WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: SD-BWI-TI-313

DOCUMENT: Spane, F.A. Jr., March 1986, Preliminary Evaluation of Piezometer Responses at DC-19, DC-20, and DC-22, During Construction of DC-23W. Rockwell Hanford Operations, Richland, WA.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: May 22, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The abstract of the document under review is repeated in its entirety.

"Water-level and pressure responses at reference repository location (RRL) piezometer sites DC-19, -20, and -22 were examined over a four-month period (August through November 1985) to evaluate any effects on baseline monitoring caused by construction activities at DC-23W. During the period of investigation, discernable changes in water level and pressure were observed within five Saddle Mountains piezometers, nine Wanapum piezometers, and four Grande Ronde piezometers at the RRL monitoring facilities. Only changes monitored within the Wanapum Basalt can be definitely correlated with construction activities that occurred at DC-23W

Water-level and pressure changes within Wanapum piezometers can be correlated with two periods of drilling fluid loss that occurred during the drilling of high transmissive zones within the Wanapum Basalt (September 12-15, 1985 and September 30 - October 3, 1985), and groundwater withdrawal during air-lift pumping (October 21-25, 1985) of the composite Wanapum Basalt. Small shifts in water level and pressure exhibited in a number of Saddle Mountains and Grande Ronde piezometers are correlated with seismic

disturbances caused by an earthquake originating in Mexico on September 19, 1985. The factor(s) responsible for small water-level and pressure changes that occurred at several Grande Ronde (i.e., Cohassett) piezometers is not completely understood. Continued baseline monitoring during future borehole construction activities, examination of possible offsite influences, and detailed hydrograph comparisons may provide additional insight as to the cause of these piezometer responses."

Williams and Associates believe that the report under review is an important contribution to understanding the hydrogeology of the RRL and vicinity. The report raises important questions with respect to hydraulic responses measured during the construction of DC-23W. However, the conclusions reached in the report are not fully supported in light of the following problem areas.

The report does not address the apparent lack of hydraulic response to the Mexican earthquake and aftershock in some of the monitored basalt flow tops. The inconsistency in the response between flow tops and within the same flow top at different locations should be addressed.

Data points on the water level hydrographs appear to have been selected arbitrarily. An explanation should be provided explaining why all the daily water level measurements were not used on the hydrographs.

Transducer drift is extremely high in several piezometers. The drift does not appear to be predictable in several cases. This variability of the transducer drift will cause difficulties in interpretating large scale test data.

There are several minor points of contention regarding the manner in which the data are presented in the report under review. Williams and Associates also believe that additional factors may account for a portion of the responses observed in the water level hydrographs for the Grande Ronde piezometers. We basically concur with the findings of Dr. Spane in that the water level responses in the Grande Ronde Basalt formations cannot be attributed conclusively or exclusively to the drilling activities at DC-23W in the Wanapum Basalts.

BRIEF SUMMARY OF DOCUMENT:

The purpose of the report under review is to present a preliminary evaluation of the possible effects of DC-23W construction activities on pressures and water levels observed in

the RRL nested piezometer sites DC-19, -20, and -22. The effects of the contemporaneous Mexican earthquakes also are addressed in the report.

DC-23W is located approximately 1.5 miles north of the RRL, approximately 6 miles north-northwest of DC-19, and approximately 2 miles north-northwest of DC-20. DC-23W is located approximately 3 miles northeast of DC-22. DC-23W is to be an instrumented baseline monitoring borehole completed in the Wanapum Basalts.

Borehole DC-23W was drilled using a bentonite base drilling fluid down to the Roza basalt flow. Only water was used as a drilling fluid from the Roza Flow to the Upper Grande Ronde Basalt (p. 12). The report states that fluid losses were ten times greater when drilling with water than when using the bentonite jell drilling fluid. A summary of drilling fluid losses and fluid production during well development are illustrated on the attached figure 3 from the report under review. It should be noted that on October 3, drilling proceeded 27 feet into the Grande Ronde Basalt Formation. The Grande Ronde portion of the borehole was cemented prior to air lift development of the entire Wanapum Basalt Formation. The average daily fluid loss to the Sentinel Gap, Priest Rapids, Roza, and Ginkgo basalt flows was approximately 250 gpm between September 30 and October 3, 1985 (p. 9). We repeat that fluid losses reported at this rate were for a water base drilling fluid. Water produced from the composite Wanapum averaged approximately 185 gpm from October 21 through October 25, 1985 (p. 9). Injected drilling fluid and groundwater were produced during well development.

The report presents both pressure hydrographs and water level hydrographs. The hydrographs have been corrected for atmospheric pressure fluctuations.

The report addresses observed water level changes in the three major basalt formations (Saddle Mountains, Wanapum, and Grande Ronde). The report states that water level and pressure fluctuations in the Saddle Mountains Basalt are not attributable to any drilling activities at DC-23W (p.19). The Mexican earthquake and its aftershock (September 19 and September 20, 1985) are interpreted to be reflected in some of the data presented for the Saddle Mountains Basalt. An example of earthquake induced changes on water levels is illustrated on the attached figure 5 from the report under review. The figure illustrates a displacement of water levels in the Mabton Interbed at borehole DB-9. The water level was shifted downward by the earthquake.

The report states that water level and pressure declines were observed within the basal Ringold and Mabton Interbed at the DC-

19 and the DC-22 sites during the period September 19-20, 1985. No similar responses were evident for the basal Ringold and Mabton Interbed at the DC-20 site. The report attributes the water level/pressure changes noted as being a response to the Mexican earthquake and aftershock. The report states that the observed water level or pressure changes cannot be attributed to the drilling activities at DC-23W (p. 22).

Hydrographs for the Saddle Mountains Basalt flows do not reflect response to drilling activities at DC-23W (p. 20). The underlying Wanapum Basalt flows do reflect drilling activities at the DC-23W site.

Figure 9, from the report under review, illustrates the classic response to drilling fluid loss and fluid withdrawal from the borehole. This hydrograph is for the Priest Rapids interflow at the DC-20 site. This downhole pressure hydrograph illustrates the pressure build-up due to fluid loss during drilling which dissipates with time after the cessation of drilling fluid loss. The pressure decline created by withdrawing the fluids from the borehole is superimposed upon this pressure decline. The report states that the monitored Priest Rapids interflow and the Sentinel Gap basalt flow top exhibit similar pressure hydrographs at DC-20. The pressure hydrograph for the monitored Gingko horizon exhibits a lesser pressure response to DC-23W activities but they lagged by approximately one-half to one day the response exhibited by the Priest Rapids interflow and the Sentinel Gap flow top (p. 31). The Priest Rapids and Sentinel Gap monitored horizons exhibit nearly identical pressure hydrographs at DC-20. The Gingko pressure hydrograph at DC-20 also shows a subtle response when compared to the response in the Priest Rapids interflow and Sentinel Gap flow top. The pressure hydrographs for DC-19 indicate that the pressure response for the Priest Rapids interflow and the Sentinel Gap flow top are similar. The pressure responses in these units at DC-19 are more subdued than are the pressure responses observed in DC-20 and DC-22. The Gingko pressure hydrograph illustrates a lesser response to the airlift development of DC-23W.

The report presents a "pressure transient response" graph for the Sentinel Gap flow top at DC-19C, -20C, and -22C. The transient response was prepared for the airlift pumping of the composite Wanapum Basalt formation. The hydrograph was plotted on log-log paper; the transient responses are matched to the leaky artesian type curves prepared by Hantush (1960). This analytical solution assumes that water is initially released from storage in the confining unit when the "aquifer" is pumped. The type curve analysis procedure applied to these data indicates that the hydraulic properties of the Sentinel Gap flow top are relatively uniform between points of observation. The report states that although the data for DC-22C cannot be matched uniquely, the

location of the plotted points indicates a larger response than anticipated based on the characteristics exhibited at DC-20C and -22C (p. 47). The report states that the cause of the larger response is unknown.

