APPENDIX C

REPORT OF INVESTIGATION OF WATER PROBLEMS AT THE GRAND RAPIDS GYPSUM MINE, GRAND RAPIDS, MI

BY

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Mr. Charles Young
Grand Rapids Gypsum Co.
Butterworth Dr. SW
Grand Rapids, Michigan

Dear Mr. Young:

In response to your authorization and with your and Mr. Johnson's assistance, I have investigated your mine water problem encountered on October 17, 1964. The investigation included inspection of the site, review and compilation of pertinent data from your well records, pumpage records and other readily available information such as oil and gas drilling records. Preliminary verbal progress reports have been made during our conferences. This letter report summarizes the pertinent geologic and hydrologic conditions, conclusions and recommendations.

INTRODUCTION:

The encountering of about 300 gpm (gallons per minute) of water in the southwest portion of your mine has raised several questions including:

1. What is the source of the water?
2. How does it enter the formation?
3. What are the hazards of encountering more water?
4. Removal by pumping or stop the flow?

In determining the answer to these and related questions, it is necessary to recognize that the occurrence of the water encountered, like all ground water, is controlled by regional and local geologic conditions. For this reason, a review of the geologic environment was made to ascertain the controling factors as revealed by the available data.

BASIC GEOLOGIC AND HYDROLOGIC CONSIDERATIONS

The geologic environment consists of unconsolidated glacial soil deposits resting on the eroded surface of the consolidated rocks of the Michigan Formation.

The unconsolidated soils consist of sands, gravels, clays and various mixtures thereof. The logs of the wells in the area report vertical and horizonal variations typical of glacial deposits. (See cross sections) Some of the records report sands and/or gravels with negligable amounts of clays while others report the opposite condition. Most, however, indicate definite stratifications of each of the soil types, the significance of the glacial soils lies in the occurrence of the permeable sands and gravels. Such soils are capable of storing and releasing waters available to them. The well records show this occurs in the area under study. Further, the reported water levels indicate the source of the waters contained in the glacial soils is largely local precipitation and the contribution of the north-south stream west of your present operations. The water levels indicate the ground waters are moving from areas of recharge in the highlands toward the Grand River. The movement of ground water is in response to the force of gravity, hence it will move from any area of high head to whatever area of lower head is available. Therefore, should your mine workings encounter permeable glacial soils, the ground water contained in such soils will naturally move into the mine. For this reason, it is imparitive that direct contact between the mine workings and the glacial soils be avoided if at all possible. The accompanying cross sections show such encounters would be possible by extending the mine openings too far to the west or south.

Other considerations regarding the relationship between the glacial soils and the consolidated rocks involve the character and configuration of the bedrock surface. Prior to glaciation of the area, the local bedrock was exposed and subjected to the natural forces of weathering and erosion like any other land surface. We therefore expect and find, as shown by the bedrock topography map, an irregularity in the bedrock surface. This irregularity or topographic relief is important in locating areas where the thickness of consolidated soils between the base of the glacial drift and roof of the gypsum bed being mined may be hazardously thin. Such an area is present at or immediately west of the site of the recently encounterd water, and is shown by the "depression" contour on the bedrock topography map. The well records indicate a "sink hole", such as have been observed in the Grandville area, exists in the bedrock surface at or near the water flow. Such features result from localized removal of soluble rocks such as limestones and gypsums by downward migrating ground waters and eventual collapse of the overlying but undermined rocks. Such a feature, buried with waterbearing glacial soils provides an excellent avenue for ground waters to migrate into the bedrock formations.

The movement of ground water in consolidated rocks differs from that in unconsolidated rocks. In the latter, the soil particles are uncemented and water surrounds the grains of soil lying below the water table. Within consolidated rocks, much or all of the space between the particles making up the rock is occupied by the cementing agent binding them together. Therefore water movement through consolidated rocks is less likely to be in pores around the grains, and more commonly is through joints, fractures and/or solution channels. Frequently, water is encountered along bedding planes and in the contact zone between beds of different types of rocks such as a change from a sandstone resting on a shale. Comparatively speaking, sandstones and limestones are more apt to be waterbearing than are shales. Within a bed of gypsum such as you mine, the physical and chemical characteristics of the mineral makes water movement through solution channels the most likely mode of occurrence. Because ground water is usually moving, the solution channels tend to be large, growing larger and yield 100 or more gallons of water per minute.

MINE WATER PROBLEM

FIG. 1 IS MISSING

Figure 1 is a map of the area showing the bedrock topography based on the readily available well log data. As mentioned previously, it is important in locating the approximate areas where: a) the bed being mined is absent: b) the bed is exposed to the glacial drift soils: and c) the thickness of consolidated soils overlying the bed may be hazardously thin. Such an area is revealed by the depression contour immediately west of the recent water occurrence.

