CHAPTER 12

The Freshwater Cycle on Molokaʻi

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Rain is the source of all freshwater on Molokaʻi. Most of the rain falls in the upland (mauka) areas at higher elevations, generally above 600 m (2,000 ft). Figure 1 shows the average amount of daily rainfall per square mile in four zones of the island; also shown is the amount of rain that runs off as surface water, evaporates and transpires back to the atmosphere, and recharges the aquifer. The wettest part of the island, the upper slopes of East Molokaʻi Volcano, receives an average of nearly 4 m (more than 150 in) of rain per year (fig. 2). The driest parts of the island, such as coastal areas of West Molokaʻi, receive an average of less than 0.4 m (15 in) per year (Giambelluca and others, 1986; fig 3).

On an average day, the entire island receives about about 2 billion liters (552 million gallons) of rain. Of this amount of rainwater, about 50 percent evaporates or is transpired by plants, about 16 percent runs off to streams, and the remaining 34 percent infiltrates into the ground and becomes ground water. Drier areas of the island (such as the West Aquifer Sector; fig. 1) tend to have a higher percentage of rainwater going to evaporation and transpiration and a lower percentage going to runoff and recharge, whereas the wetter areas (such as the Northeast Aquifer Sector; fig. 1) tend to have a higher percentage of rainwater going to runoff and recharge and a lower percentage going to evaporation and transpiration (Shade, 1997).

