HURRICANE HORTENSE

Impact on Ground Water in Puerto Rico

REGIONAL ESTIMATES OF AQUIFER SPECIFIC YIELD

The USGS maintains a network of ground-water-level observation wells throughout Puerto Rico as part of its cooperative program with Commonwealth of Puerto Rico government agencies. Although the primary use of this network is to assess water-level trends, various other uses of the stage data can be made for hydrologic or hydraulic analysis. During the passage of Hurricane Hortense on September 9-10, 1996, rainfall throughout the area that is underlain by the central part of the north coast limestone aquifer was between 7 and 10 inches within a 24-hour period. In direct response to this rainfall, ground-water levels increased from about 1 to 3 feet within the upper aquifer (or part of the north coast limestone aquifer contained within the Aymamón and Aguada Limestones). This relatively instantaneous slug of aquifer recharge
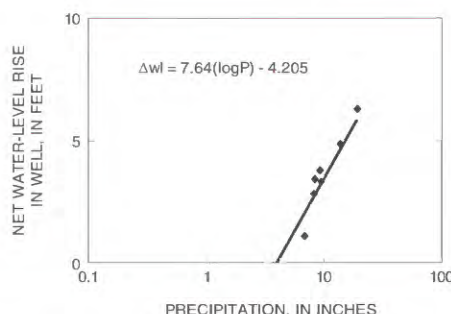

Figure 2. Relation of net water-level rise and precipitation.

provided the opportunity to make regional estimates of the specific yield (Sy) of the aquifer in the area between the Río Grande de Manatí and Río de la Plata (fig. 1). In addition to the ground-water level stage rise data obtained during this intense rainfall event, other data in USGS files from another major rainfall event in December 1981 were used for the analysis. A plot of the data was used to define a best fit line to determine the

x-axis intercept value, which corresponds to the threshold rainfall amount above which the aquifer responds to recharge —thus, the rainfall amount in excess of the intercept value is the amount of aquifer recharge inducing the water-level rise (fig. 2). An estimate of Sy at the observation well can be obtained as follows:

$$Sy=(TR-T)/WR,$$

where

TR is the total rainfall amount for the locality,

T is the threshold rainfall amount above which a water-level rise was registered at the well (or equivalent to 3.6 inches as given by the x-intercept of the best fit line), and

WR is the net water-level rise in equivalent units (inches).

The results obtained indicate that Sy ranges from an average of about 0.25 near Barceloneta (0.22 to 0.28) to 0.13 in areas between Manatí and Toa Baja (0.12 to 0.14). An unexpected result of the analysis is that the Sy at the USGS Sabana Hoyos index monitoring well at Vega Alta is 0.28 with the 1981 data and is 0.14 with the 1996 data. The difference can be the result of a general decline of the water-table surface at Sabana Hoyos, which was about 6 feet higher in 1981. Thus, it is possible that for regional ground-water analysis a Sy value near 0.25 is valid only for parts of the aquifer near the pre-development water table where typically a high zone of dissolution exists. Once aquifer development lowers the water table below this zone a more appropriate estimate of Sy for the upper aquifer is 0.10.
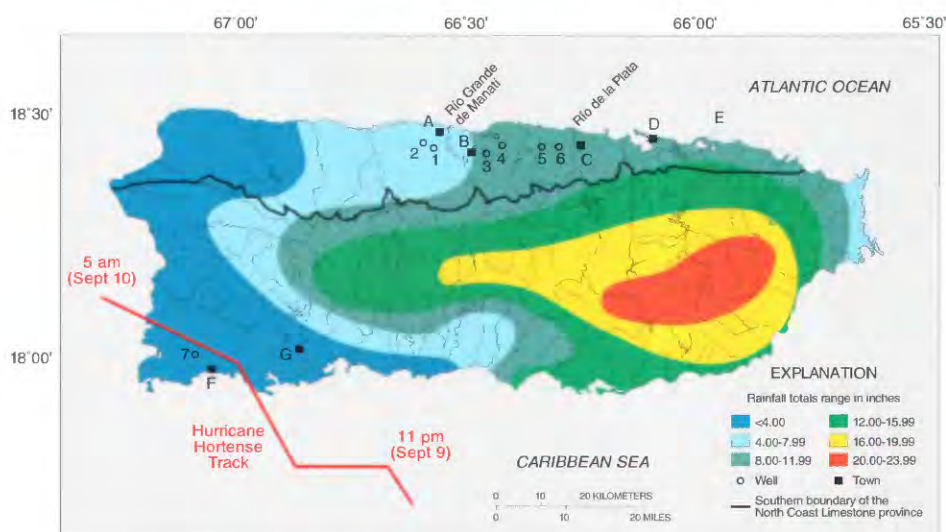

Figure 1. National Weather Service 24-hour rainfall distribution in Puerto Rico for Hurricane Hortense, September 9-10, 1996. Place names are: A, Barceloneta; B, Manatí; C, Toa Baja; D, San Juan; E, Luis Muñoz Marín International Airport; F, La Parguera, and; G, Yauco. Well names are: 1, Lederle; 2, Tiburones #1; 3, Coto Sur #7; 4, Tortuguero TW#3; 5, Sabana Hoyos; 6, Higuillar #4, and; 7 Pozo Vivoni.

USE OF WATER-LEVEL DATA TO ESTIMATE BAROMETRIC PRESSURE IN THE EYE OF HURRICANE HORTENSE DURING LANDFALL IN SOUTHWESTERN PUERTO RICO

An indirect estimate of the minimum barometric pressure of Hurricane Hortense as it passed through southwestern Puerto Rico was made by correlating daily water-level fluctuations at the USGS observation well at Pozo Vivoni in the Lajas valley (18°01′32″N; 67°03′38″W) with daily barometric pressure observations. By correlating water-level changes in the well with barometric pressure, it is possible to calculate the "barometric efficiency" (BE) of the well, given as:

$$BE=(\Delta wl/\Delta bp)100,$$

where

Δwl corresponds to the water-level change in the well, and

Δbp corresponds to the barometric pressure change calculated in equivalent units of feet of water (1.13 feet of water is equivalent to a barometric pressure of 1.0 inch of mercury).

