11

Sands encountered in this boring are silty sands and clayey silty sands having permeabilities 30 times less than the value used in the study. Unit 2 clays were not encountered, although Unit 2 was modeled at this location.

Comparison of Soil Data at Boring B-79-1
Figure C12

Actual Unit 2 clays are only about one foot thick, not 18 feet thick as used in the study. There are no other soil borings in this area to identify Unit 2 and Unit 3. The thicknesses shown are assumed.

Comparison of Soil Data at Boring B-79-3
Figure C13

The Unit 2 clay encountered is only 1 to 2 feet thick and not 18 feet thick as used in the model. The Unit 3 sands were encountered about 15 feet higher than the elevation used in the study. There are no other borings in this area to identify Unit 3.

Comparison of Soil Data in the Cowles Bog Area

There are approximately 12 USGS piezometers installed in the Cowles Bog area. These are shown on Figure 2. The piezometers are shallow and soil information is available only from 7 to 20 feet. No deep borings were drilled to locate Units 1, 2 and 3. Hence, the thickness and permeability determinations of the units in this area for model analysis must have been assumed.

Comparison of Soil Data in the Area Surrounding Cowles Bog

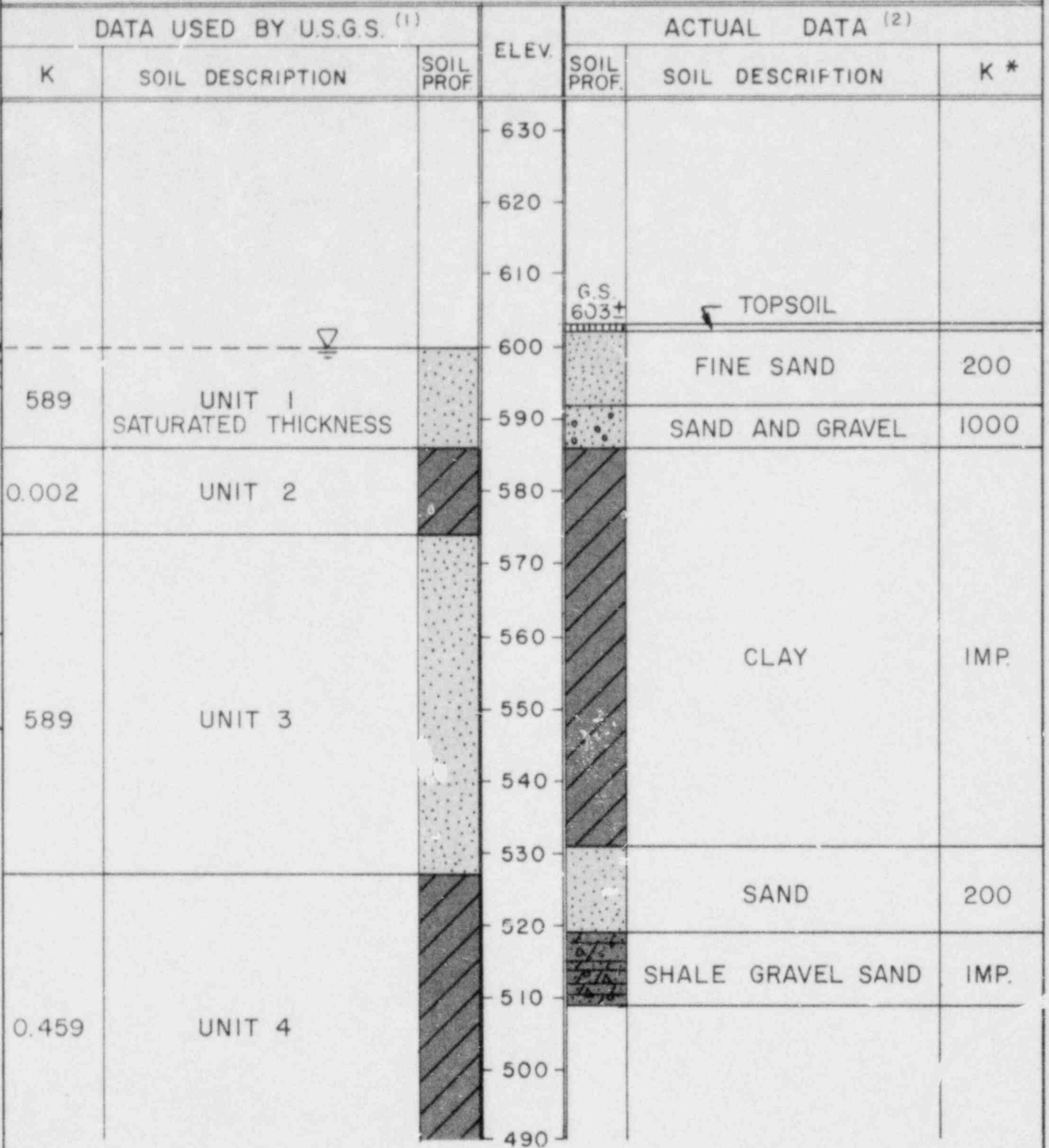
There are no deep soil borings in the one square mile area surrounding the Cowles Bog to define Units 1, 2 and 3. It is overly simplistic to merely assign soil layer thicknesses and permeabilities over so large an area with little or no subsurface data.

