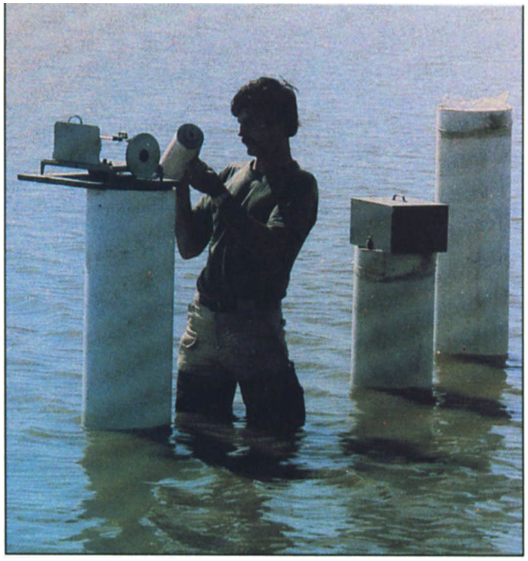

Infiltrometers (left) were installed in Kings County evaporation pond to estimate seepage. Rainfall, evaporation, drainage flows, and changes in pond water levels (here being checked by co-author Blake McCullough-Sanden) were also measured.

Evaporation pond seepage

Mark E. Grismer ❑ Blake L. McCullough-Sanden

Rates of seepage from operating evaporation ponds decline substantially as they age and as salinity increases

Since Kesterson Reservoir was closed nearly two years ago, attention has focused on local evaporation ponds for disposal of subsurface drainage water. Several such ponds exist in the San Joaquin Valley with a total acreage far exceeding that of the 1200-acre Kesterson Reservoir. Although each local evaporation pond is different, they all have features of concern to environmental interests.

Drainage water evaporation ponds are designed to receive and hold subsurface drainage water until it evaporates. As the water evaporates, chemical constituents are progressively concentrated, including some that are potentially hazardous, such as arsenic and selenium.

Primary concerns in evaluating the effectiveness of evaporation ponds as environmentally acceptable methods of drainage water disposal are related to the effects of the ponds on wildlife and degradation of adjacent waters by seepage. Seepage of concentrated chemical constituents to adjacent groundwater or irrigation supply canals makes the evaporation pond a point source of pollution similar to other waste impoundments subject to regulation.

Several factors may affect seepage from evaporation ponds: the permeability of pond bed materials (usually on-site compacted soils), interactions between pond waters and bed materials, and microbial activity within or near the bed. Other factors affecting seepage rates, such as proximity to unlined canals and buried stream channels, also may be important.

The primary measurable factor controlling seepage unique to each pond is the permeability of the bottom soils. Although effects of salinity on soil permeability have been studied, these effects vary greatly with the chemistry and concentration of the saline water. Such experiments have typically used salt concentrations much lower than those encountered in evaporation ponds. Effects of microbial activity on permeability of soils have been examined under a variety of conditions, and generally permeability decreases with time of inundation under nonsterile conditions.

The purpose of this study was to assess the effects of salinity and time of ponding on estimates of seepage from evaporation ponds. We took both laboratory and field measurements in the study.

Laboratory measurements

Large, 6-inch-diameter, undisturbed soil cores were collected from five operational evaporation ponds. Several of the cores were divided into subcores 3 inches by 3 inches in diameter taken at depths of 0.5 to 3.5, 5 to 8, 9 to 12, and 13 to 16 inches from the soil surface. The subcores were fitted and sealed with plexiglass ends and set up to measure permeability.

Drainage water having an electrical conductivity (EC) of 10 dS/m (6100 ppm total dissolved salts) was applied to the cores for three days to ensure saturation and uniform electrolyte concentration. Biological activity was minimized in some of the cores by the addition of chloroform to the percolating drain water.

Percolating drainage water having progressively larger EC values was applied over periods of one to five days in an effort to exaggerate variations in evaporation pond salinity resulting from evaporation and fresh drain water additions. The salinity of inflow and outflow water was measured periodically along with the permeability of each subcore.

