Article 169

HYDROGEOLOGY OF THE SANTIAGO AREA, CHILE

By WILLIAM W. DOYEL, ROBERT J. DINGMAN, and OCTAVIO CASTILLO U.,[1]
Washington, D.C., Lawrence, Kans., and Santiago, Chile

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Abstract.—Wells tapping unconsolidated valley fill in the Valle Central supply a large part of the water needs of Santiago. The east side of the valley is underlain by unconfined deposits that yield hard water whose mineral content increases westward in the direction of ground-water flow. Flowing wells on the west side of the valley tap a confined aquifer that yields bicarbonate water of lower mineral content and hardness.

The Santiago area is a part of the Cuenca de Santiago (Santiago basin), the northernmost portion of the great Valle Central (Central Valley) of Chile. The Valle Central lies between the snow-capped Cordillera de los Andes and the lower Cordillera de la Costa (Coastal Range) and extends from the Cuesta de Chacabuco southward to Puerto Montt (fig. 169.1). The many streams that discharge into the Valle Central from the Cordillera de los Andes are used extensively for irrigation and, in the Santiago area, for a part of the water supply of the city. Santiago, with a population of 2,093,000 in 1961, uses approximately 8.0 cubic meters per second of water, 40 percent (3.2 m^3/sec) of which is ground water. Approximately one-fourth of the ground water is obtained from a system of collection galleries in the Vitacura area (fig. 169.2); the remainder is obtained from 339 privately and publicly owned wells that range in depth from 12.6 to 236 m (Castillo and others 1963). The ground water is used for public water supply (74 percent), industry (23 percent), and irrigation (3 percent).

The Valle Central is the topographic expression of a great north-trending graben that separates the Cordillera de los Andes from the geologically older Cordillera de la Costa (W. D. Carter, written communication, 1962). Although the geologic age of ash-flow deposits in similar structural valleys in northern Chile indicates that downwarping in those valleys occurred in the early or middle Tertiary (Dingman, 1963), the major downward movement in the Valle Central probably occurred near the end of the Tertiary. The total thickness of unconsolidated sediments in the Cuenca de Santiago is not known because the few wells that completely penetrate the fill are located near rock outcrops. As the bedrock was subjected to erosion and tectonism after formation of the graben, its surface is characterized by high relief; Cerro Santa Lucia and Cerro Renca are the tops of bedrock hills whose lower slopes have been buried beneath valley fill. A gravity survey made by Edgar Kausel (written communication, 1960) showed the maximum depth to bedrock to be between 300 and 500 m, but until proved by test drilling these depths must be considered only approximate. In 1962, the first of a series of deep wells was being drilled in Santiago to explore for deeper aquifers and to determine the thickness of the fill.

The surficial deposits in the basin are colluvial, fluvial, and fluvioglacial materials of Quaternary age. Some unconsolidated deposits in the vicinity of Santiago, which were described as glacial moraines by Brüggen (1950), Karzulovic (1958), and others, have since been examined by R. F. Flint, R. W. Lemke, Ernest Dobrovolny, Kenneth Segerstrom (Art. 152), and the authors, all of whom agree that the deposits were laid down by mudflows as a relatively thin slurry. At present, ground-water supplies are obtained from fluvial materials, possibly valley-train deposits, consisting of interconnected lenses of highly permeable sand and gravel interbedded with thick layers of clay-rich mudflows of low permeability. Most of the drilled

[1] Geologist, Instituto de Investigaciónes Geológicas de Chile.