APPENDIX C

LIST OF FIGURES

DRAWN BY EJN 10-30-80
CHECKED BY JWW 10/31/80
APPROVED BY RCV 10-31-80
DRAWING NUMBER MW79-720A2

DATA POINT Dune Acres Well No. 1 LOCATION N. 1,512,450 ± E. 499,550 ±



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

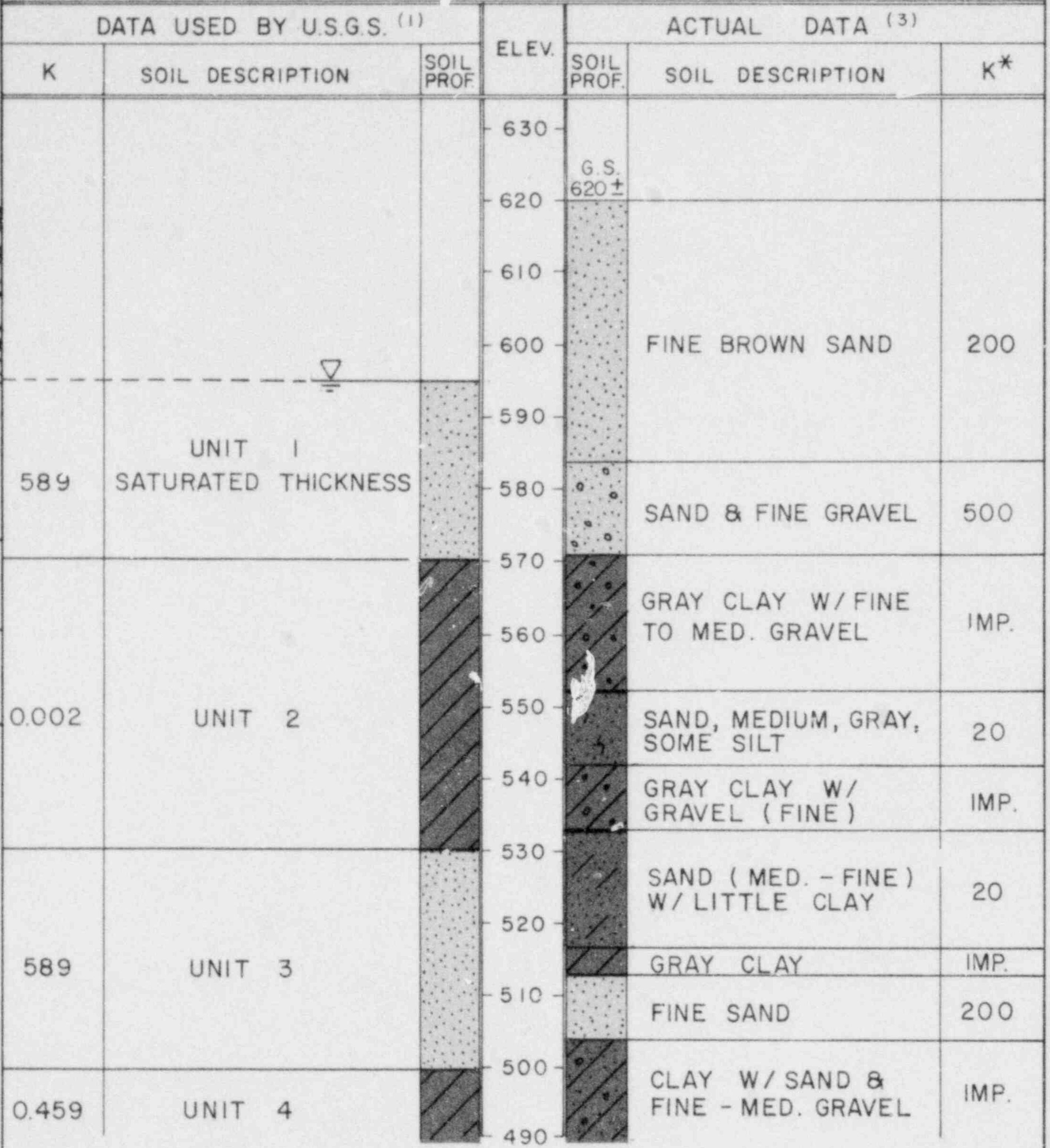
IMP PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C

FIGURE C 1
COMPARISON OF DATA
Dune Acres Well No 1
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY ZJN 10-30-80 CHECKED BY VWW 10-3/-80 APPROVED BY RCV 10-31-80 DRAWING NUMBER MW79-720A 3

DATA POINT USGS Piezometer 101 LOCATION N. 1,508,651 ± E. 489,329 ±



LEGEND

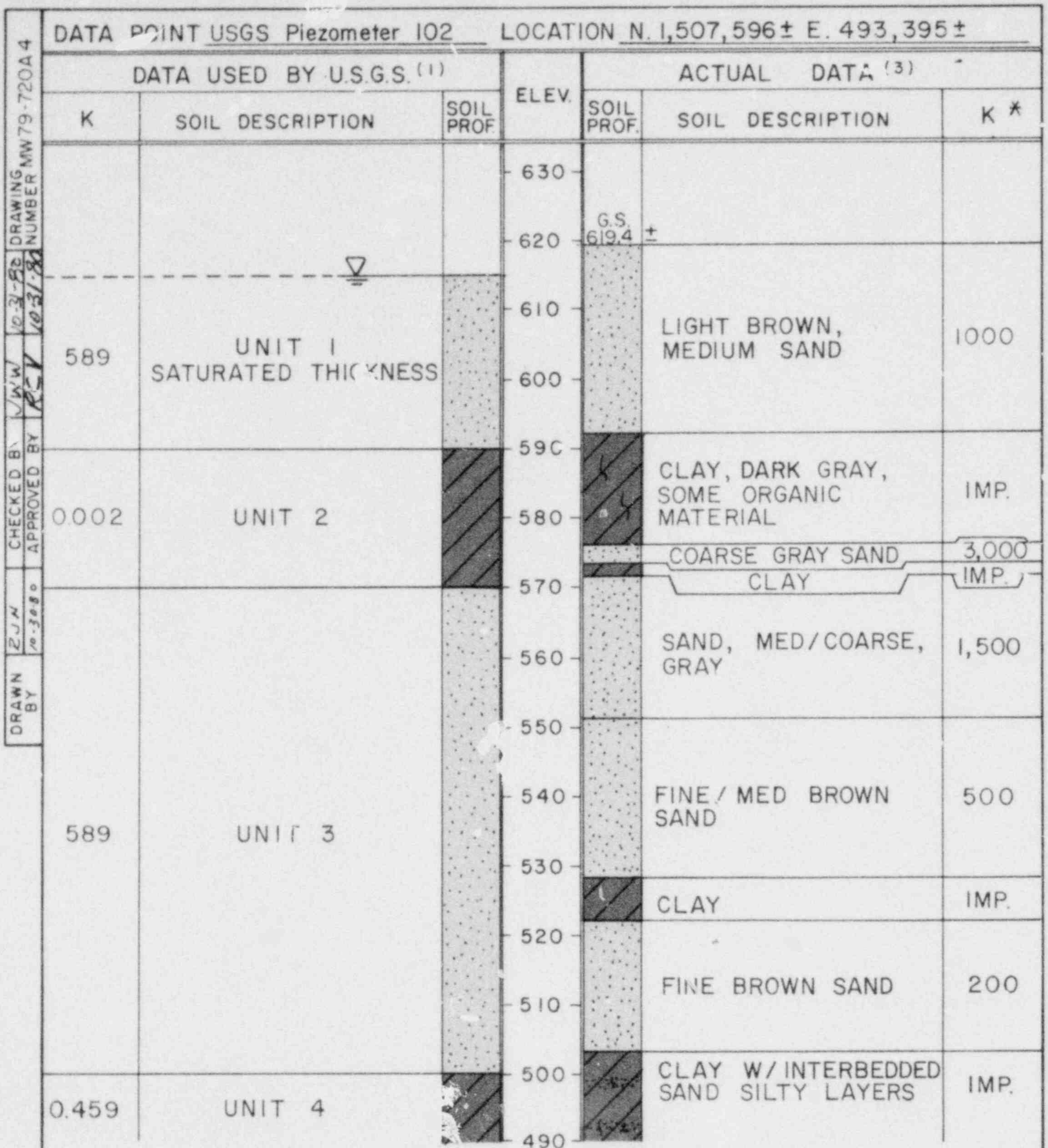
K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

IMP - PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C

FIGURE C 2
COMPARISON OF DATA
USGS Piezometer 101
[illegible] GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