The report addresses several possible hypotheses for the water level and pressure responses recorded for the Priest Rapids interflow and the Sentinel Gap flow top. These hypotheses include: 1) lack of piezometer isolation, 2) enhanced local vertical hydraulic conductivity, 3) presence of natural, pervasive vertical fracturing, and 4) "existence of a single geohydrologic unit, encompassing the Priest Rapids, Roza, and Sentinel Gap flows" (p. 48).

Each of the preceding hypotheses is discussed in the report. Evidence is supplied that reflects the permeable nature of the Roza flow top at DC-20C. A segment of a caliper log is provided that shows the large borehole diameter created when drilling this flow top. The report states that hydrogeologic features which would allow communication across the basalt flows have not been identified in the geologic investigations or geological surveys on the site. The occurrence of pervasive hydraulic communication across the basalt flows is addressed. This relationship is addressed with respect to analytical simulations of the possible hydrogeologic responses of a pumped and an unpumped aquifer in an ideal situation. The report states that modeling studies will be used to examine the effects of leakage on the hydrogeologic system as envisioned at the site. The report attributes the definition of a "geohydrologic unit" to Maxey (1964) as being "... an aquifer, confining unit, or a combination of aquifers and confining units that compose a framework for a reasonably distinct hydraulic system" (p. 53). The report discusses the probability that the Priest Rapids Interflow and the Sentinel Gap flow top at the three RRL piezometer sites does indeed act as a single geohydraulic unit in an areal sense. The report states that this hypothesis will be tested by conducting controlled well interference tests at each of the RRL piezometer sites.

The report addresses the possible effects of drilling DC-23W and the subsequent construction activities at the site on monitored water levels and pressures in the Grande Ronde Basalts at the RRL piezometer clusters. The data have been corrected for atmospheric pressure fluctuations. Extended hydrographs are included in the report for DC-20, DC-22, and DC-19. These extended hydrographs illustrate the water levels in these boreholes from April 1984 through November 1985. Identifiable water level responses in the Wanapum Basalt piezometers reflect the drilling of borehole DC-23W. Correlation of water level fluctuations in the Rocky Coulee and Cohassett flow tops at DC-20 and in the Cohassett flow top at DC-19 with drilling activities at DC-23W is possible. The report discusses these apparent

responses to construction activities at DC-23 in some detail.

Figure 31 is an expanded water level hydrograph for the monitored Grande Ronde Basalt flow tops at DC-20. The Umtanum flow top exhibits a significant decrease in water level which apparently is coincident with the earthquake in Mexico on September 19, 1985. The abrupt decline in water level is pervasive throughout the period of record on this expanded hydrograph. The report states that hourly downhole pressure readings were evaluated with respect to the seismic disturbances. The supporting figures for this evaluation were not included in the report under review. The report states that no direct association could be found as exhibited at the Mabton Interbed at DC-19D. The report states that "No associated hydrologic response to the seismic event (s) was definitely established within other Grande Ronde piezometer zones" (p. 60). The variability in response was not addressed in the report under review. The report also states that a nearly identical water level response pattern for the Rocky Coulee and Cohassett piezometers at DC-20C suggests a highly communicative condition between the two horizons at the site. It is not known whether this communicative condition is due to insufficient piezometer isolation or due to natural conditions in and among the flow tops.

The report presents an expanded water level hydrograph for the Cohassett flow top at DC-20C (figure 34). This hydrograph is corrected for atmospheric pressure effects and earth tide effects. The report states that the expanded hydrograph illustrates that the shift in water levels occurred between October 24-26, 1985; the shift did not occur between October 18-21, 1985, as suggested by the uncorrected hydrograph. The water level shift is approximately 0.2 ft. The report states that DC-23W construction activities are not reflected completely in this hydrograph. Air-lift pumping the composite Wanapum Basalt flow tops seems to have created a water level decline in the Cohassett flow top. The absence of a corresponding water level increase at DC-20C is not evident during construction activities in which drilling fluid losses occurred (September 29 - October 2, 1985). The report contends that the absence of a recognizable recovery pattern following the water level decline also argues against any significant association with the drilling and construction activities at DC-23W.

An expanded water level hydrograph for the monitored Grande Ronde flow tops at DC-22C is appended to this review as figure 35. The report states that no discernable hydrologic response for these monitored Grande Ronde horizons can be attributed to the construction activities at DC-23W (p. 66).

An expanded water level hydrograph for the monitored Grande Ronde flow tops at DC-19C is appended to this report as figure 36.

Figure 36 illustrates the relatively constant water levels in the Rocky Coulee flow top and in the Umtanum flow top at DC-19C. Water level fluctuations in the Cohassett flow top are subject to further consideration. It should be noted that borehole DC-19 is located farther from DC-23W than is borehole DC-20 or borehole DC-22. The water level hydrograph for the Cohassett flow top was expanded as figure 37; this figure is appended to this review. The report states that the low magnitude water level decline of approximately 0.1 ft. (Sept. 20-24, 1985) appears to have no relationship with construction activities at borehole DC-23W. The report "suggests that there is a possible association of this water level decline with the Mexican earthquakes" discussed earlier (p. 66). The report notes that the minor water level increase reported between October 2 and October 4 may be attributable to the recovery phase following the preceding water level decline. The report also states that the water level decline shown in figure 37 suggests a possible association with air-lift pumping the composite Wanapum Basalt flow tops between October 21 and 25, 1985. The report states that a comparison of the water level declines of figure 37 with figure 34 for the period October 18-28, 1985, within the Cohassett horizon are very similar. The report suggests that the cause of the decline in October 1985 had widespread influence and was not the result of individual piezometer site activities such as pressure probe installation.

The report discusses the pressure and water level responses outlined previously. The report states that piezometers that exhibit changes include the Umtanum, Rocky Coulee, and the Cohassett flow tops at DC-20C and the Cohassett flow top at DC-19C (p. 70). The report states that the water level change reported in the Umtanum flow top at DC-20C appears to be associated with the Mexican earthquake on September 19, 1985. The response registered for the Rocky Coulee flow top is attributed to intercommunication with the Cohassett and Rocky Coulee horizons in the vicinity of DC-20C. The report states that the most significant water level response identified for the Cohassett horizon at DC-19C and DC-20C appears to be associated with airlift pumping of the composite Wanapum Basalt at DC-23W between October 21-25, 1985. The report states that the lack of equivalent response to other construction activities at DC-23W negates the interpretation of an apparent response to airlift pumping. The report states that the absence of a recognizable recovery pattern following the water level decline argues against any significant association.

The report states that significant occurrences of anomalous behavior are occurring in the pressure transducers. The transducers are exhibiting excessive instrument drift, nonlinear trend behavior, and erratic pressure fluctuations (p. 71). The report states that 13 of the 27 piezometers examined exceed

manufacture reported specifications or may complicate analysis of planned hydrologic tests in the RRL area.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

This document is significant to the Waste Management Program because the drilling activities at DC-23W apparently significantly perturbed the water levels in the Wanapum Basalt formation in the vicinity of the RRL. The perturbation facilitated a qualitative evaluation of the responses to fluid withdrawal during development of the DC-23W piezometer. Qualitatively, the response indicates that the basalt flow tops constitute a leaky artesian system with water being derived from storage in the aquitards. This response is noteworthy in that it assists in the predesign of the large-scale hydraulic stress test which will be conducted around the RRL. The qualitative evaluation of the drilling induced perturbations also provides some indication of the extent of vertical isolation of the basalt flow tops at the Hanford site. Vertical isolation is important to consideration of contaminant transport from the RRL.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

We conducted a less than comprehensive literature search and review pertinent to the elastic response of aquifers to seismic events as interpreted at the Hanford site. We believe that this topic should be investigated further.