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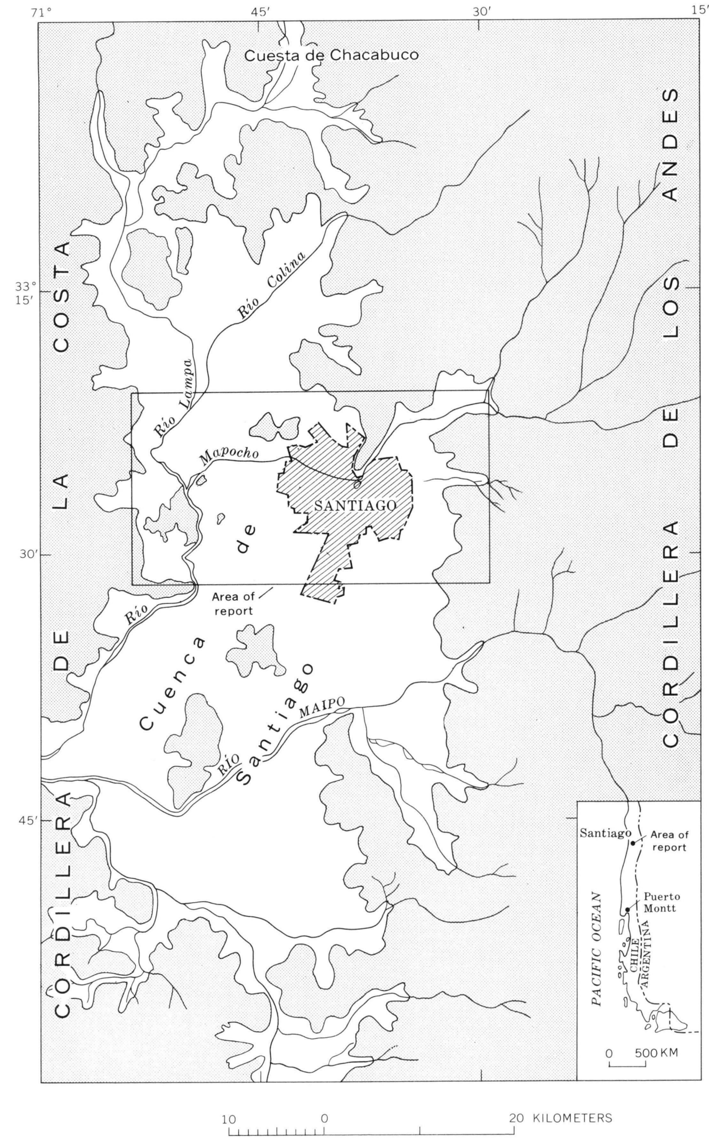

Figure 169.1—Map of the Santiago area, Chile.

wells in the Santiago area produce ground water from depths of 50 to 100 m.

The character of the deeper unconsolidated sediments in the valley is not known; they probably are of continental origin and consist of detrital material derived chiefly from erosion of the Cordillera de los Andes and, to a lesser extent, from erosion of the Cordillera de la Costa. The deeper deposits may be largely of lacustrine origin. Approximately 50 kilometers north of Santiago, the Valle Central is terminated by bedrock hills that rise 200 m or more above the present valley floor. About 50 km south of Santiago is a bedrock hill that does not completely close the present valley but marks the southern end of Cuenca de Santiago and may have formed a barrier behind which a lake may have formed during Pleistocene time.

Flowing wells with yields of up to 200 liters per second have been obtained from deltaic sediments that were deposited in a large glacial lake formed by glacial damming in the San Carlos area of the Valle Central, 300 km south of Santiago. It is conceivable that, during one of the Pleistocene glacial stages, similar ice tongues may have extended into the Cuenca de Santiago, blocking the drainage and forming a glacial lake. Sediments deposited in such a lake may have formed an areally extensive aquifer, which would be in contrast to the lenticular, fluvial deposits which now are the source of ground water for Santiago.

At present almost all the sediments being deposited in the Valle Central are derived from the Cordillera de los Andes, where heavy precipitation and steep gradients combine to produce rapid erosion. The Cordillera de la Costa has a much slower rate of erosion because the rainfall is less and the gradients are gentler. Colluvium and some alluvial sediments derived from the Cordillera de la Costa are present, however, along the western side of the valley.

Ground water presently used in and near Santiago is obtained from an unconfined aquifer in which the water table slopes generally southwestward. The average hydraulic gradient is about 10 m/km in the eastern part of Santiago but decreases to about 3 m/km in the southwestern part of the city. Although infiltrating rainfall and irrigation water are sources of some recharge in the central part of the basin, the principal source of recharge is runoff from the west slope of the Cordillera de los Andes. The Río Colina and Río Lampa in the northern part of the basin, the Río Mapocho, which flows through Santiago, and the Río Maipo, approximately 25 km south of Santiago, contribute a large percentage of the recharge along the eastern side, as shown by the slope of the water table away from those rivers (Castillo and others, 1963). The remainder of the recharge infiltrates through the alluvial and colluvial sediments that lap up onto the flanks of the Andean foothills.

Because the more permeable water-bearing materials are lenticular or narrowly enlongate, nearby wells may penetrate different bodies of water-bearing material; however, comparable water levels and similar responses to ground-water withdrawals demonstrate that the principal aquifer is hydraulically continuous throughout the central and eastern parts of the area. Perched bodies of ground water are found near the Río Mapocho as a result of the lenticularity of the sediments and the relative impermeability of the underlying beds.