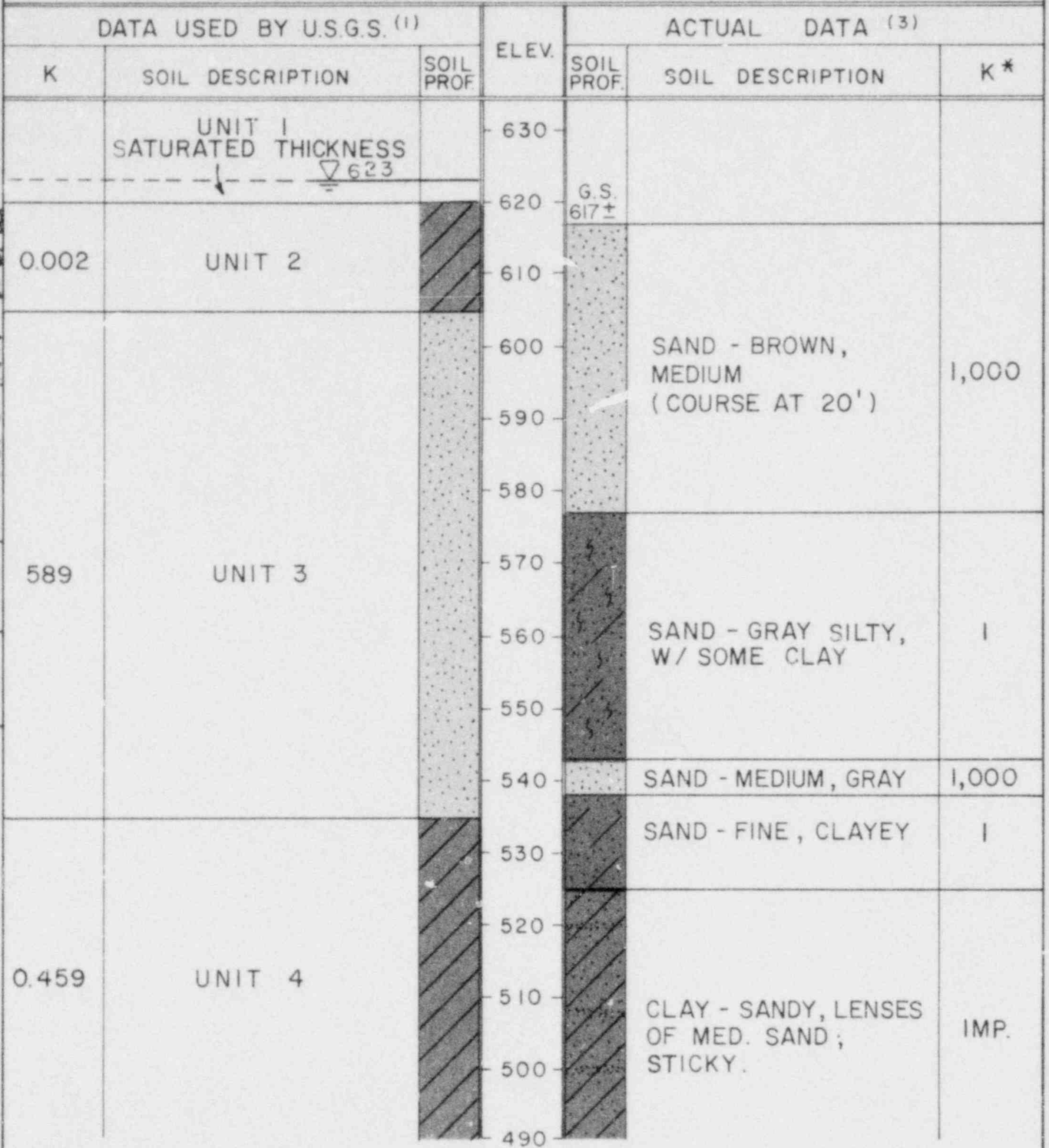
IMP PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C

FIGURE C 3
COMPARISON OF DATA
USGS Piezometer 102
BAILLY GENERATING STATION
NUCLEAR I
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY RJN 10-30-80
CHECKED BY VWW 10-31-80
APPROVED BY RCV 10-31-80
DRAWING NUMBER MW79-720A 5

DATA POINT USGS Piezometer 103 LOCATION N. 1,505,491 ± E. 496,645 ±



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

IMP - PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C.

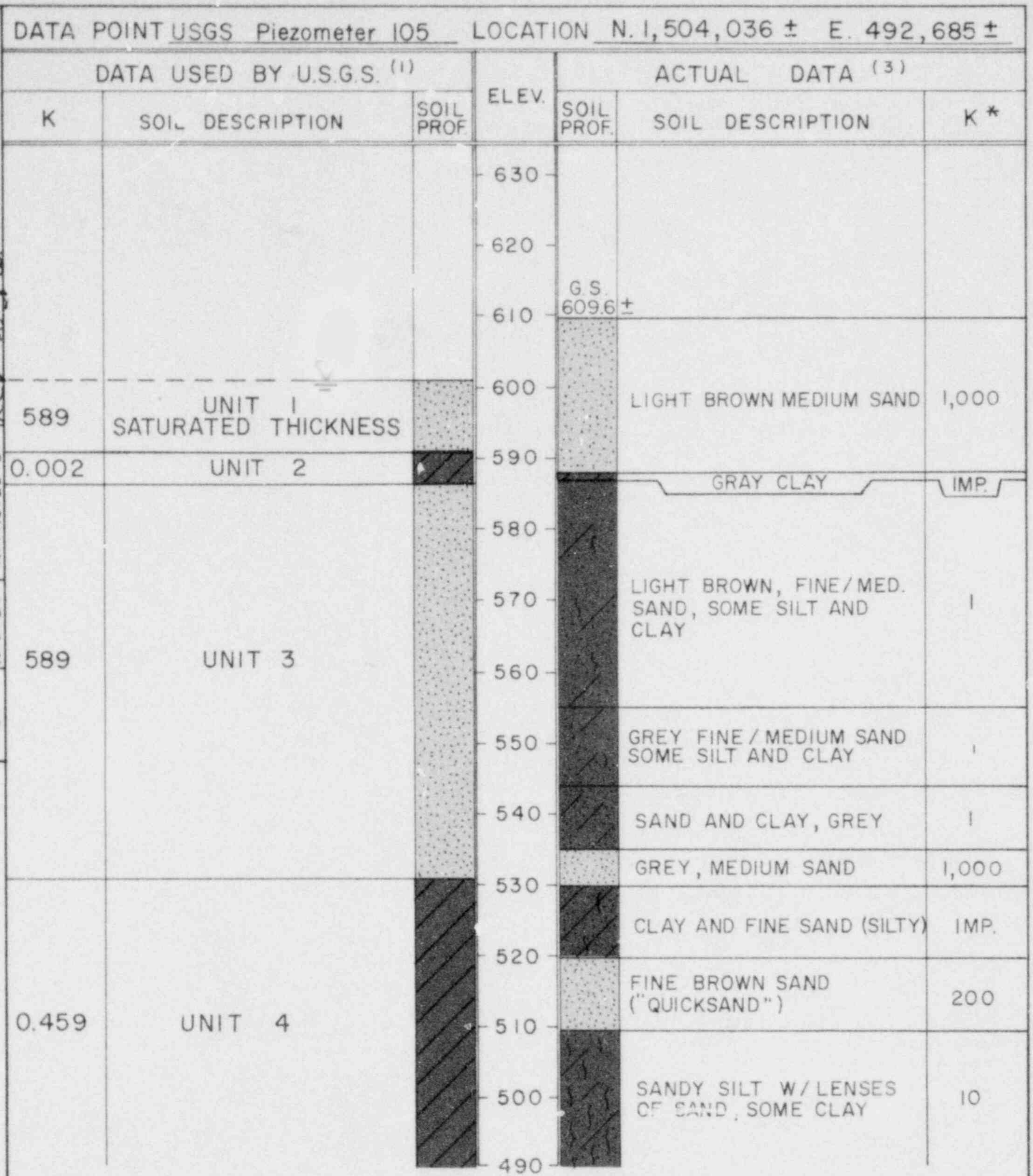
FIGURE C 4
COMPARISON OF DATA
USGS Piezometer 103
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY ZJK 10-30-80