Also shown on figure 1 are the approximate contours on the water table. While the contours are based on reported water levels noted coincidentally in the drilling of core holes, Mr. Raymer of the O.S. Raymer Co. provided information on four water wells which confirmed the interpreted water levels. The significance lies in the basic characteristics of water level trend rather than in the actual levels. Water tables naturally fluctuate through the year with the seasonal variations in precipitation. They also vary in response to "drought years" versus "wet years". At the present time we are in a drought period with water levels generally at or near record lows throughout Michigan. As the water table varies in altitude, so does the amount of ground water in motion and hence, the amount of water that might be expected to enter the mine through a given opening.

Figure 2 is a graph summarizing the weekly high and low water levels measured in the Pittsburgh shaft and the days the dewatering pump(s) were in operation. It is very apparent that the water encounter of October 17 represented an "interception" of water which previously found its way into the Pittsburgh shaft. The rapidity of the effect on the Pittsburgh shaft supports the theory that a solution channel was intercepted. Most recently, I understand the amount of water entering the mine has been decreasing, necessitating throttling of the pump in the mine. Though the exact cause of this cannot be identified, one or more of the following causes may be responsible for the diminishing flow.

The solution channel may be plugging up with sediments, thus inhibiting the passage of water. If this is the cause, the flow may continue to dimmish, but probably will not completely stop. Also, the pumpage at the Pittsburgh shaft should remain diminished.

The natural "winter decline" in the water table may be responsible for the decline in flow. If this is the cause, the pumpage at the Pittsburgh shaft should remain low and in the spring and summer of the year the flow should again increase.

The water may have eroded a new channel to a lower outlet. In this case the flow should stop in the mine and will probably find its way to the Pittsburgh shaft.

Figures 3 and 4 are cross sections portraying the distribution of permeable unconsolidated soils and their relationships to the underlying consolidated rocks. The vertical scales of the sections are exaggerated out of proportion with the horizonal scale. The horizonal well relationships are proportional to the distances between wells along the lines of the sections as shown on figure 1. Section A-A' (Fig.3) also shows the estimated water table profile. The sections clearly show the soil and water head conditions are suitable for migration of ground waters from the glacial drift into the consolidated rocks. Analyses of the water quality at the flow site in the mine (Hardness 63-69 grains per gallon and Chlorides 91 to 114 parts per million) and at the Pittsburgh shaft (Hardness 93g/g and Chlorides 167 ppm) are also indicative of such migrating ground waters rather than native waters within the rocks.

Based on the available well log information, water pumpage information, water quality information and water level information, it is my opinion that water flow represents a "tapping" of a solution channel receiving water from the glacial drift through a buried "sink hole" or similiar feature.

RECOMMENDATIONS

The recent encountering of water, though not the first, emphasizes the need to avoid working too close to the "pinch out" of the formation or in areas where the roof of consolidated rocks may be thin or saturated with water. The presently available information, as shown by the bedrock topography, indicates that such conditions exist west of your operation, in the vicinity of the water encounter and in the southern portion of the area next scheduled for mining. The latter is based on a few scattered well records and should be explored by drilling to clarify the existing information. Recommended locations for six exploratory holes are shown on figure 1 and numbered in the suggested order of drilling. Depending on conditions encountered at each site, it may be necessary to drill offset holes to clarify the geologic picture if unusual conditions are encountered. During the drilling, the glacial soils should be carefully logged and water levels measured where ground waters are encountered. Electric logging of the open rock holes would be in order if water is encountered in the rock and stands in the hole. The logging would identify the water producing zone or zones missed or mudded off in the drilling process.

A change in exploration hole plugging practices is recommended to obtain better assurance that abandoned holes do not act as avenues for the migration of ground waters. Waterbearing and suspected waterbearing beds within the consolidated rocks should be isolated above and below each zone with a waterproof "bridge" and at least 3-feet of cement grout placed on the top of each bridge. Normal well cementing practices allow 72 hours between operations after placing cement grout. Where "high-early" cement is used the time period is reduced to 48 hours. In any event, each hole should be bridged 3 to 5-feet below the "Drift" to rock contact and cement placed to backfill the hole from the bridge to the top of the rock.