Available information is insufficient to determine the area or areas of ground-water discharge. The relation of the streams in the central part of the Santiago

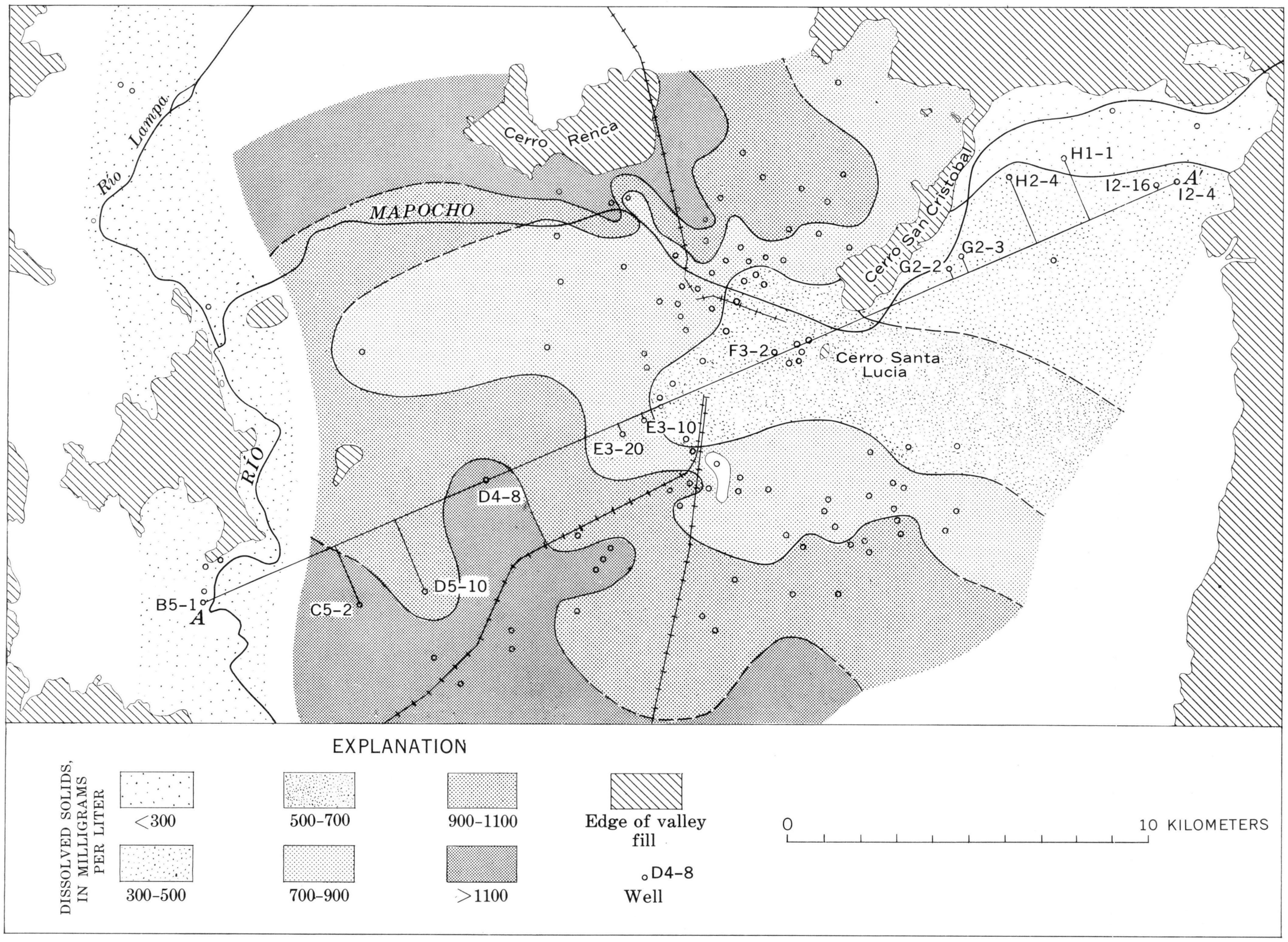

FIGURE 169.2.—Map showing dissolved-solids content in ground water of the Santiago area, Chile. Analyses made in the laboratory of the Instituto de Investigaciones Geológicas de Chile in 1960–61.

area to the water table has not been studied, nor are data available regarding the movement of ground water south of the report area. The Río Mapocho, however, probably serves as a ground-water drain in the western part of the basin.

The relatively few wells drilled along the western side of the Cuenca de Santiago are flowing artesian wells. Although evidence of a geological separation, such as might result from faulting, is lacking, the difference in the chemical quality and temperature between the water from the flowing wells in the western part and from the water-table wells in the central and eastern part of the area indicates the existence of some sort of barrier, either geologic or hydraulic, the nature of which is not yet understood.

Figure 169.2 shows the distribution of dissolved solids in the Santiago area, based on analyses reported by Castillo and others (1963). The ground water has a low dissolved-solids content, 200–300 milligrams per liter, near the Río Mapocho in the eastern part of the area. The dissolved-solids content increases in the direction of ground-water movement to as much as 700 mg/l in the central part of the area and to more than 1,000 mg/l to the southwest. The dissolved-solids content of water from flowing wells along the western side of the basin, however, is less than 300 mg/l. As shown in figures 169.2 and 169.3, the change is rather abrupt from the more highly mineralized water yielded by wells tapping the unconfined aquifer to the east.