CHECKED BY WW 10-31-80

APPROVED BY RCV 10-31-80

DRAWING NUMBER MW79-720A6



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS

* - ESTIMATED

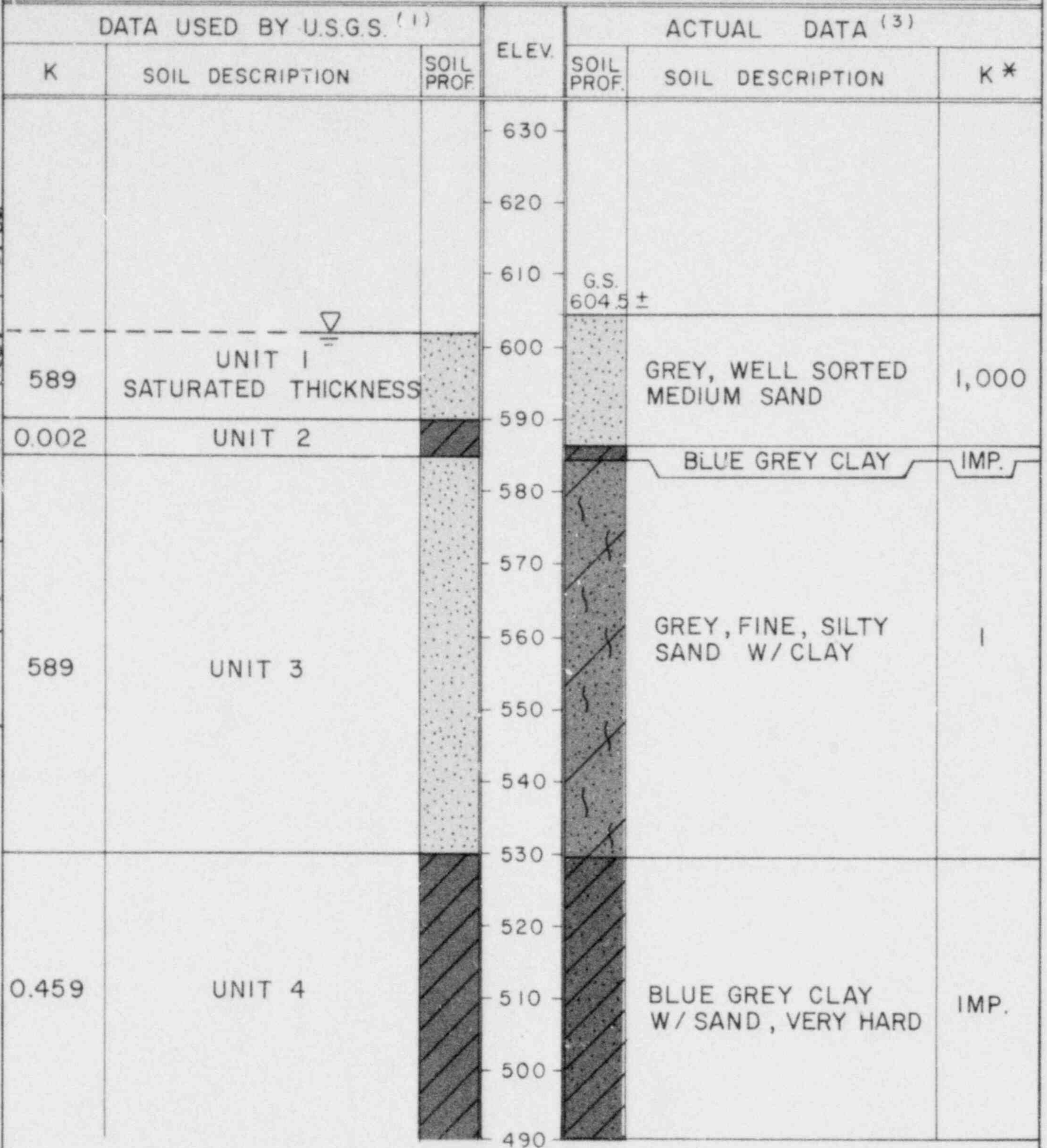
IMP - PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C

FIGURE C 5
COMPARISON OF DATA
USGS Piezometer 105
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY ZJN 10-30-80
CHECKED BY VWW 10-31-80
APPROVED BY RCV 10-31-80
DRAWING NUMBER MW79-720A7

DATA POINT USGS Piezometer 107 LOCATION N. 1,509,681 ± E. 499,625 ±



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS

* - ESTIMATED

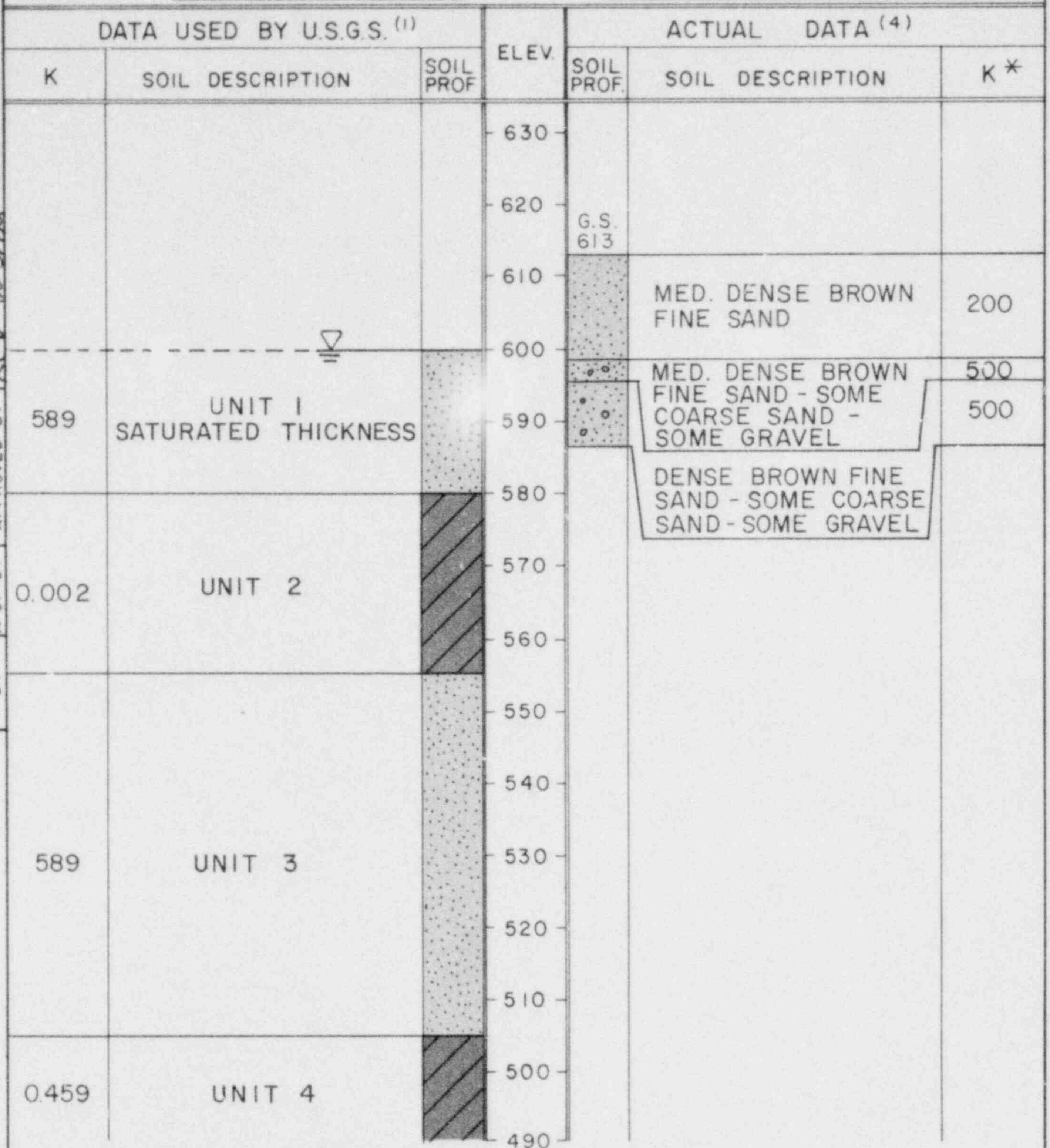
IMP - PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C

