Figure 1. A view of the world-famous Number 6 Hole of the Mauna Lani Golf Course, island of Hawaii.

Water . . . The Limiting Factor for Golf Course Development in Hawaii

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COMMON MENTAL images of Hawaii include lush tropical rain forests, rainbows, waterfalls, and exotic tropical flowering plants. While these are all certainly part of Hawaii, the availability of adequate high-quality irrigation water is the limiting factor for development of golf courses in many parts of the state.

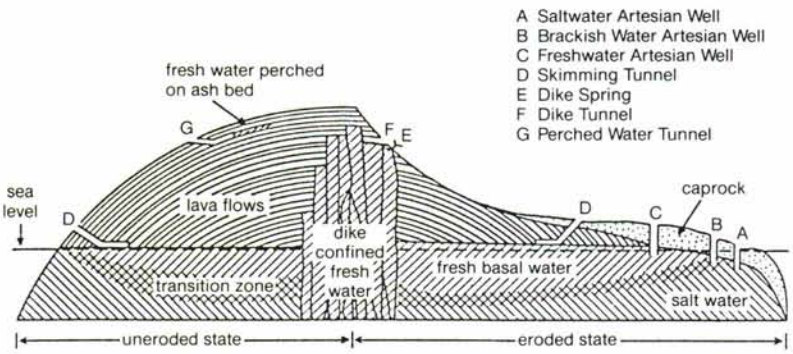
How could this be? Why is water a limiting factor in golf course development in a state that includes the wettest spot on earth? The problem is not in the amount of water that falls, but in the groundwater system of the islands, and where good water is found in relation to where golf courses are developed.

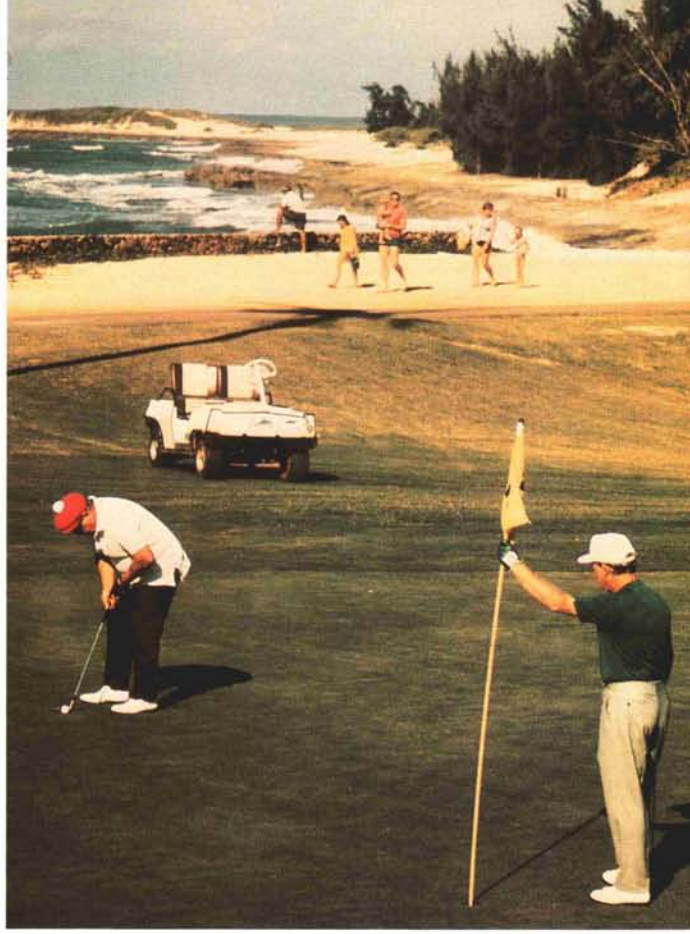
The Hawaiian Islands are relatively high islands. Northeasterly trade winds carry moisture-laden clouds over these volcanic peaks. As the clouds rise, cooling occurs and moisture is released. Extremely heavy amounts of rainfall may occur in some areas. Mount Waialeale, on the Island of Kauai, for example, is said to be the wettest spot on earth, with an annual rainfall of 460 inches. The leeward side of all islands, however, is very dry because most of the moisture is released by the clouds as they sweep up the windward slopes. Great variation in rainfall can occur in very short distances. For example, famous Waikiki beach, on the Island of Oahu, is located at the foot of Manoa Valley. Annual rainfall at the beach is approximately 20 inches. At the back of Manoa Valley, perhaps less than five miles as the crow flies, annual rainfall is about 250 inches.