The hardness of the water presents the same general picture as the dissolved-solids content. Close to the Rió Mapocho in the eastern section of Santiago the hardness is relatively low, less than 400 mg/l (computed as $CaCO_3$), but it increases to nearly 800 mg/l southwestward. However, the water from flowing wells on the western side of the basin has a hardness of less than 200 mg/l. Moreover, the water from flowing wells on the west side of the basin is characterized by a higher proportion of sodium and a lower proportion of sulfate

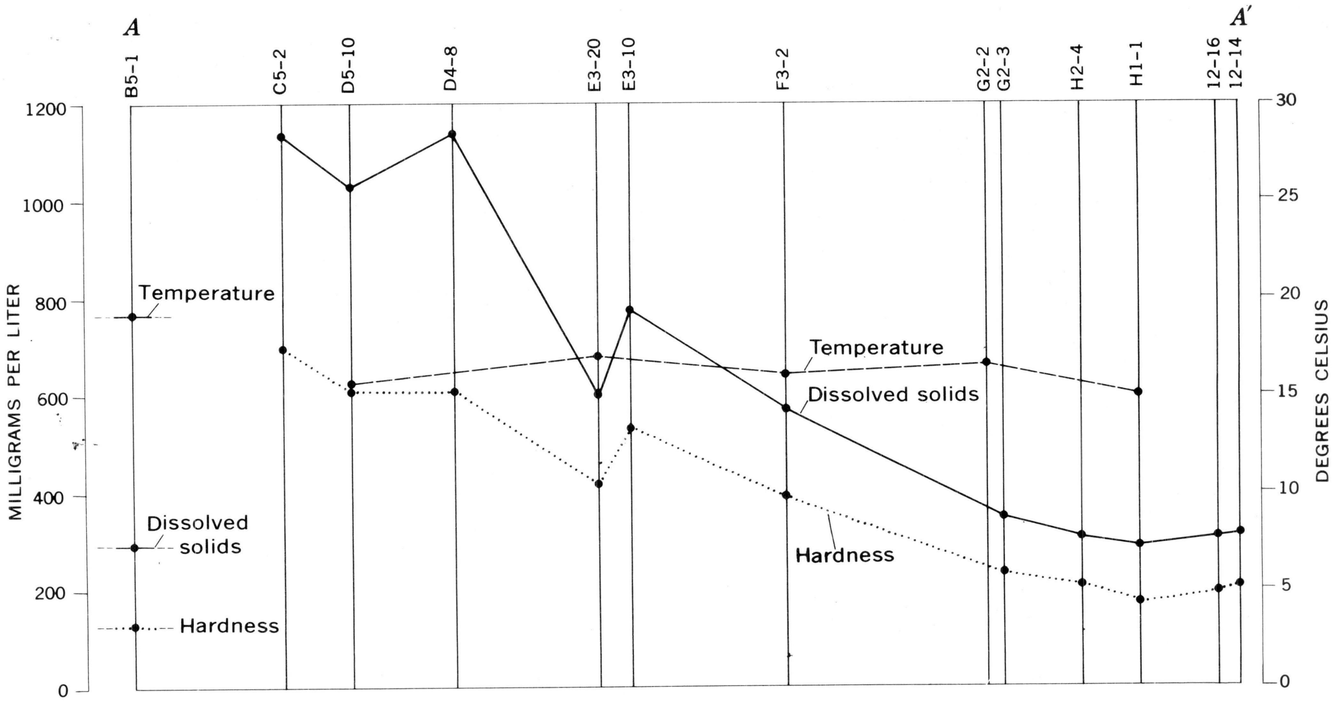

FIGURE 169.3.—Changes in dissolved-solids content, hardness, and temperature of ground water along line *A–A′* (fig. 169.2).

and chloride as compared to the water from wells east of the Rió Mapocho. The low proportion of sulfate and chloride is reflected in the noncarbonate hardness, which commonly is very low in the well water of the west side of the basin. These differences in chemical quality suggest that there is little or no interconnection between the unconfined aquifers of the east and central parts of the area and the confined aquifers tapped in the western part.

The problem of the marked differences in water quality cannot be resolved on the basis of geologic information now available. The differences may be due to geologic barriers such as faults or facies changes. On the other hand, the artesian water of the west side may be characteristic of a confined aquifer that passes beneath the unconfined aquifers to the east. Should such a deeper aquifer be present it would be of considerable economic importance to the area.

Additional geological and hydrological data are necessary to define the control mechanism of the ground-water system in the Cuenca de Santiago, particularly the separation between the artesian and nonartesian waters. The test-drilling program now in progress (1963), as well as the continuing investigations by the Instituto de Investigaciones Geológicas de Chile, should provide sufficient information for a better understanding of ground-water conditions and for a better utilization of ground-water resources.

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