The decrease in the amount of water entering the mine has delayed the urgency of a decision on how to handle this or other flows entering the mine. With the "reprieve" in time, it is recommended that:

1. The exploration holes be drilled and the data analized.
2. Run such elevation surveys as necessary and program future mine floor elevations (based on holes in 1. above) to construct a "drainage map" of the mine. Select locations for future sumps that can recieve mine waters by gravity.
3. As the need arises install pumping stations to remove waters from the sumps. Consideration should be given to water removal with turbine pumps installed in wells drilled into the sump from the overlying land surface. Such facilities might involve more expensive pumping units but would be advantageous in minimizing pipeline needs, potential flooding out of power lines and/or motor. They might also prove invaluable in emergency rescue operations.

4. Future mining areas should be explored by drilling on a more orderly pattern than appears to have been practiced in the past. The pattern should be adjusted to the parcel under consideration but basically a 400 to 500 grid spacing would be in order. This will permit evaluating ore quality and quantity, roof thickness variations, evaluation of water conditions, and programing of mining proceedure, drainage provisions etc.

5. Limits of mining operations should be based on the roof conditions as well as quality and quantity of ore. Depending on the types of rocks, their thickness and structural characteristics, the presence or absence of porosity and water, it appears that 15 to 20 feet of consolidated rocks in the roof is minimal. Where there is evidence of porosity, water and waterbearing soils resting on the bedrock, the roof thickness design should be increased, perhaps into the range of 30-35 feet.

In summary, the investigation has indicated the source of the waters entering the mine is the waterbearing glacial soils which overlie the consolidated rocks. The present information indicates the water enters the consolidated rocks - and gypsum bed - through natural features such as joints, fractures and solution openings. The hazard of encountering additional water is ever present. The probability of encountering water increases as mining progresses toward the "pinch out" of the gypsum bed or the thickness of consolidated rocks in the roof diminishes. The method of removal is largely a matter of economics. The best method lies in developing a mine drainage plan to be used if water is encountered after efforts to avoid it through plans developed from exploratory drilling fail.

If after review of this report any questions arise or clarification is needed, please feel free to schedule a conference at your convenience. I thank you for the fine cooperation throughout the study and the opportunity to be of service. If I may be of further service in this or other matters please contact me.

Yours very truly,

Edward M. Burt

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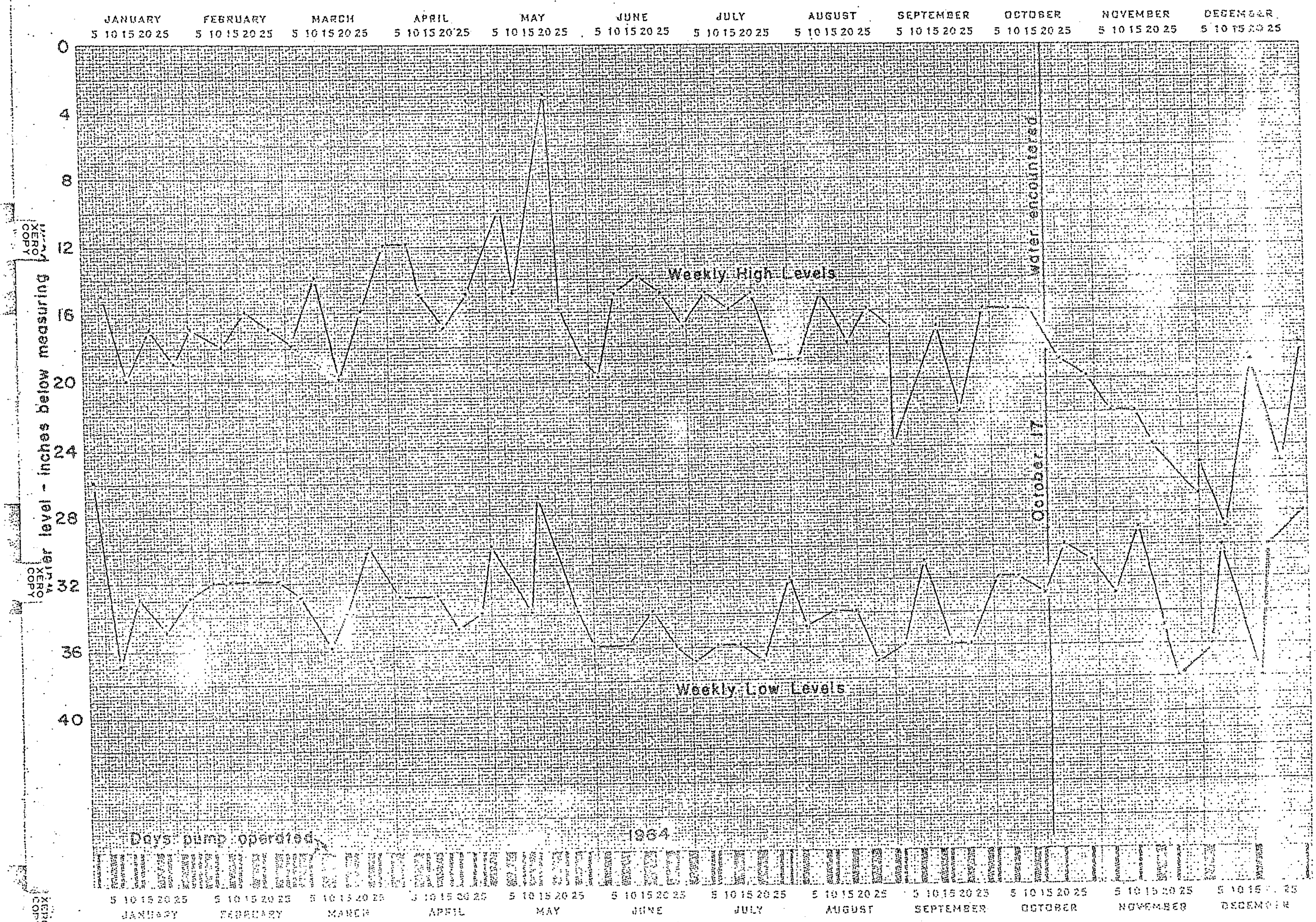