We do not disagree with the major conclusions drawn from the analysis of the perturbations and drilling activities at borehole DC-23W. We do wish to express several minor concerns regarding the report. Table 2 (p. 19) states that the average daily fluid loss of water for the Sentinel Gap, Priest Rapids, Roza and Gingko Basalt flow tops or interflows was 250 gpm. The report states on page 15 that the average rate of fluid loss was 210-225 gpm. The disparity between the two figures should be clarified.

Hydrographs presented in the report under review have been corrected for barometric effects and in several instances for earth tide effects. The validity of these corrections must be accepted on face value as corroborative evidence for these corrections is not included in the report.

The report states (p. 22) that the Mabton Interbed at DC-19D exhibited a more regular pressure response subsequent to the earthquake than it exhibited prior to the earthquake. The report does not discuss this apparent change in pressure fluctuations

within the Mabton interbed at this site. It is possible that the seismic event altered the transducer response, not the hydrogeologic system. This point is applicable for all borehole sites.

The report attributes the deflections in the continuous water-level measurements (p. 22) to "elastic formation responses to the passage of seismic waves within the earth." The report should state that the lower water levels noted in the Mabton Interbed at borehole DB-9 and in the Umtanum flow top at borehole DC-20C may be due to an increased porosity if these water level changes are related to the seismic events in Mexico.

Figure 24 illustrates the transient pressure responses for the Sentinel Gap flow top at boreholes DC-19C, DC-20C, and DC-22C. Rockwell should place the type curves on the figure to which the data have been matched. It is difficult to envision the relationship of the data to the type curve due to the odd scale at which the figure was reproduced. Figure 24 indicates that B values were determined for boreholes DC-20C and DC-22C. The figure states that no match was obtained for DC-19C. Conversely, page 47 states that a B value of 2.9 was obtained for borehole DC-19C. The report should be consistent.

The report states (p. 48) that "The stress and stress relief associated with drilling can cause additional formational fracturing, which can radiate from the borehole into the surrounding basalt." This fracturing can cause significant problems with interpreting single well test data.

The report states (p. 53) that a time-series analysis conducted by the University of Arizona indicates a high correlation ($R \geq 0.92$) between the Priest Rapids interflow and the Sentinel Gap flow top at all three RRL piezometer sites. The report does not state what type of data were used in the time-series analysis. We suspect that the time-series analysis was conducted on water level data. The report should so-state or explain otherwise.

The report states (p. 60) that no hydrologic response to the Mexican earthquake can be identified for the Grande Ronde piezometer zones other than that for the Umtanum flow top at borehole DC-20C. The report does not discuss the relevance of the absence of hydrogeologic response to the seismic event at the other Grande Ronde piezometer zones and sites. The report should address these differences. One can expect that if one flow top responded to an earthquake then others should respond.

Figures 31, 32, 34, 35, 36, and 37 present water level hydrographs for various monitored flow tops at the site. The data points on these figures seem to have been selected arbitrarily. No explanation is given in the report as to how

these data points were selected. The report states that daily water level measurements were obtained on all horizons. An explanation should be provided as to why only selected data points are shown on the figures.

We believe the discussion of the difficulties encountered with the pressure transducers is worthy of further analysis and discussion by Rockwell. Transducers will be relied upon for obtaining a major portion of the data that will be obtained during the large-scale test. Questions about the reliability of the transducers raises serious concerns about the data that will be collected during the large-scale test. Rockwell Hanford Operations should address the data variability that is being attributed to transducer problems.

The water level responses noted for the Grande Ronde flow tops are of such low magnitude that little substantive analysis can be conducted with respect to their association with drilling activities in the Wanapum Basalt formation at DC-23W. The low magnitude responses and the uncontrolled nature of the fluid losses and the fluid withdrawals at DC-23W preclude any positive statements regarding their association.

We are not convinced that the water level fluctuations monitored in the Grande Ronde basalt flow tops cannot be attributed to construction activities at borehole DC-23W. The absence of any response in the Grande Ronde formation flow tops to fluid losses in the Wanapum formation flow tops may be attributable to unknown causes. Hysteresis in the basalts is a possible confounding factor. Hysteresis represents an unequal pore water pressure response to loading and unloading of an adjacent basalt flow. For example the pressure response in the Grande Ronde Basalt formation might not be the same for an equal pore water pressure increase from drilling fluid injection and a pore water pressure decrease due to air lift pumping. The high in-situ lateral stresses evident at the BWIP site also may play a role in modifying the nature of responses transmitted vertically through the basalt flows. We have investigated these possible responses in a cursory nature but we have not achieved any consensus regarding the possible effects of hysteresis and high in-situ stress on the effects of drilling perturbations. Our opinion is that hysteresis probably is not significant but that it nevertheless should be evaluated as an influencing variable.

The report suggests that the "cause of the decline registered in October 1985 had widespread influence and was not a result of individual piezometer site activities (e.g. pressure probe installation)" (p. 70). This statement reflects an uncertainty that must be clarified before large scale test data can be evaluated adequately.

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Rexin, E.E., Oliver, J., and Prentiss, D., 1962, Seismically-Induced Fluctuations of the Water Level in the Nunn-bush Well in Milwaukee. Bulletin of the Seismological Society of America, vol. 52, no. 1, p. 17-25.

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Vorhis, R.C., 1955, Interpretation of Hydrologic Data Resulting from Earthquakes. Geologische Rundschau, vol. 43, no. 1, p. 47-52.

Vorhis, R.C., 1964, Earthquake Induced Water Level Fluctuations from a Well in Dawson County, Georgia. Bulletin of the Seismological Society of America, vol. 54, no. 4, p. 1023-1133.