The sodium adsorption ratio (SAR) is an index of the relative concentration of sodium, calcium, and magnesium in the soil solution. When soil salinity is low, permeability has been shown to increase as the SAR value of the inflow solution increases. Past studies, however, have typically considered SAR values of 30 or less. In this study, SAR values of the inflow solution increased in the same stepwise fashion as EC, with values ranging from 210 to 660.

Field measurements

Infiltrometers 6 inches in diameter and 40 inches tall were installed in an evaporation pond in Kings County approximately seven months after construction and filling. Originally, 24 groups of three infiltrometers were installed on a 500- by 400-foot grid spacing. This grid arrangement was used to estimate pond seepage rates during the winter months of November 1985 through February 1986.

In May, the 24 groups were replaced with 90 individual infiltrometers set on a 200-foot grid pattern to get a clearer picture of the change in seepage rates in space across the pond. This second grid arrangement was used during the summer months of May through August 1986.

Seepage was also estimated by a volume mass balance, where rainfall, evaporation, changes in pond water levels, and drain flows into the pond were measured. The depth of water required to balance these components provides an estimate of total seepage. Seepage rates by this method were determined for winter, spring, and summer periods.

Permeability and salinity

Data collected from the nearly sterile and the nonsterile cores varied, although there were identifiable trends in drain water salinity and biological activity. Generally, as time of ponding and drain

