TRACKING "LAKE SHADOWS": DISTRIBUTION AND WATER-QUALITY IMPLICATIONS OF LAKE-WATER RECHARGE ON GROUNDWATER DOWNGRADIENT FROM GLACIAL KETTLE LAKES ON CAPE COD, MASSACHUSETTS

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The Cape Cod unconsolidated sand and gravel aquifer is pitted with more than 400 groundwater-flow-through kettle lakes. In groundwater-flow models of western and central Cape Cod, about 25 percent of the total simulated recharge to the aquifer from precipitation discharges into lakes and subsequently seeps back into the groundwater before discharging to streams and the coast. The result is lake-water plumes, or "lake shadows," in the groundwater downgradient from the lakes. The lake shadows deflect regional groundwater flow paths and are different chemically from groundwater recharged beneath dry land, thus complicating the distribution of contaminants in the aquifer. The isotopic composition of groundwater (delta-^{18}O and delta-^{2}H) was used to map lake shadows in the western Cape Cod aquifer downgradient from several large kettle lakes. Lake water is isotopically heavier than groundwater outside of the lake shadows because of evaporation in the lakes. Profiles of delta-^{18}O and delta-^{2}H from borings drilled at varying distances downgradient from the lakeshores indicated lake shadows that varied in thickness depending on location around the downgradient perimeter of the lakes. At one site about 50 m downgradient from the shoreline of an 82-hectare, 20-m-deep kettle lake, the lake shadow was more than 75 m thick, indicating rapid vertical penetration of lake water into the aquifer. At most sites, the lake-shadow zone was underlain by isotopically light groundwater that had recharged upgradient of and passed beneath the lake.

The distribution of lake shadows provided insights about the distribution of groundwater contaminants originating on land. Lake shadows commonly had different redox and nutrient conditions than groundwater recharged under dry land, thus affecting contaminant mobilization and transformation downgradient from lakes. Several contaminant plumes composed of chlorinated solvents terminated by discharging to lakes, whereas others were diverted by complex groundwater flow paths around lake shadows to unexpected locations farther downgradient. One contaminant plume composed of per- and polyfluoralkyl substances (PFASs) from a fire-training area discharged into a lake, and PFASs were present at elevated levels in the lake water and in the lake-shadow groundwater more than 3 kilometers from the source.