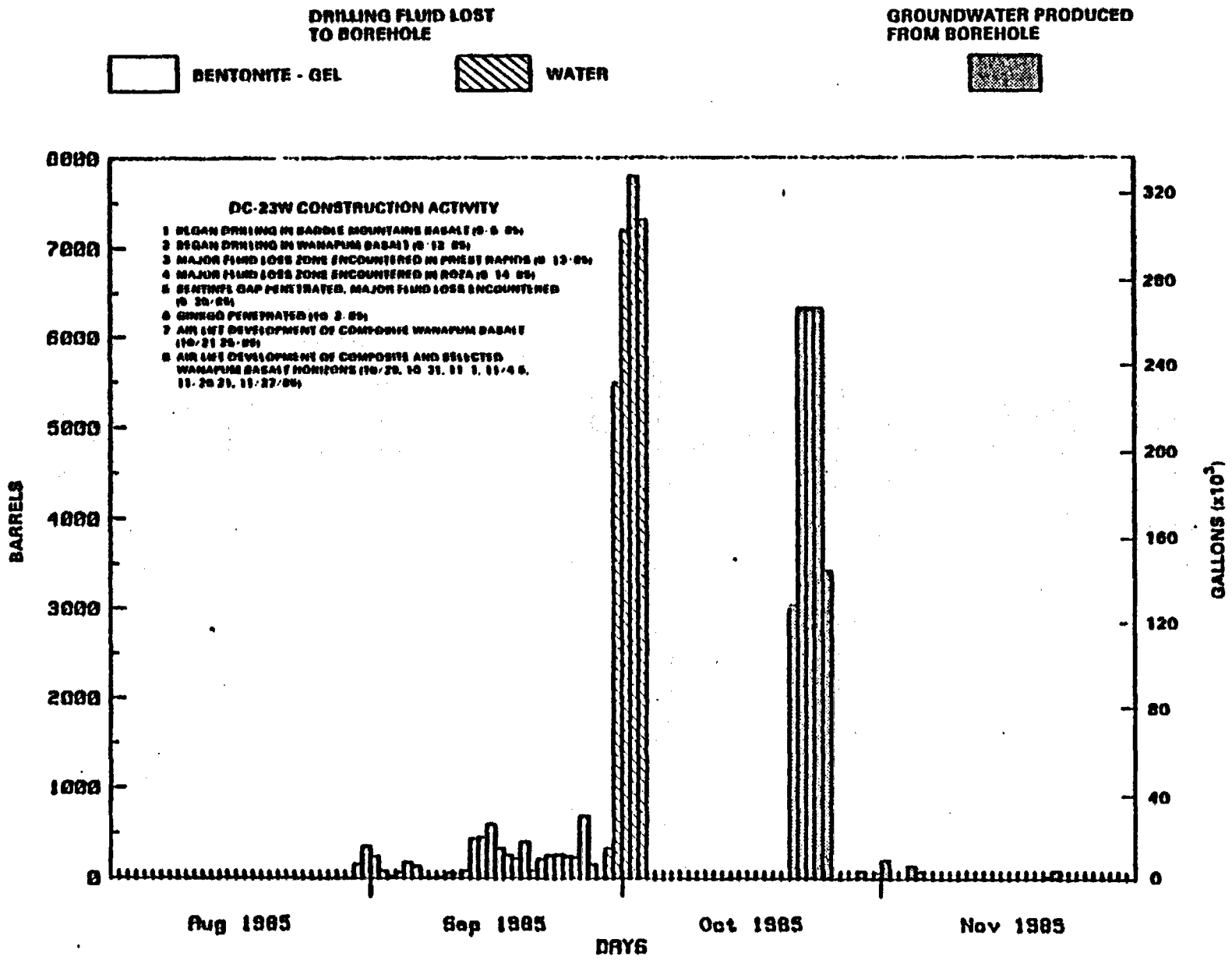

FIGURE 3. Estimated Daily Fluid Loss and Groundwater Production During Drilling and Development Activities at DC-23W.

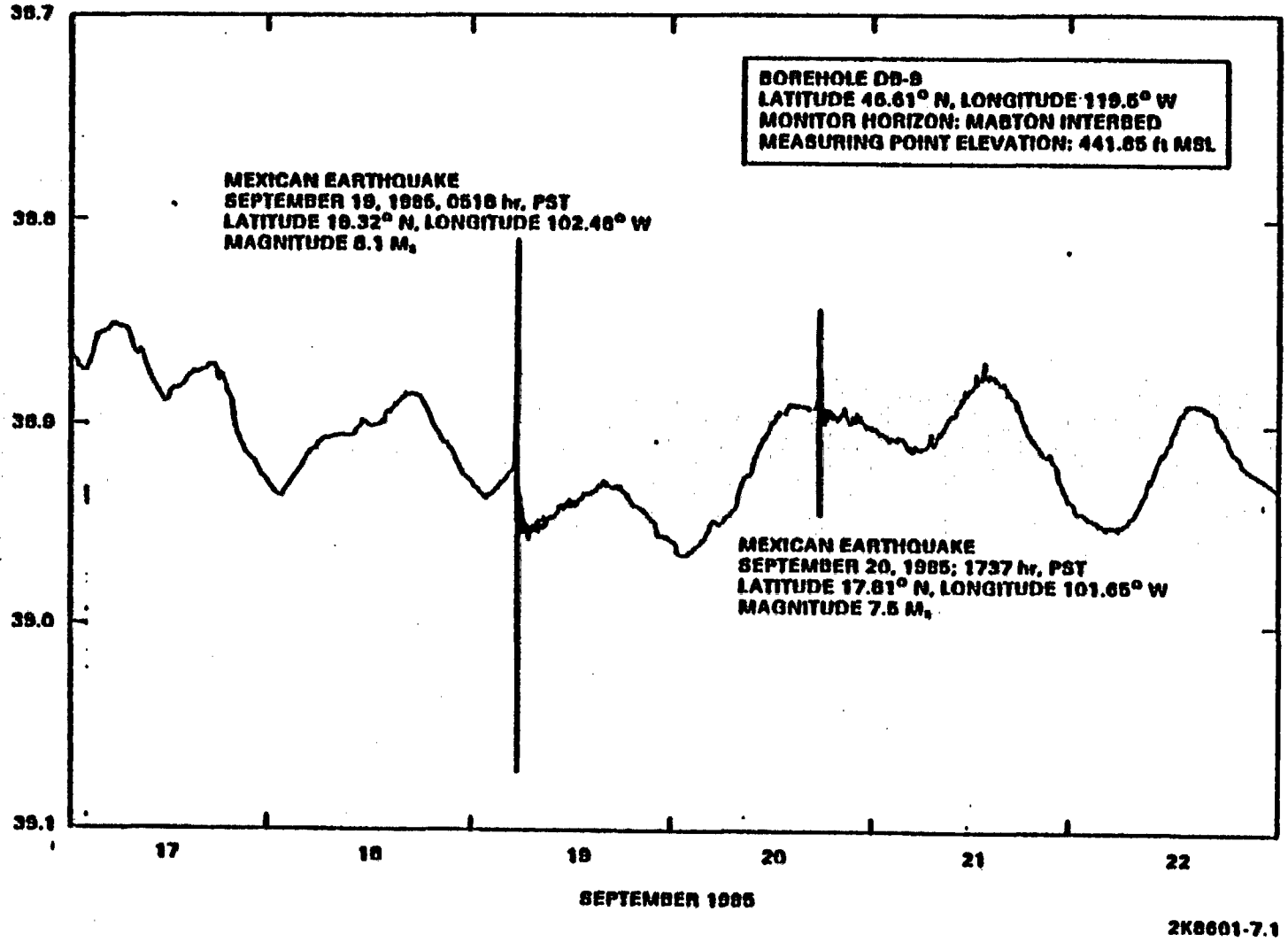

FIGURE 5. Continuous Water-Level Record for the Mabton Interbed at Borehole DB-9, Showing the Transient Response to the Mexican Earthquakes on September 19 and 20, 1985.