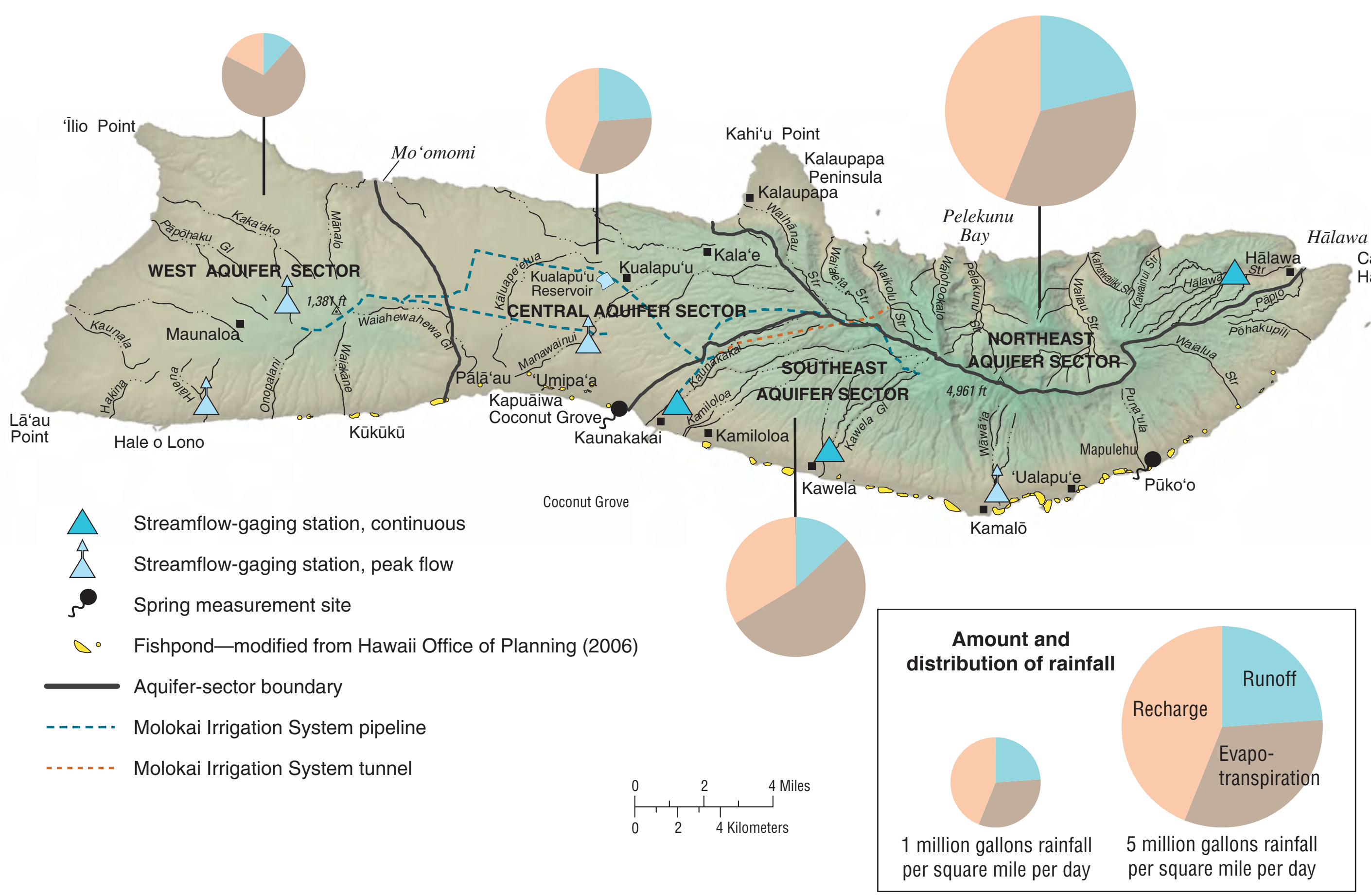

Figure 1. Map of Molokaʻi showing average annual rainfall per square mile in different areas of the island. The percentage distribution of the rainwater into runoff, evaporation and transpiration, and ground-water recharge is shown in pie charts. The size of each pie chart indicates the total amount of rainwater. The map also shows the locations of stream (continuous-record and peak-flow) and spring-discharge monitoring stations operated by the U.S. Geological Survey in 2007. Data from these stations can be found at http://hi.water.usgs.gov/ (last accessed April 29, 2008).

Figure 2. View of Pelekunu Valley, on the northeast coast of Molokaʻi, showing lush vegetation and deep erosion in the valleys resulting from the wet climate in the northeastsern part of the island.

Figure 3. View of the south coast of Molokaʻi from Kamiloloa to Lāʻau Point as seen from Kawela, showing the subdued landscape and sparse vegetation that result from the arid climate in the southwestern part of the island. The fringing coral reef, coastal fishponds, and mudflats at Pālāʻau are also visible.

Recharge is important because it replenishes underground aquifers with freshwater. This fresh water flows slowly through the aquifers and eventually discharges from springs and seeps into streams or the ocean. Under natural conditions, the average rate of recharge to an aquifer balances the amount of discharge. Water removed from aquifers by pumping is no longer available to discharge to streams or the ocean. Such ground water pumped from aquifers supplies most of the freshwater for drinking and other uses on Moloka‘i. For the period 2000 to 2002, about 4.2 million gallons (about 16 million liters) a day was pumped for domestic use on the island. About 50 percent of this water is pumped from the Kualapu‘u area. To assist in managing the supply of ground water, computer models are used to simulate the flow of ground water and evaluate the effects of pumping (Oki, 1997, 2000, 2006). Water use on the island of Moloka‘i is regulated by the State of Hawai‘i Commission on Water Resource Management, which designated the entire island as a Ground Water Management Area in 1992.

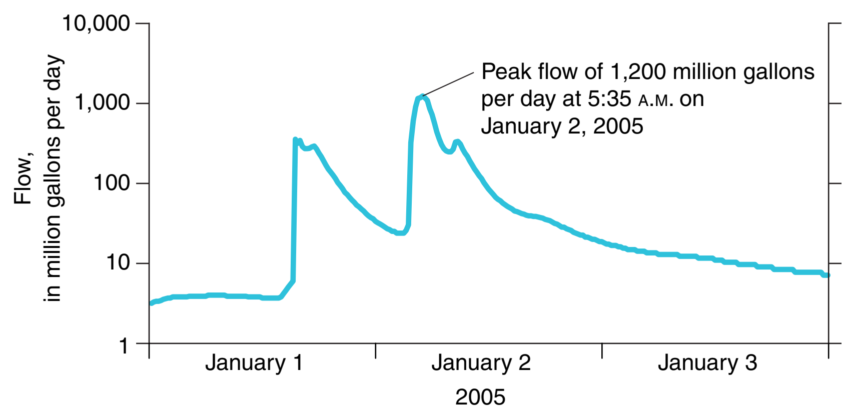

Figure 4. Flow in Hālawa Stream during January 1–4, 2005, showing rapid changes in flow from less than 10 million to more than 1,000 million gallons per day. The high rates of flow are caused by direct runoff of rainfall, whereas the sustained low rates are caused by the base-flow discharge of ground water into the stream.