FIGURE C 6
COMPARISON OF DATA
USGS Piezometer 107
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWING NUMBER MW79-720A8
CHECKED BY VWW 10-31-80
APPROVED BY RCV 10-31-80
DRAWN BY RJN 10-30-80

DATA POINT BORING 705 LOCATION N. 1,509,128 E. 492,630



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

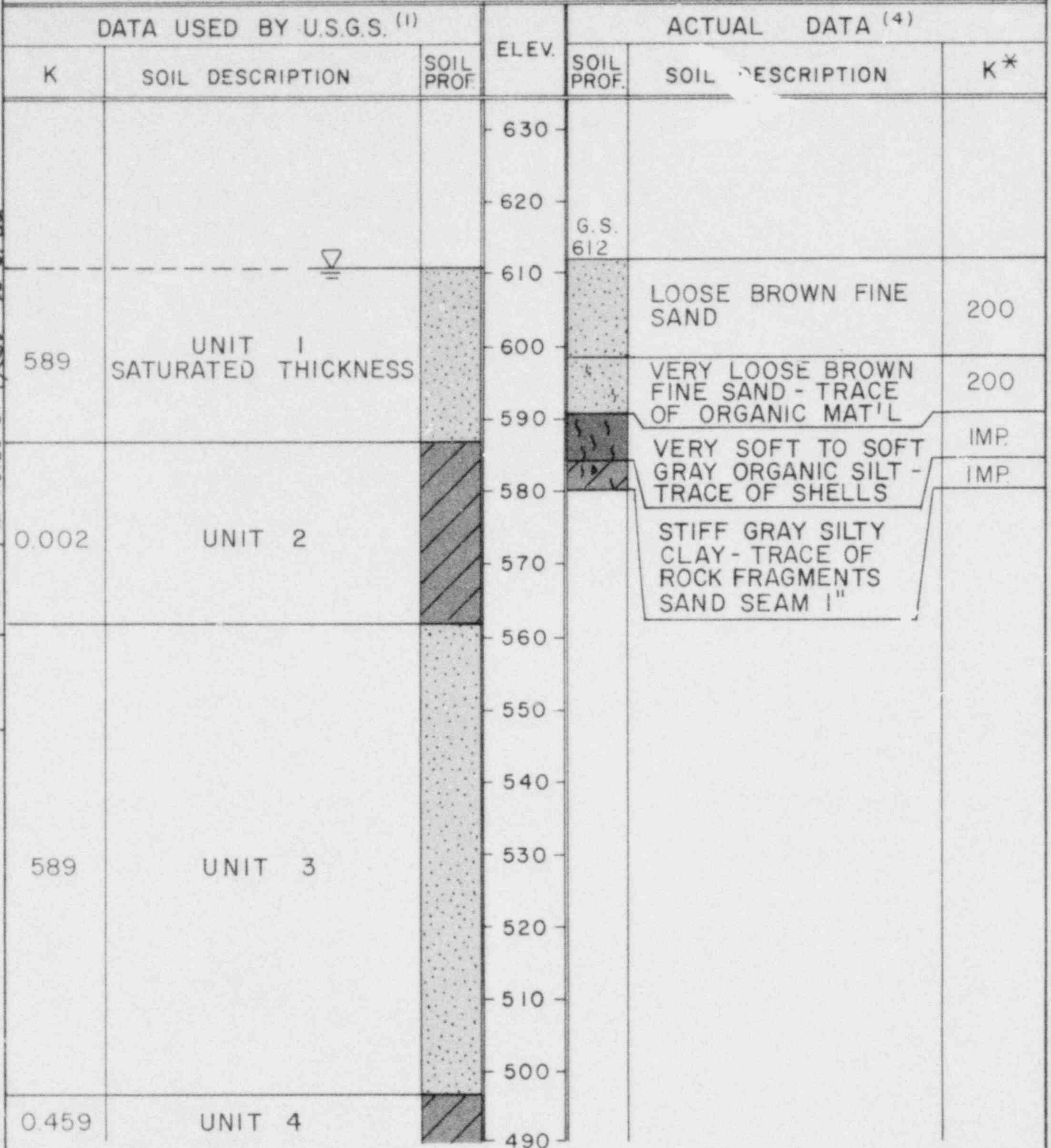
IMP - PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCES OF APPENDIX C

FIGURE C 7
COMPARISON OF DATA
Boring 705
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY T.I.N. 10-30-80
CHECKED BY JWW 10-31-80
APPROVED BY RCV 10-31-80
DRAWING NUMBER MW79-720A9

DATA POINT BORING 706 LOCATION N. 1,508,283 E. 493,580



LEGEND

K - PERMEABILITY EXPRESSED IN $10^{-4} cm/sec$ UNITS.