DC-20C HYDROGEOLOGIC UNIT: PRIEST RAPIDS INTERFLOW

CONTROL DATUM ELEVATION (ft): 711.31 PROBE SEAT DEPTH (ft): 1617

ADJUSTED TO A CONSTANT ATMOSPHERIC PRESSURE OF 14.347 PSI

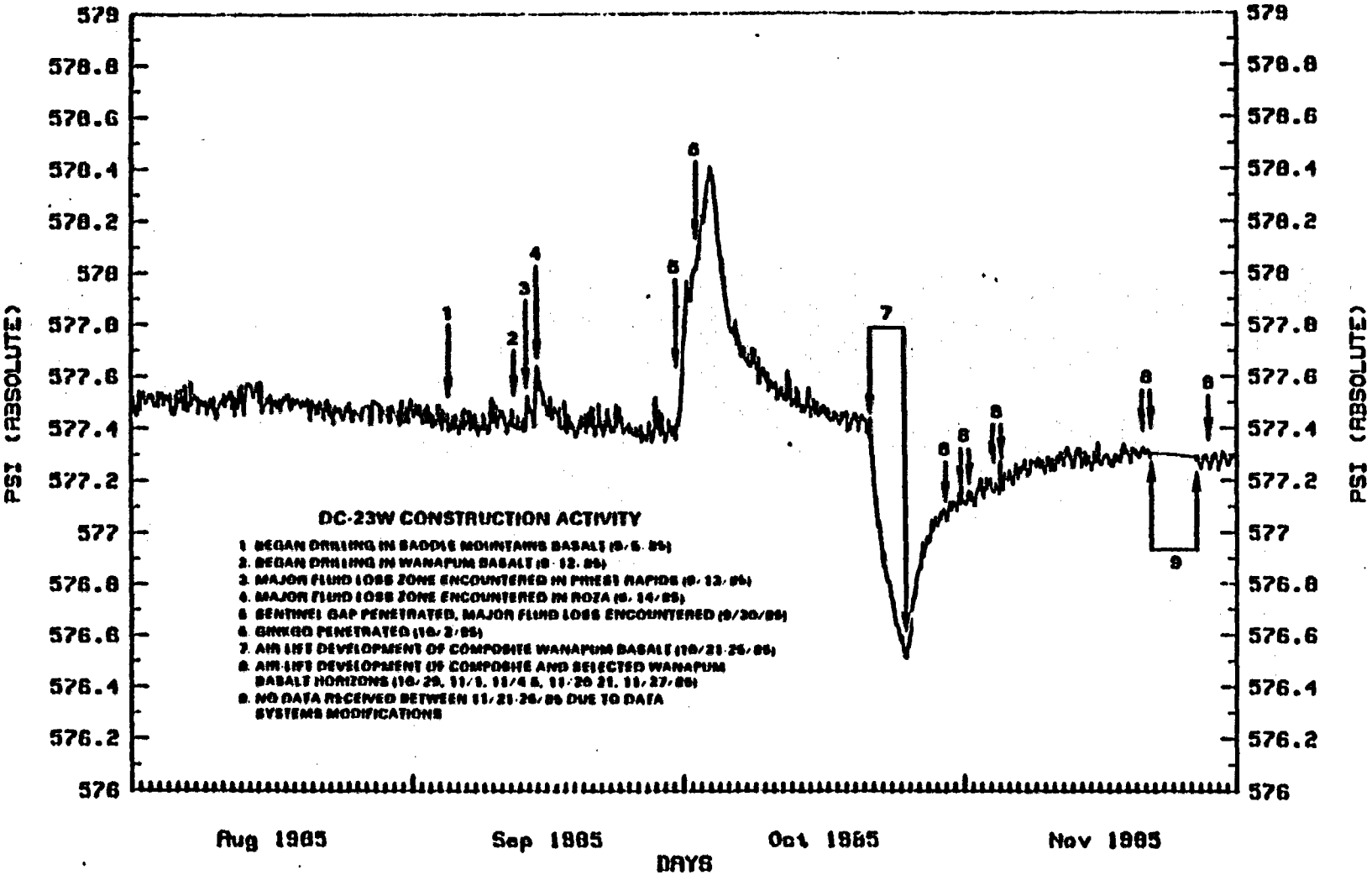

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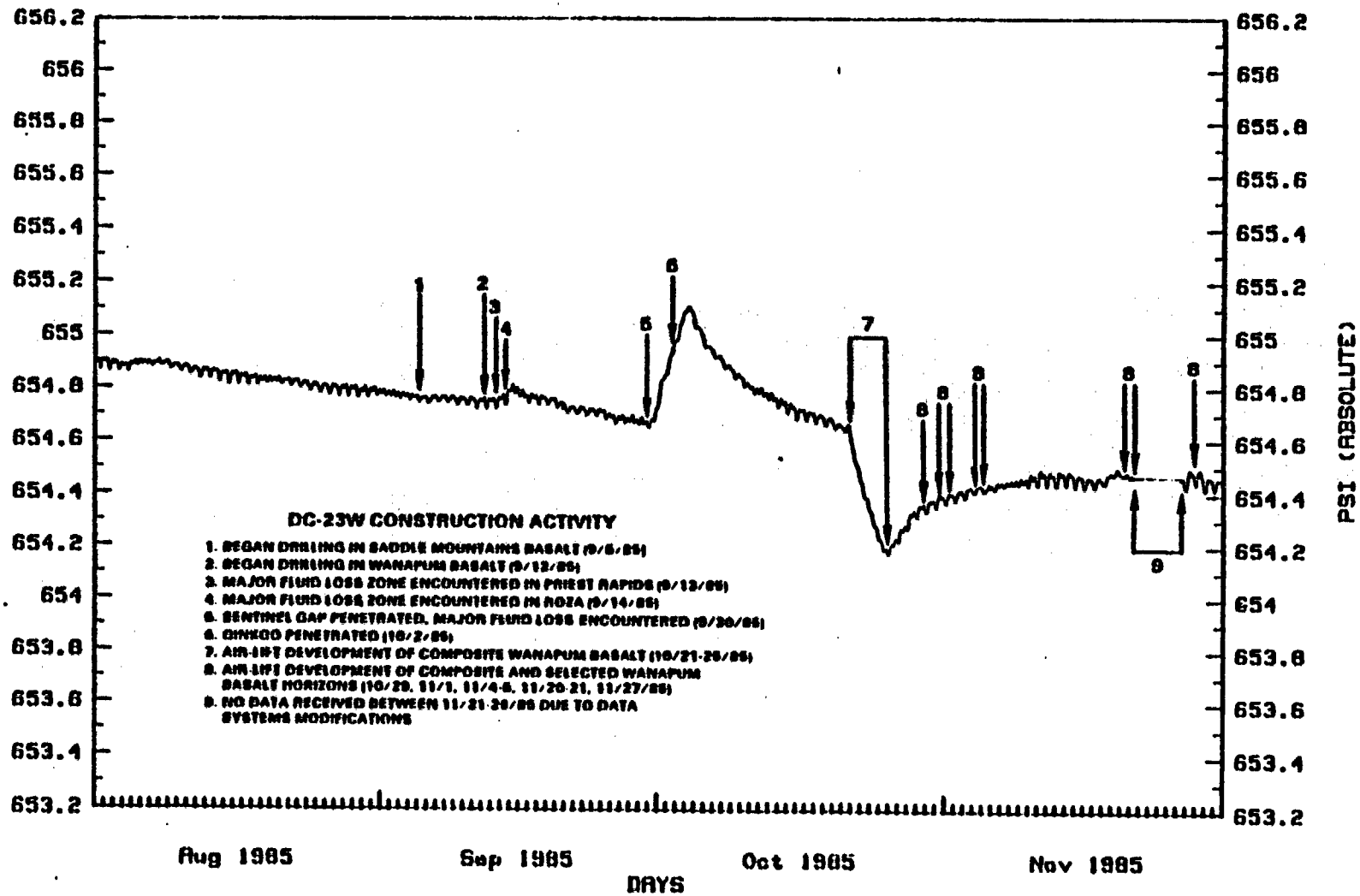
FIGURE 9. Downhole Pressure Hydrograph, DC-20C Priest Rapids Interflow Zone; 8/1 - 11/30/85.

DC-22C HYDROGEOLOGIC UNIT: PRIEST RAPIDS INTERFLOW

CONTROL DATUM ELEVATION (ft): 670.28 PROBE SEAT DEPTH (ft): 1752

ADJUSTED TO A CONSTANT ATMOSPHERIC PRESSURE OF 14.347 PSI



HYDROGRAPH PRODUCED BY
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FIGURE 14. Downhole Pressure Hydrograph, DC-22C Priest Rapids Interflow Zone; 8/1 - 11/30/85.