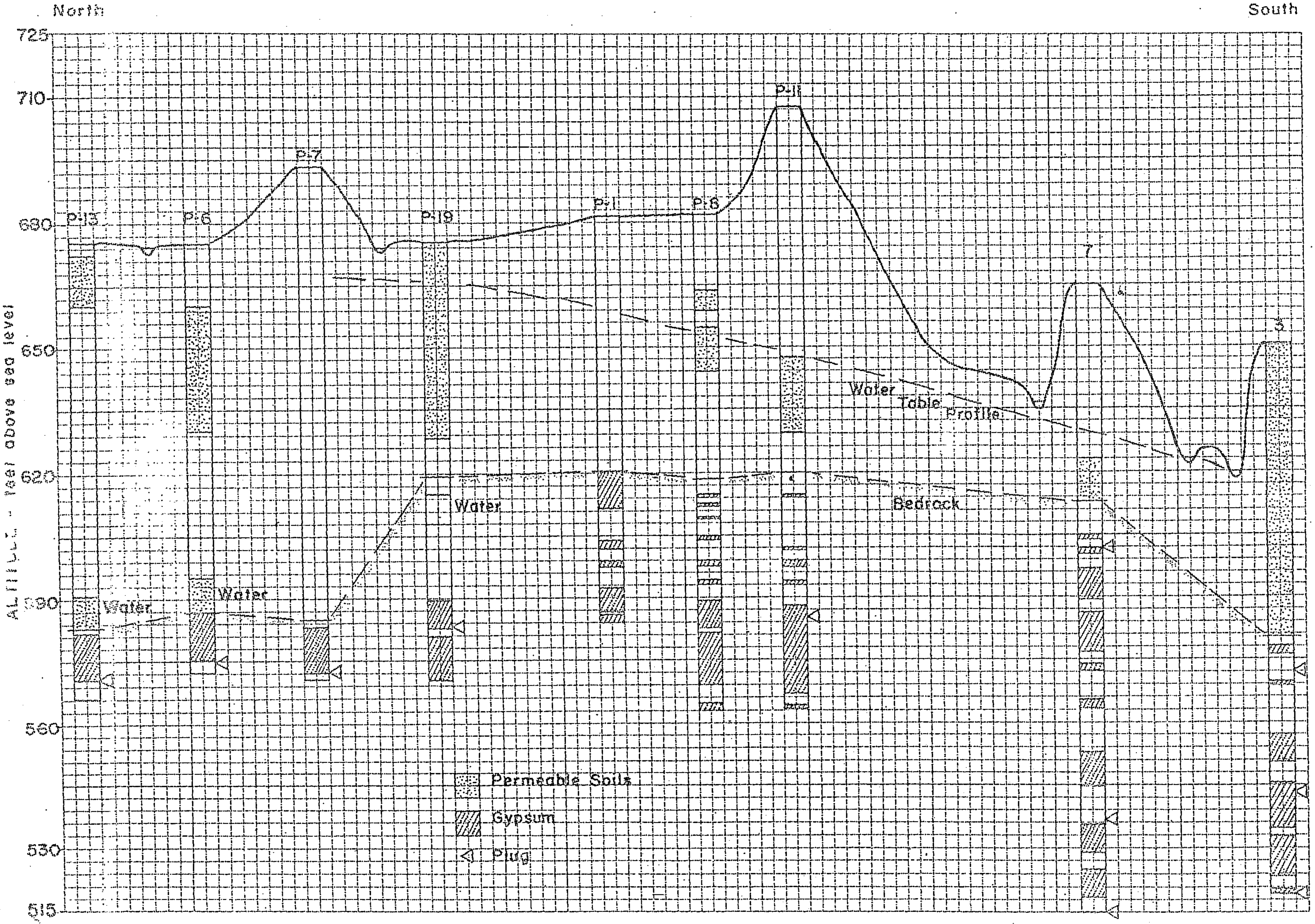

Fig. 3 - Section A - A' Paralleling Stream