* - ESTIMATED

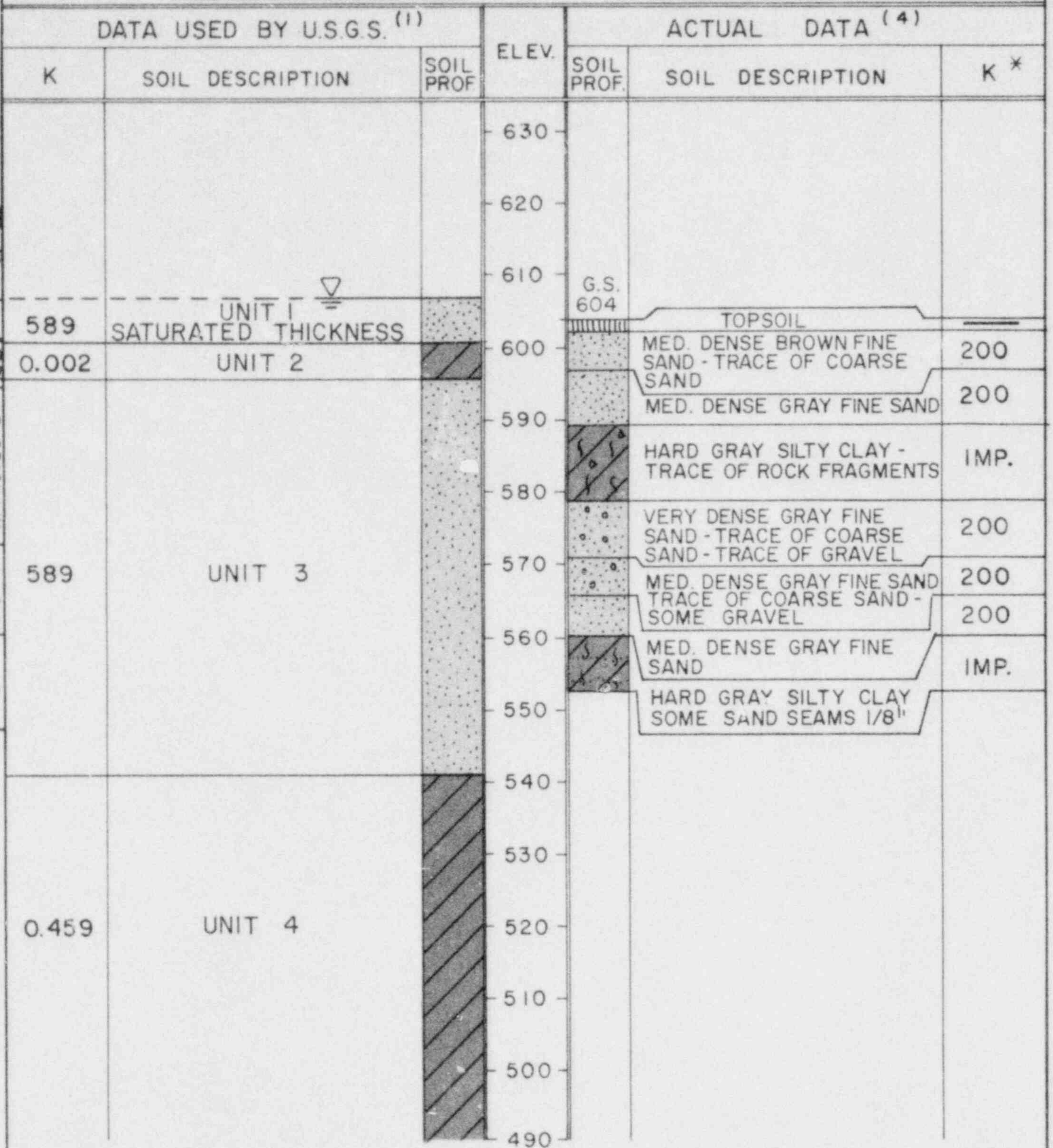
IMP. - PRACTICALLY IMPERVIOUS

(1) - INDICATES REFERENCE OF APPENDIX C

FIGURE C 8
COMPARISON OF DATA
Boring 706
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY ZJK 10-30-80 | CHECKED BY JWW 10-31-80 | APPROVED BY RCV 10-31-80 | DRAWING NUMBER MW79-720A10

DATA POINT BORING 709 LOCATION N. 1,506,953 E. 499,133



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS

* - ESTIMATED

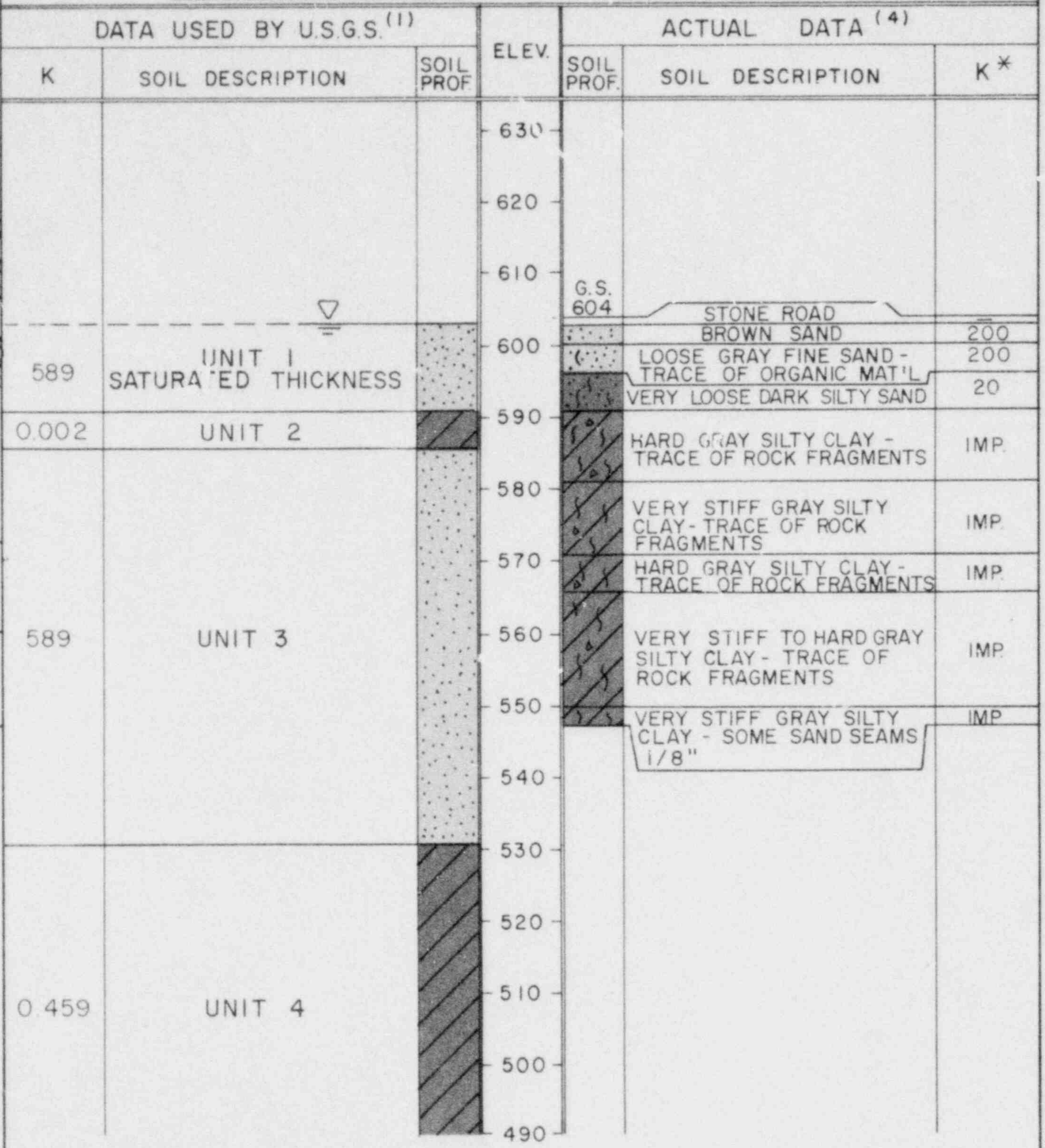
IMP. - PRACTICALLY

(1) INDICATES REFERENCE OF APPENDIX C

FIGURE C9
COMPARISON OF DATA
BORING 709
BAILLY GENERATING STATION
NUCLEAR I
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