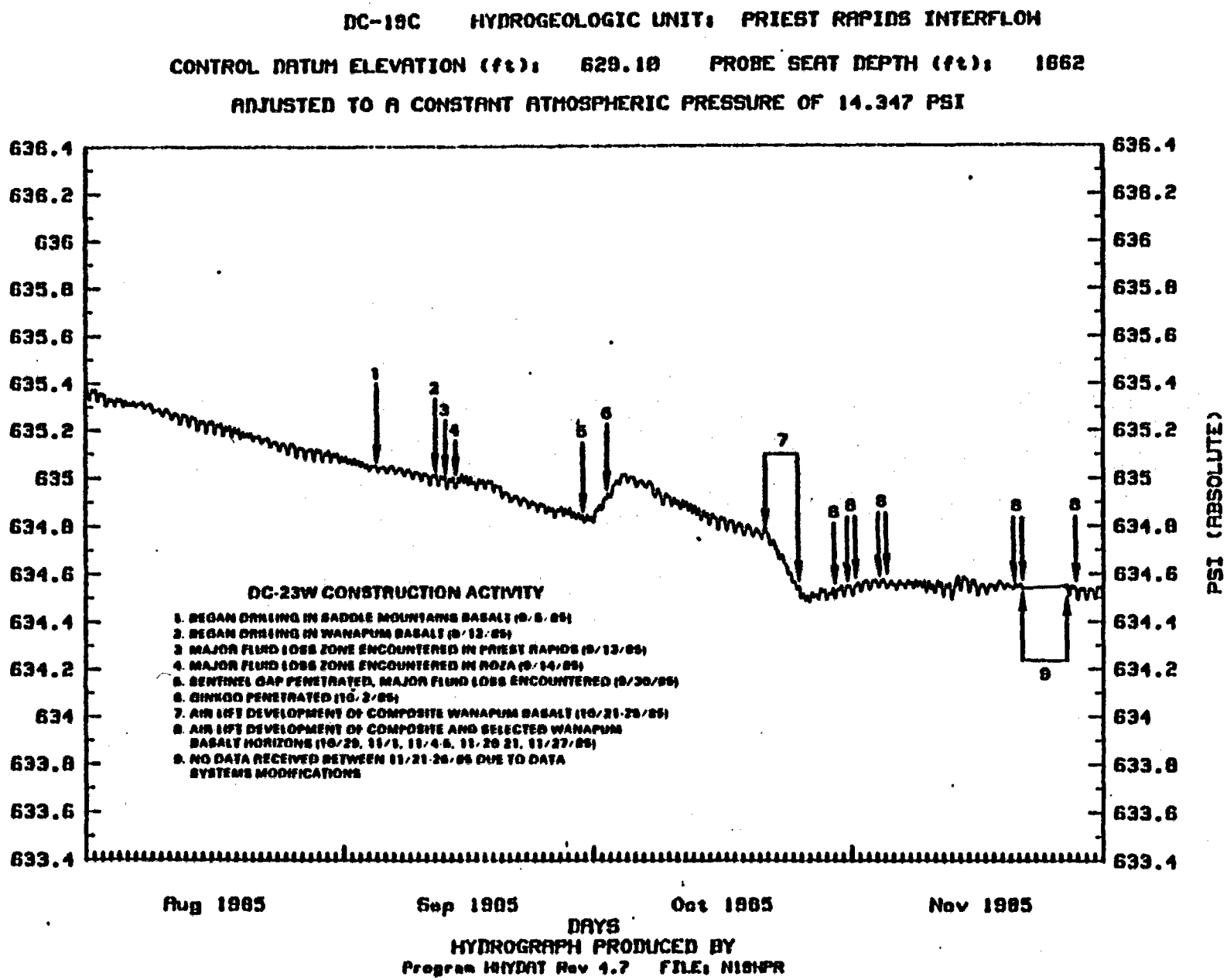

FIGURE 19. Downhole Pressure Hydrograph, DC-19C Priest Rapids Interflow Zone; 8/1 - 11/30/85.

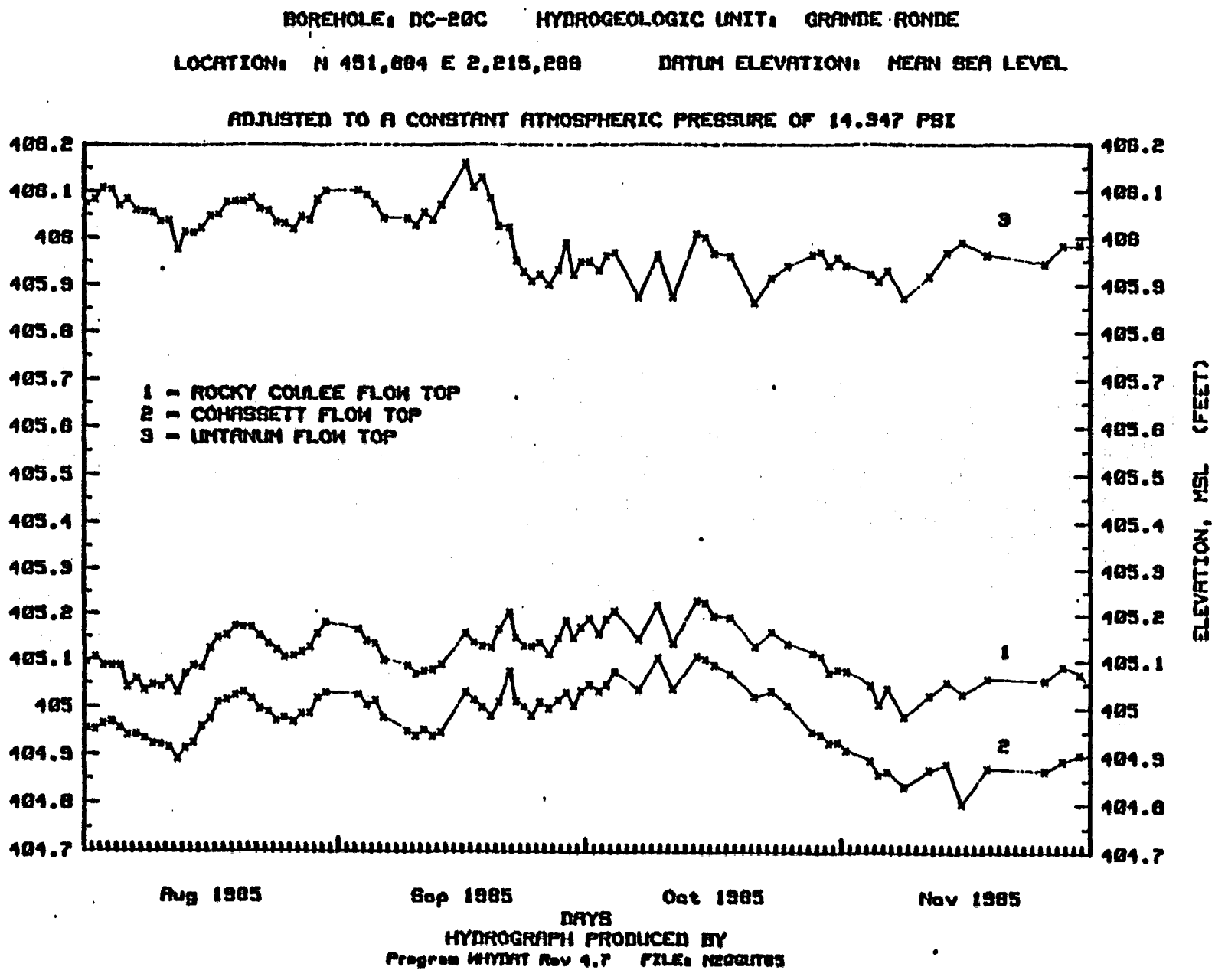

FIGURE 31. Expanded Water-Level Hydrograph for Monitored Grande Ronde Horizons, DC-20C.