The freshwater system typical of those of all islands is shown in *Figure 2*. Rainfall occurs at higher elevations, percolates through the porous lava, and perches as a lens of fresh water of varying thickness on top of the heavier salt water in the porous rock formation of the island. The older islands, Kauai, Oahu, and Maui, have caprock formations at their coasts. These are denser lava formations that occurred after the islands were almost completely formed. Caprock formations, being dense and practically impervious to water, help to hold the fresh water in and greatly increase the thickness of the freshwater lens.

The island of Hawaii, which is still in the formation process, does not have a caprock formation, and thus the lens of fresh water is not nearly as thick. In addition to the basal lens of fresh water, significant amounts of water may be held in porous materials between denser

(Below) Figure 2. Typical groundwater system of the Hawaiian islands. (Right) Figure 3. Resort golf courses in Hawaii are typically near the beach on the drier side of the islands. (Opposite page, top) Figure 4. Diagramatic illustration of the method of obtaining soil solution samples by means of suction lysimeters. (Bottom) Figure 5. Golf courses on the leeward coast of the island of Hawaii are often constructed in raw lava flows.





lava in vertical formations. This type of formation is termed a dike. There is also some water perched in porous material on impervious volcanic ash formations. The latter two types of water systems are being developed for potable water on Oahu.

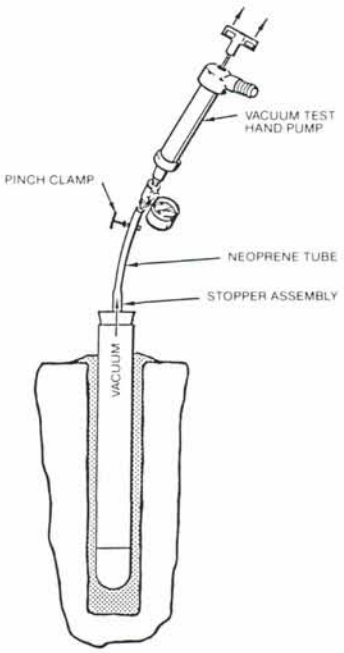
FORTUNATELY, because of high rainfall on the windward elevations of all the major islands, there has been ample water of very high quality for potable water supplies. Recently, however, because of tremendous population increases on the island of Oahu, the thickness of the basal lens has been decreasing at an alarming rate. The period from 1978 through 1980 saw three consecutive years of extremely low rainfall. At this time, the Oahu Board of Water Supply instituted severe water restrictions, with limits on the amount of water per household, as well as restrictions on commercial users of water, such as golf courses. Golf course water allotments were set at 50 percent of the average use of preceding years. Since that time there have been periodic appeals to homeowners and others to conserve water. Because of the large amount of development in recent years, the water supply on Oahu is particularly critical.

With the exception of Oahu, there is little concern for potable water supplies. There are severe problems, however, in regard to water for irrigation of golf courses, especially on Oahu and Hawaii. Most golf courses in Hawaii are constructed as part of resort developments or real estate projects. Because of the attraction of the ocean with the beautiful sand beaches and palm trees, resort developments and real estate projects are usually located near the ocean, usually on the drier, leeward side of the islands.

Figure 3 shows a typical resort golf course on the leeward coast of Oahu. This presents a critical problem of obtaining water of suitable quality to irrigate the golf course. On the leeward coast of Oahu, wells near the coast have become increasingly salty as the thickness of the freshwater lens has decreased. On the leeward coast of Hawaii, the freshwater lens is very thin because of the lack of a caprock formation. Large demands placed on the lens, as in the case of several golf courses located in close proximity, results in mixing of underlying salt water and increasing salinity. Because of low rainfall, high temperatures, and constant winds, water use requirements of turfgrasses is high on the leeward coasts, further increasing the demands on available water.