DRAWN BY ZJN 10-30-80
CHECKED BY JWW 10-31-80
APPROVED BY RLV 10-31-80
DRAWING NUMBER MW79-720A11

DATA POINT BORING 712 LOCATION N. 1,509,322 E. 499,095



LEGEND

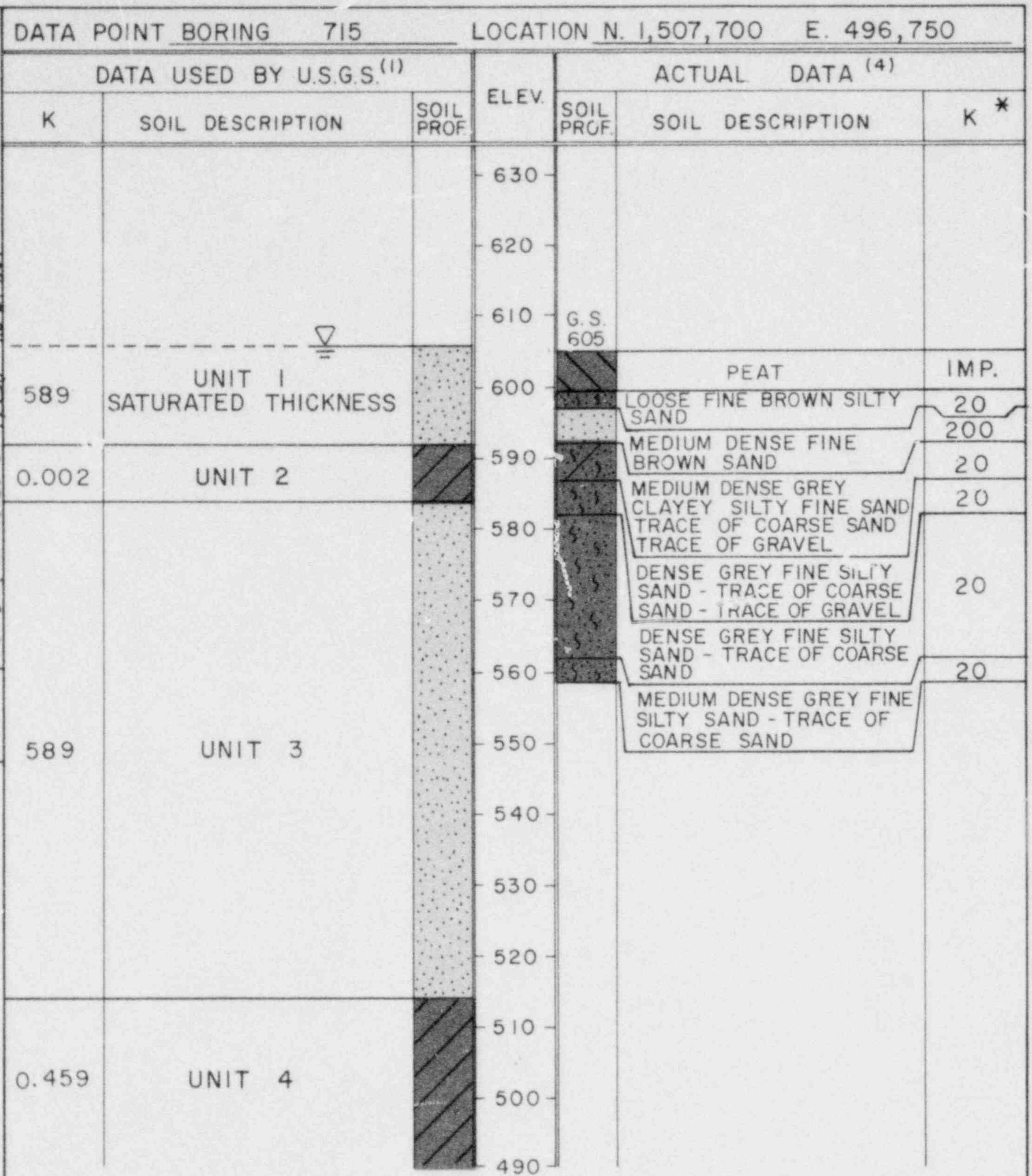
K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

IMP. PRACTICALLY IMPERVIOUS

(1) INDICATES REFERENCE OF APPENDIX C

FIGURE C 10
COMPARISON OF DATA
Boring 712
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA



DRAWING NUMBER MW79-720A12
DRAWN BY PJN 10-30-80
CHECKED BY JWW 10-31-80
APPROVED BY PCH 10-31-80

LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

IMP - PRACTICALLY IMPERVIOUS

(1) INDICATES REFERENCE OF APPENDIX C

FIGURE C 11
COMPARISON OF DATA
BORING 715
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