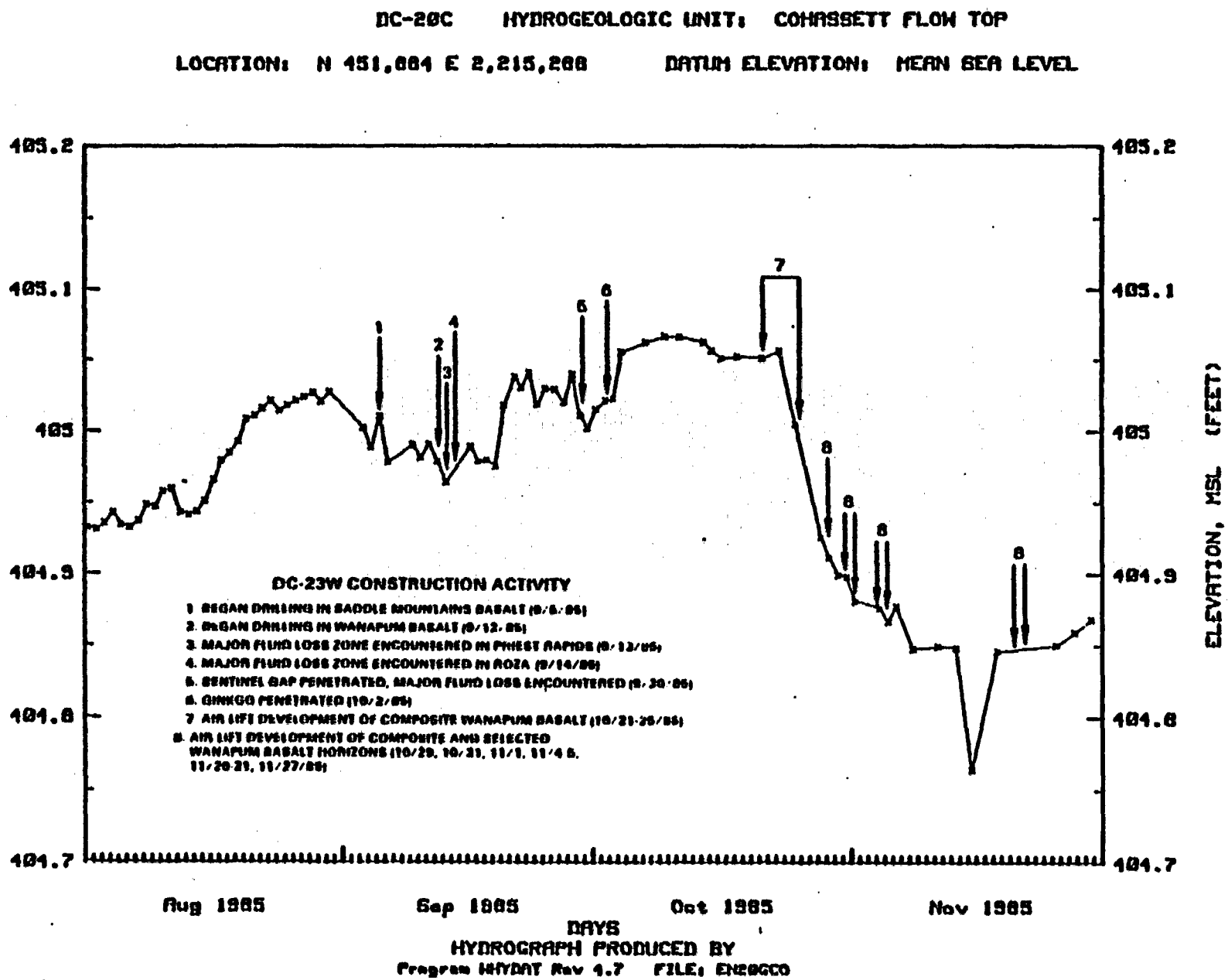

FIGURE 34 Water-Level Hydrograph (Corrected For Atmospheric Pressure and Earth Tide Effects), for the Cohassett Flow Top at DC-20C.

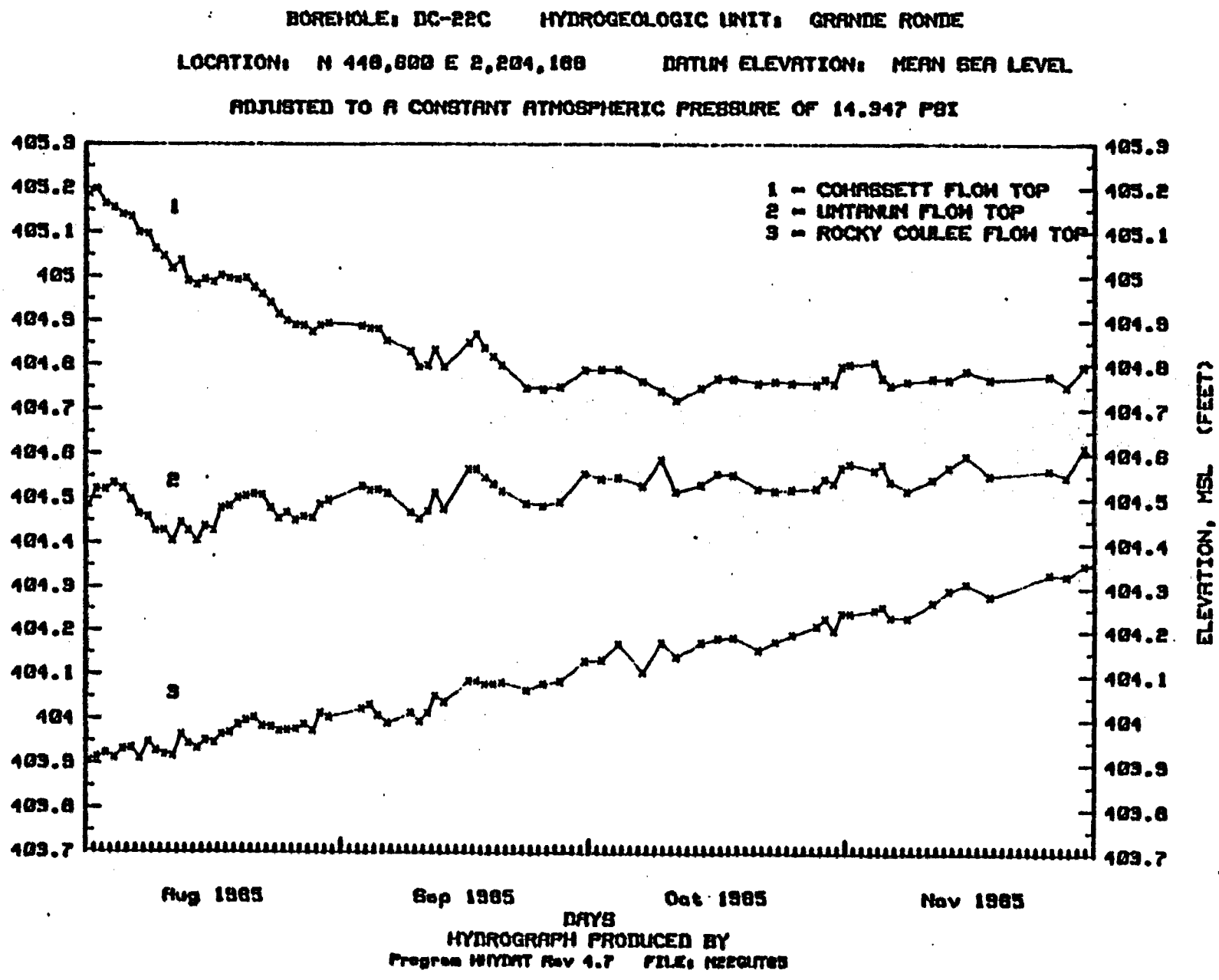

FIGURE 35. Expanded Water-Level Hydrograph for Monitored Grande Ronde Horizons, DC-22C.