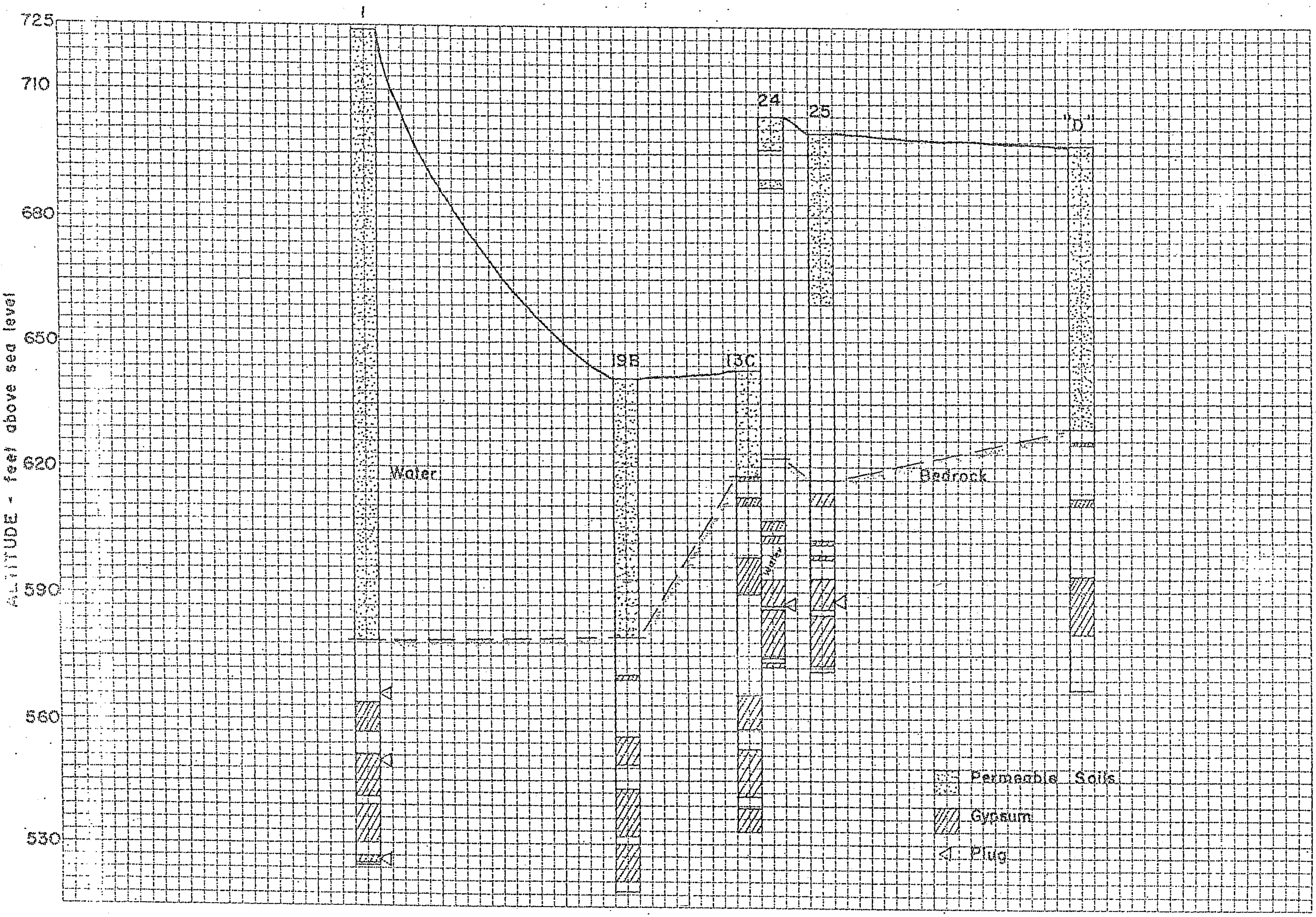

Fig. 4- Section B - B' East - West thru Water Problem Area.