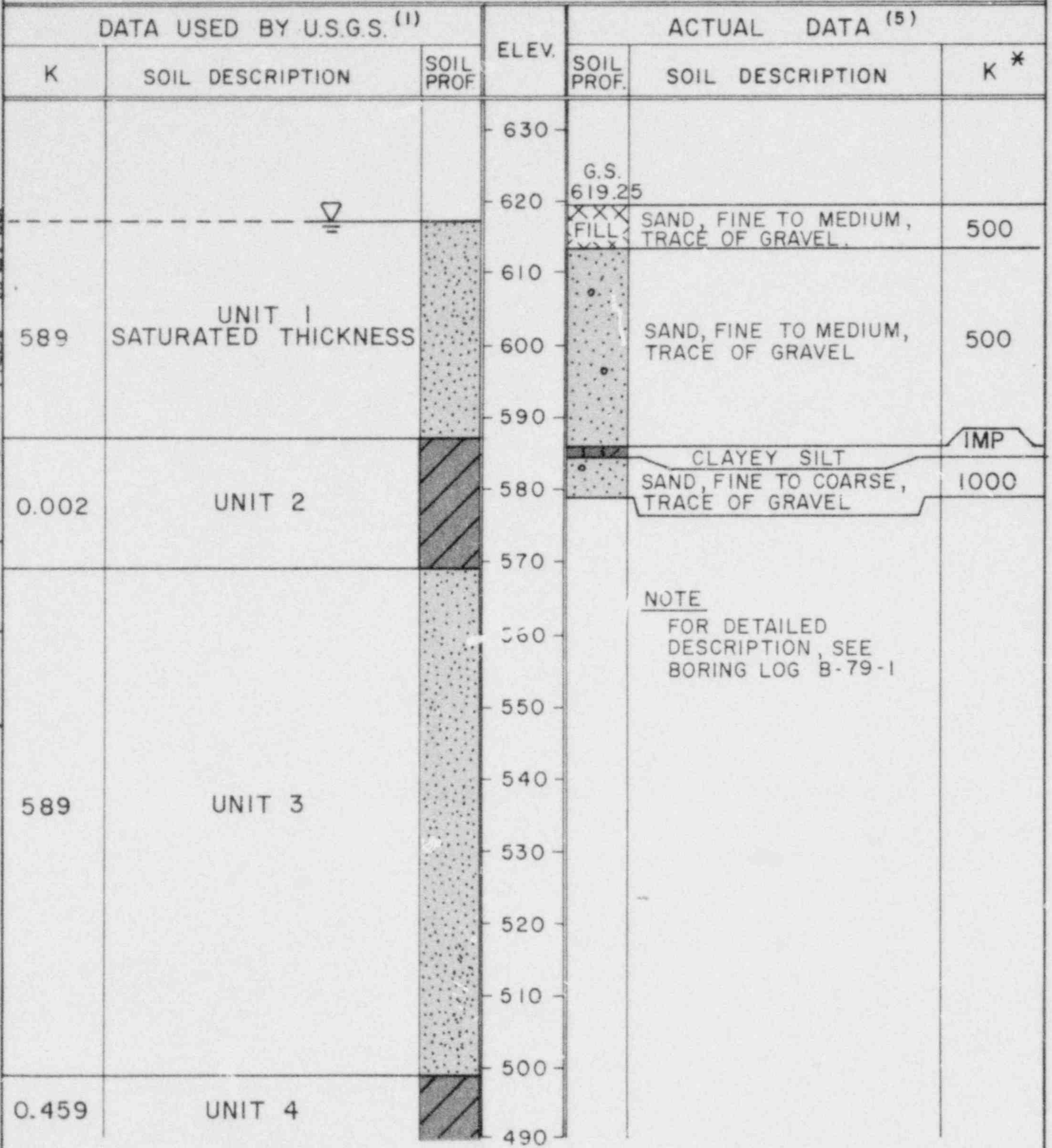
DRAWING NUMBER MW79-720A13

CHECKED BY JWW 10-31-80

APPROVED BY RCH 10-31-80

DRAWN BY ZJN 10-30-80

DATA POINT BORING B-79-1 LOCATION N. 1,507,489 E 492,532



LEGEND

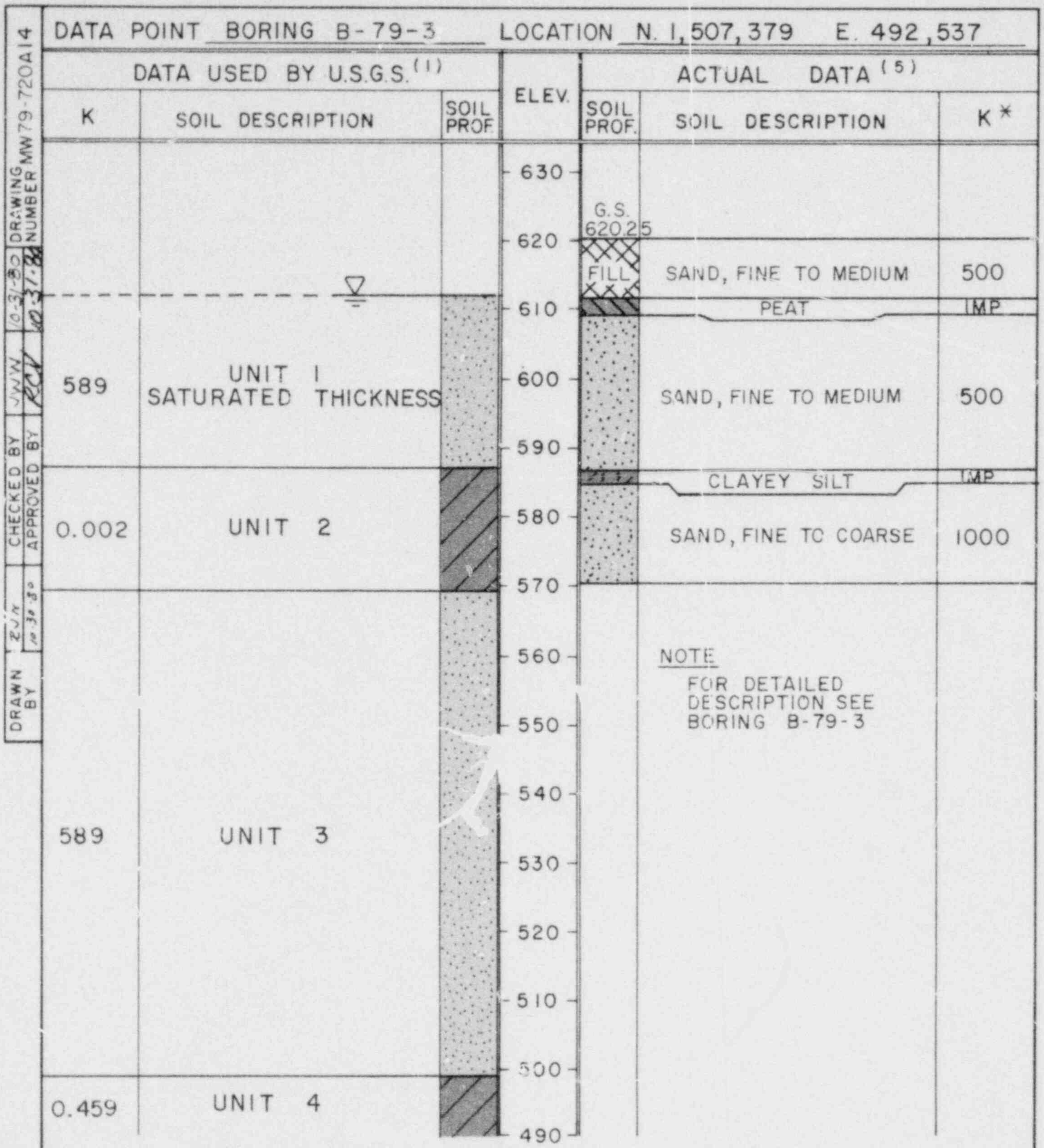
K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS.

* - ESTIMATED

IMP - PRACTICALLY IMPERVIOUS

(1) INDICATES REFERENCE OF APPENDIX C

FIGURE C12
COMPARISON OF DATA
BORING B-79-1
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA



LEGEND

K - PERMEABILITY EXPRESSED IN 10^{-4} cm/sec UNITS

* - ESTIMATED

IMP. - PRACTICALLY IMPERVIOUS

(1) INDICATES REFERENCE OF APPENDIX C

FIGURE C13
COMPARISON OF DATA
BORING B-79-3
BAILLY GENERATING STATION
NUCLEAR 1
PREPARED FOR
NORTHERN INDIANA PUBLIC SERVICE CO.
D'APPOLONIA

LIST OF REFERENCES FOR APPENDIX C

(1) USGS Report 78-138, Figures 6, 7, 8, 9 and 10 (See Appendix B)

(2) *Well Log No. 1, October 16, 1953, City of Dune Acres, Porter County, Indiana*, Layne Northern Co., Inc. Mishawaka, Indiana.

(3) Division of Water, Department of Natural Resources, State of Indiana, *Water Well Logs for USGS Wells 101, 102, 103, 105 and 107, Porter County, Indiana*.

(4) D'Appolonia Consulting Engineers, Inc., Chesterton, Indiana, *Boring Logs 705, 706, 709, 712 and 715, Project No. 70-114*.

(5) Sargent & Lundy, Engineers, Chicago, Illinois, *Boring Logs B-79-1 and B-79-3, Project Number 5560-31*.