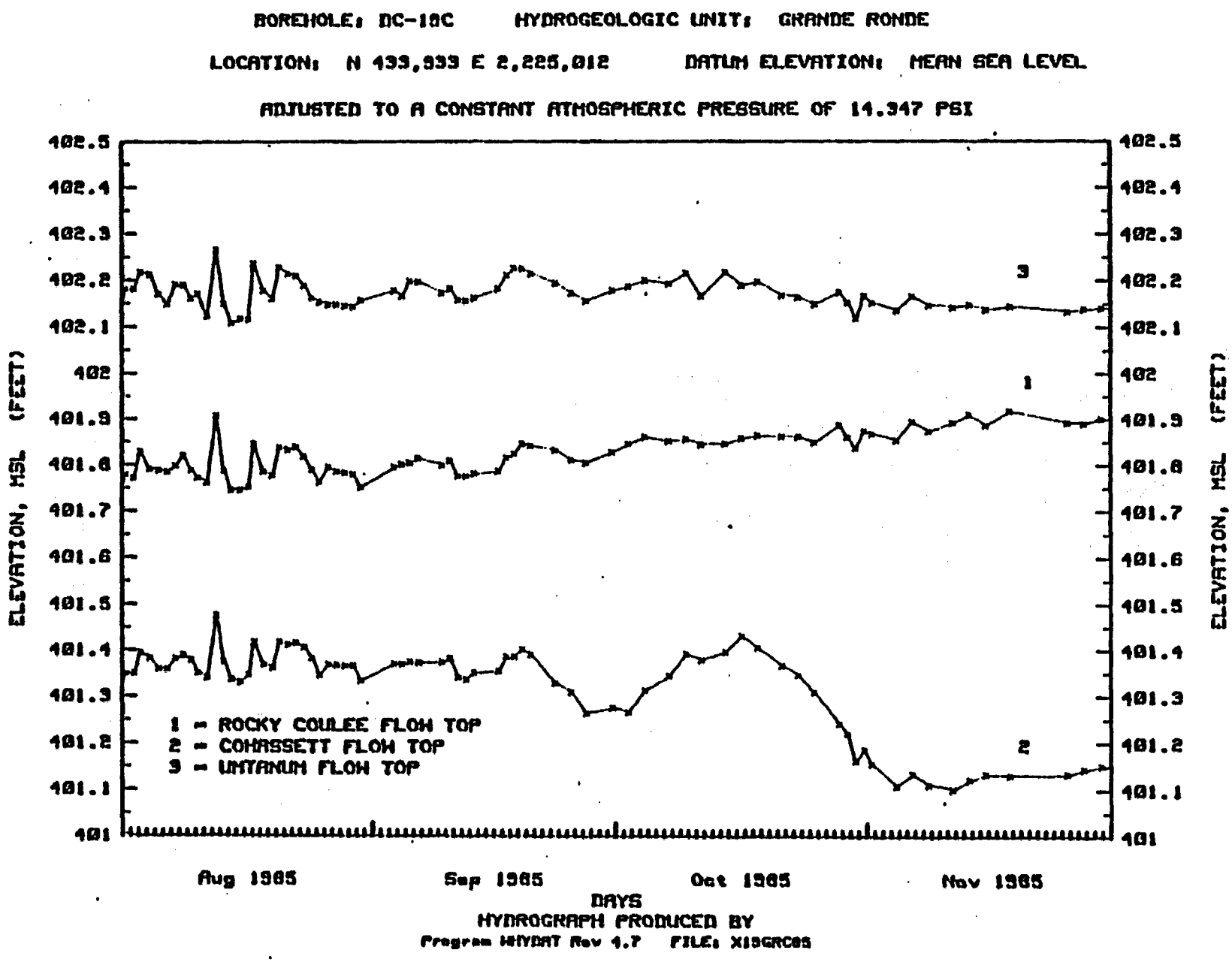

FIGURE 36. Expanded Water-Level Hydrograph for Monitored Grande Ronde Horizons, DC-19C.

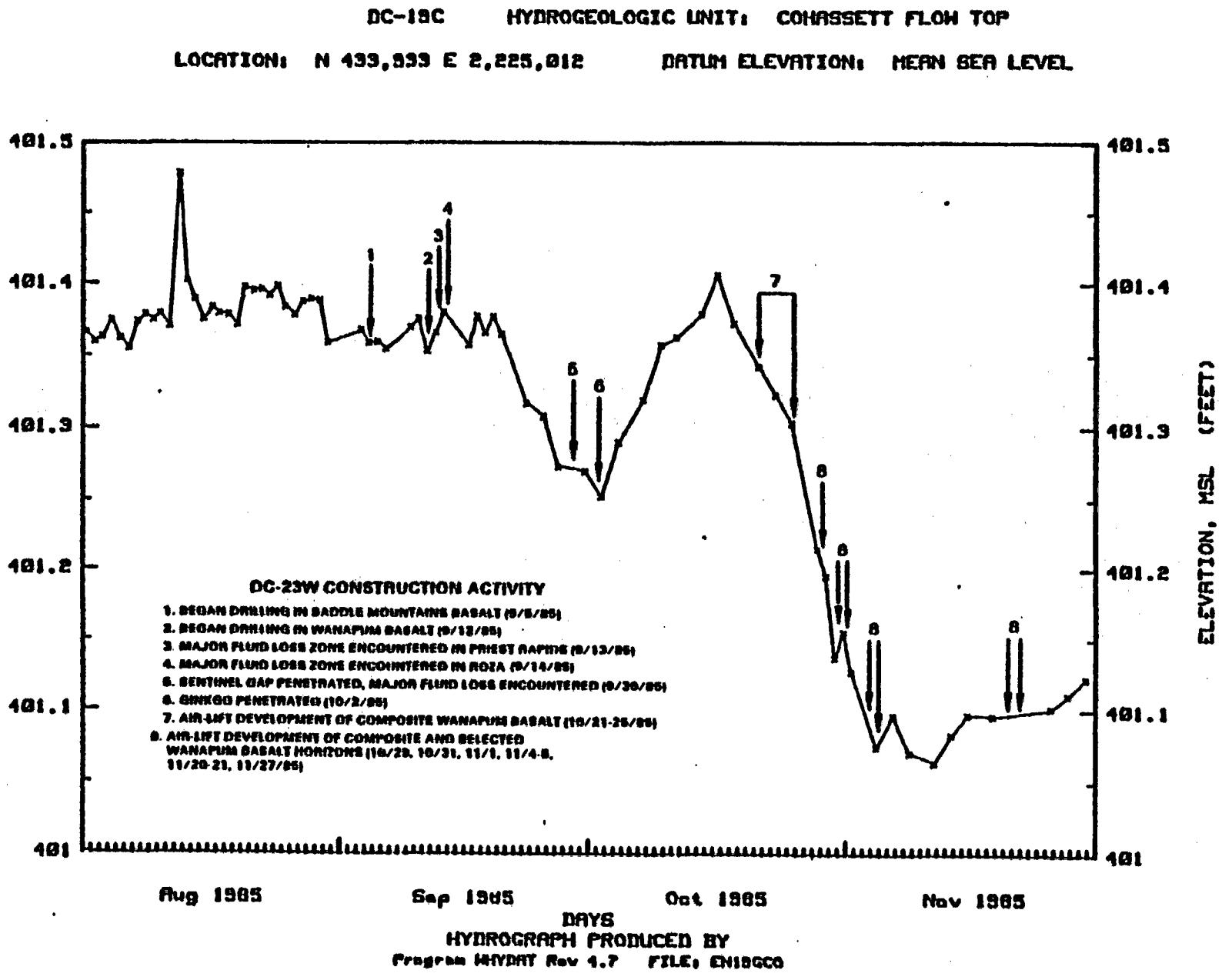

FIGURE 37. Water-Level Hydrograph (Corrected For Atmospheric Pressure and Earth Tide Effects), for the Cohassett Flow Top at DC-19C.