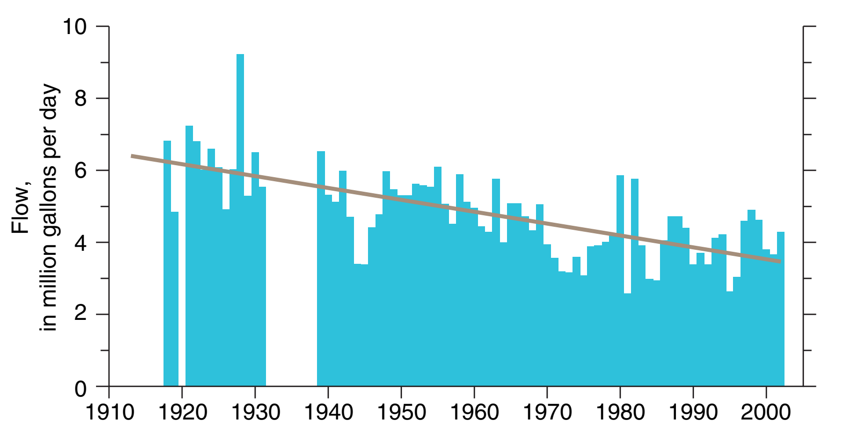

Figure 5. Average annual base flow in Hālawa Stream since 1918. The solid brown line shows the long-term trend of declining flow (from Oki, 2004). Base flow is estimated from daily records of total flow using computerized methods that separate the measurement of total flow into direct runoff and base flow. Note: data are missing for the years of 1920 and 1932 to 1938.

Ground-water discharge along the south shore of Moloka‘i is much higher on the east because of the greater amount of rain that falls on that part of the island. For example, between Kawela and Pūko‘o the discharge of freshwater is estimated to be approximately 4.0 million gallons per day per mile (about 9.4 million liters per day per kilometer) of coastline. On the west side, between Hale O Lono and Kūkūkū Gulch, the discharge of freshwater is only one-tenth as much, approximately 0.39 million gallons per day per mile (about 0.9 million liters per day per kilometer) of coastline.

Water in streams comes both from the direct runoff of rainfall and from the discharge of ground water from springs and seeps (which is called base flow). Streams on the northeast side of the island flow continuously (perennial streams) and are sustained by base flow because their valleys have eroded deeply enough over time to cut into the water table (fig. 2). Hālawa Valley, on northeast Moloka‘i, contains a good example of a perennial stream. Streamflow in Hālawa Valley has been measured for most of the time since 1917 at a site where the stream drains an area of about 11.9 km^2 (about 4.6 mi^2) that receives an average of 2 m (80 in) per year of rainfall. Since 1917, the median flow at that site has been about 8.4 million gallons (about 32 million liters) per day. However, flow has varied from a daily low of 0.56 million gallons per day to a peak flow of 17,400 million gallons per day (about 2.1 million to 65,900 million liters per day). Figure 4 shows an example of how flow can change very rapidly. Such extremes in the amount of flow are typical of streams in Hawai‘i, and a rapid increase in flow can be very dangerous if people are crossing or playing in the stream. Great caution should be exercised around any stream during periods of rain.

Flow can also change over a period of many years. For example, from 1918 to 2002, the average annual base flow in Hālawa Valley has decreased by an average of 0.53 percent per year; this equals a cumulative decline of 44 percent (fig. 5). This decline is a result of lower rainfall in the second half of the 20th century (Oki, 2004), but it is not known if this trend is part of a long-term cycle or represents a distinct change in climate.

Most streams on Moloka‘i have no base flow and are ephemeral; they flow to the ocean only when there is enough rain to generate runoff. Runoff from watersheds carries sediment and other materials from the land to the ocean. In 2004 a gage was built to measure the amount of water and sediment flowing in Kawela Stream about 600 m (about 2,000 ft) inland from the coast. The flow at the gage is from a drainage area of about 13.7 km^2 (about 5.3 mi^2) with an average annual rainfall of about 1.1 m (45 in). The amounts of water flow and sediment load measured by the gage are shown in figure 6.