Golf courses being constructed on the leeward coast of the island of Hawaii present special problems in obtaining suitable materials for growth of turfgrasses. This coast of Hawaii is composed of raw lava flows that have undergone little weathering. Golf courses are constructed by first crushing the lava to a workable size by heavy equipment, grading to the golf course architect's specifications, adding a filter layer of cinder or other available material, and finally adding a rootzone layer of volcanic ash soil, fine cinders, or whatever material is available. The contrast between raw lava flows and green grass results in some of the most beautiful golf courses in the world.

Figure 1 shows a view of the sixth hole of the Mauna Lani golf course. *Figure 5* shows a closer view of a fairway bordered by raw lava. This type of construction, with a fine rootzone material overlying a coarser lava subsurface layer, results in a perfect example of a perched water table, which is the under-



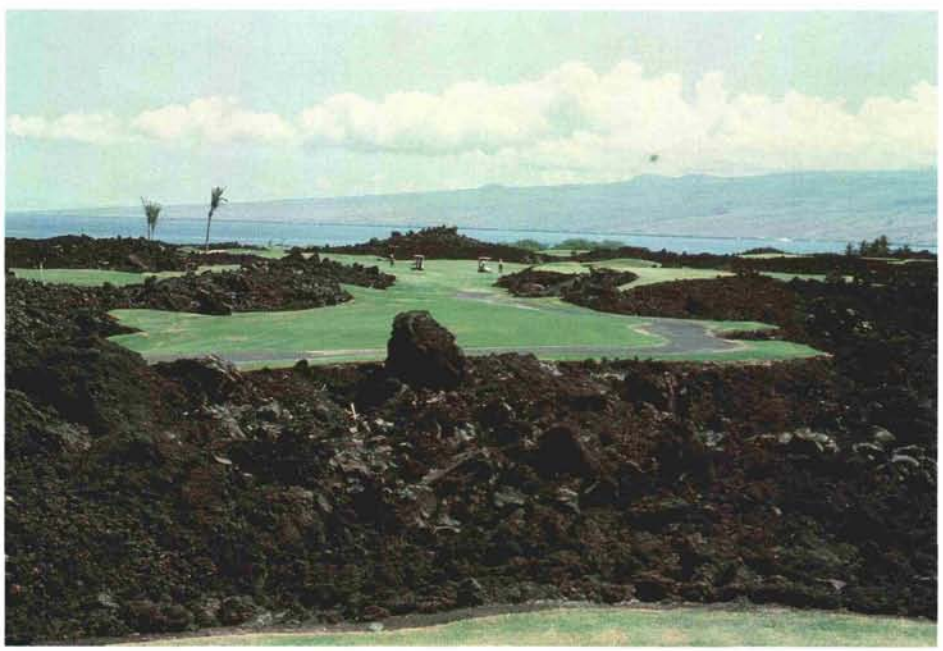
lying principle for the USGA Green Section specifications for construction of golf putting greens. Water will not move out of the finer layer until it is completely saturated. Then water only moves by gravity.

Because of low rainfall at this location, there is little chance of extended periods of rainfall to saturate the soil and leach accumulated salts. Since the available water in this area of Hawaii is brackish (average salinity readings of 3.0 to 3.5 mmhos/cm) and the water infiltration rate of the rootzone material is slow, extremely high salt buildup is occurring in some cases.

BECAUSE OF the problems with obtaining adequate high-quality irrigation water, research is being conducted at the University of Hawaii on effects of sewage effluent and brackish irrigation water on soil chemical properties and growth of turfgrasses. As part of this research, soil solution sampling stations have been established at four golf courses, two each on Oahu and Hawaii.

The soil solution is sampled monthly by means of suction lysimeters installed at different depths *(Figure 4). Table 1* shows selected soil chemical properties from these four locations. It is clearly apparent that soil salinity levels have reached excessive levels in certain cases.

Fortunately, bermudagrasses are used on golf courses in Hawaii and are very salt tolerant. Experiments are presently being conducted to determine if salinity levels can be reduced by increasing leaching, gypsum applications, and aerification treatments.



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