The barometric efficiency of the well was calculated using barometric pressure data obtained at the National Weather Service station at the Luis Muñoz Marín International Airport in San Juan several days prior to and after the passage of

Table 1. Storm strength and barometric pressure

Safir-Simpson Scale	Category	Pressure (mb)
Depression	TD	-----
Tropical Storm	TS	-----
Hurricane	1	> 980
Hurricane	2	965-980
Hurricane	3	945-964
Hurricane	4	920-944
Hurricane	5	< 920

Hurricane Hortense (fig. 3). The barometric efficiency of the well ranged from 38 percent prior to the hurricane to 88.5 percent calculated for September 13-14, 1996. The increase in barometric efficiency may be related to the effect of rainfall on the clayey soils which constitute the confining bed of the local aquifer, thus forming a more effective seal. Water-level fluctuations at the Pozo Vivoni observation well virtually followed the daily variation in barometric pressure until September 8, 1996. Movement of the hurricane toward southwestern Puerto Rico is evident in the water-level response at Pozo Vivoni which reversed its trend at 2215 hours on September 9 at a stage of 39.98 feet below land surface datum and peaked at 0300 hours on September 10 at a stage of 39.71 feet. The barometric efficiency at peak stage was calculated as 59 percent (average of 39 percent on September 8 and 79 percent on September 12). A water-level difference of 0.27 foot at the well is equivalent to a barometric change of 0.27/0.59 or 0.46 foot of water. This is

equivalent to a pressure difference of 0.41 inch of mercury (in Hg). This difference subtracted from the average of the minimum barometric pressure readings at San Juan of 29.79 in Hg (992 millibars) on September 7 and 29.75 in Hg on September 8, which corresponds approximately to the maximum water levels at the well on the same days, results in a calculated minimum pressure of 29.36 in Hg in the eye of Hurricane Hortense as it crossed the Lajas valley. The minimum barometric pressure reading estimated by the National Weather Service for Hurricane Hortense during its passage through southwestern Puerto Rico was 29.29 in Hg (989 millibars). Actual barometric pressure readings reported during the passage of Hurricane Hortense were 29.58 in Hg (999 millibars) at La Parguera (about 3.6 miles south of the center of the eye) and 29.78 in Hg (1005.6 millibars) at Yauco (about 3 miles east of the center of the eye).

The water-level response at the Pozo Vivoni observation well demonstrates a seldom considered potential threat related to hurricanes making landfall. In addition to torrential rainfall, flooding, and high winds, hurricanes which make landfall could be the "catalyst" for triggering landslides as a result of a relational sudden upward and lateral displacement of ground water in direct response to the lowered atmospheric pressure. This potential threat becomes more critical with stronger hurricanes (table 1) and if the local hydrogeologic conditions favor the presence of ground water in sloping terrain under confined conditions.
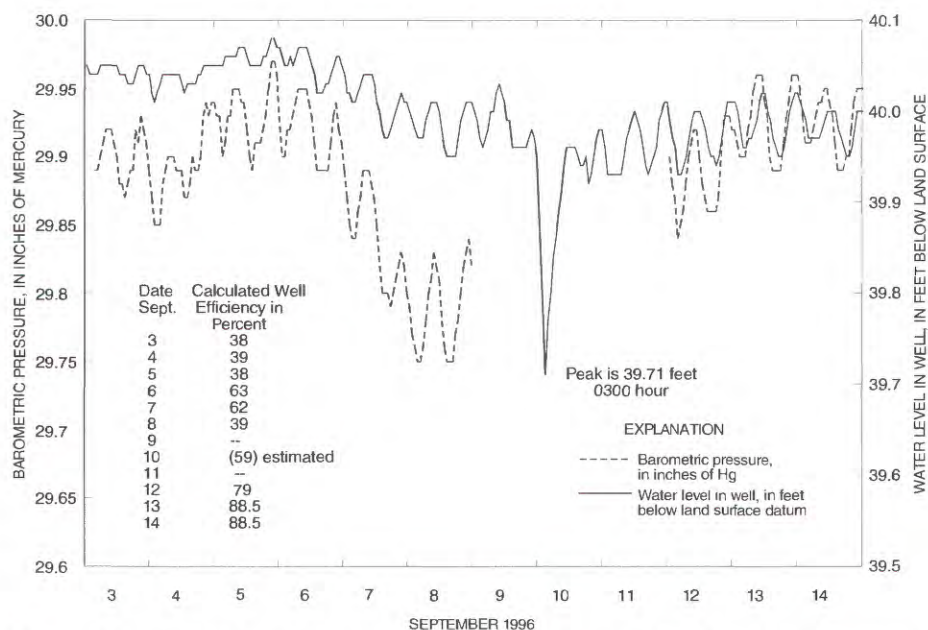
—Fernando Gómez-Gómez

Date Sept.	Calculated Well Efficiency in Percent
3	38
4	39
5	38
6	63
7	62
8	39
9	--
10	(59) estimated
11	--
12	79
13	88.5
14	88.5

Peak is 39.71 feet 0300 hour

EXPLANATION

----- Barometric pressure, in inches of Hg

——— Water level in well, in feet below land surface datum

Figure 3. Recorded water-level trend at Pozo Vivoni observation well in the Lajas valley and its relation to daily barometric pressure variations as recorded at the National Weather Service station in San Juan, Puerto Rico.