For the one-year period from October 1, 2004, to September 30, 2005, water flowed in the stream 29 percent of the time. The median flow, during times when the stream was flowing, was 2.2 million gallons (about 8.3 million liters) per day, and the peak flow was 345 million gallons (about 1,300 million liters) per day. The concentration of suspended sediment ranged from 1 to 1,700 mg/L. The total amount of sediment carried towards the ocean at this site during this period was 2,789 tons, and the highest amount for a single day was 1,030 tons on March 9, 2005. The five days with the highest sediment load contributed more than 90 percent of the total sediment load for the year. Information from this site will be used to estimate the amount of sediment reaching the coral reefs along the south coast of Moloka‘i and provide information on how the coral reefs are being affected by processes in the watershed. This information can also be used to assess the effectiveness of watershed management plans because it will be possible to measure reductions in the rate of erosion over time.

The U.S. Geological Survey (USGS) has measured flow in both perennial and ephemeral streams on Moloka‘i since 1917. At one time (1968), 9 continuous and 11 peak-flow stream gages were in operation on the island, but as of 2007 only 3 continuous and 4 peak-flow stream gages were in operation. The locations of these sites are shown in figure 1. Data from most of these sites are available on the internet at www://hi.water.usgs.gov/ (last accessed July 11, 2007). Funding to operate these stations currently comes from the State of Hawai‘i Department of Land and Natural Resources, the State of Hawai‘i Department of Transportation, Maui County Department of Water Supply, and the USGS Cooperative Water Program.

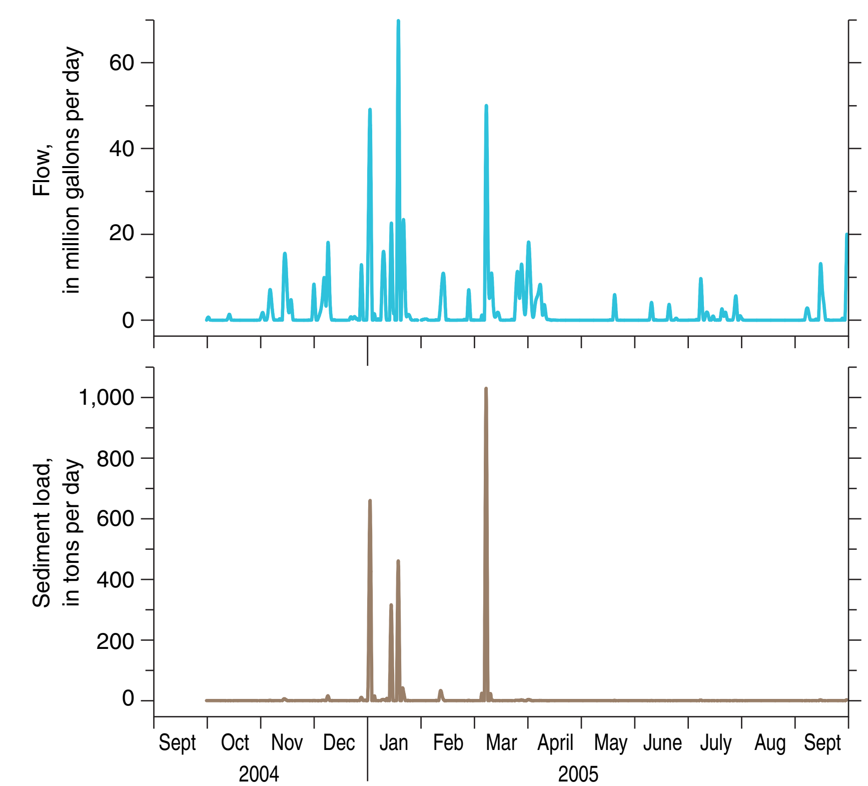

Figure 6. Graphs of daily flow (top) and sediment load (bottom) for Kawela Stream during the one-year period from October 1, 2004, to September 30, 2005. Streamflow occurred only intermittently, and most of the sediment load occurred during a few periods of wet weather. Instantaneous values can differ substantially from daily values because streamflow can vary greatly even during one day.

Suggested citation:

Tribble, Gordon, and Oki, Delwyn S., 2008, The freshwater cycle on Moloka`i, *Chapter 12 of* Field, M.E., Cochran, S.A., Logan, J.B., and Storlazzi C.D., eds., The coral reef of south Moloka`i, Hawai`i; portrait of a sediment-threatened fringing reef: U.S. Geological Survey Scientific Investigations Report 2007-5101, p. 109-110 [http://pubs.usgs.gov/sir/2007/5101/sir2007-5101_chapter12.pdf].