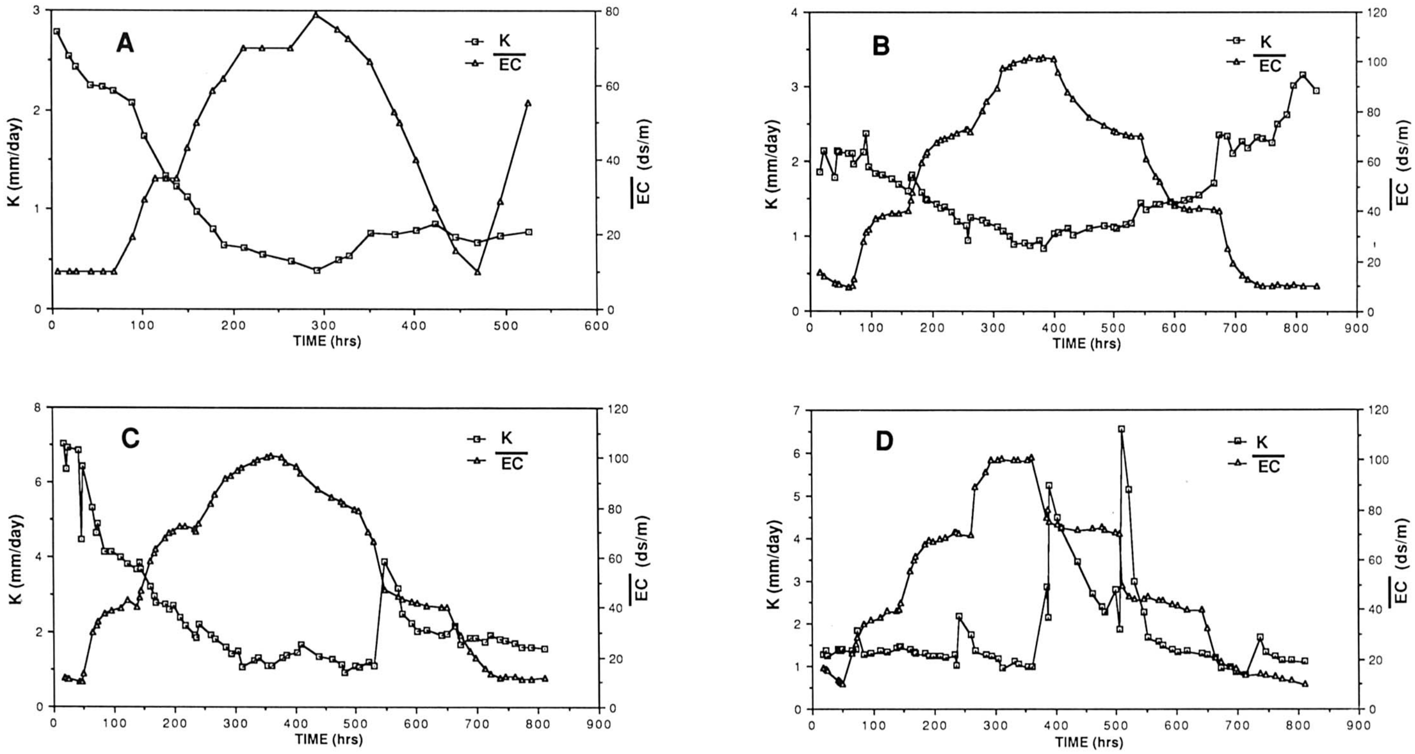

Fig. 1. When percolating drain water was nonsterile (A and B), permeability, K, decreased as mean salinity, $\overline{EC}$, increased. Permeability declined irreversibly as time of ponding increased (A) but rose again in relation to a decrease in salinity (B). When drain water was nearly sterile (C and D), permeability tended to decrease with time (C) and showed only temporary, erratic changes at higher salinity levels.

water salinity increased, permeability decreased. Average salinity in figure 1 was determined from solution displacement considerations and represents the average EC of the core when measurements of permeability (K) were taken.

Under nonsterile conditions, permeability decreased substantially as salinity increased (fig. 1A and B). There also appeared to be a reduction in permeability simply due to the time of ponding (fig. 1A). As drain water salinity decreased, permeability tended to increase and return to its original rate at the start of the experiment. Increasing permeability with decreasing salinity is particularly evident in figure 1B. Overall, when biological activity is present, it appears that the length of time of ponding causes an irreversible decrease in permeability. However, decreased permeability caused by increasing salinity appears somewhat reversible when salinity decreases.

When biological activity was reduced, permeability tended to decrease with time of ponding and was relatively insensitive to changing drainage water salinity (fig. 1C and D). Results shown in these figures also are typical of the variability in permeability associated with controlling biological activity. A comparison of results shown in figure 1A and B with those in C and D suggests that reversibility of salinity effects on permeability is related to microbial activity.

Based on the laboratory experiments, seepage from evaporation ponds should decrease with time of continuous ponding and increasing pond water salinity. Microbial activity at the pond bottom may result in some fluctuations in seepage rates as pond water salinity increases and decreases with evaporation and addition of fresh drainage water.

Measurements of pond seepage

During the winter, the average seepage rate measured by mass balance was 5.83 feet per year, and decreasing trends in seepage were not detected. During the spring and summer, however, the average seepage rate declined to 3.76 feet per year, or 36 percent less than the winter rate.

Seepage rates for most infiltrometers proved to be similar to the seepage estimated by mass balance. However, infiltrometers installed in areas of the pond bottom having coarse-textured soils showed decreases of 500 to 700 percent in seepage.

Over the entire monitoring period, pond water salinity ranged between 12.0 and 23.4 dS/m, with the minimum EC occurring in December. Pond water EC gradually increased within this range during the summer months, although such increases probably had a minor effect on seepage rates from the pond.

Seepage from evaporation ponds

Seepage from drainage water evaporation ponds is of concern to both environmental and agricultural interests because of potential degradation of adjacent groundwaters. From laboratory and field experiments, it appears that rates of seepage from operational evaporation ponds decline substantially after construction. This decline is irreversible during continuous ponding and may be a result of microbial activity and deposition of suspended matter in pond water. Seepage rates also decrease as the salinity of the pond water increases as a result of chemical precipitation and reaction with pond bed materials, although this process may be partially reversible. Moreover, additional measurements of groundwater elevation and quality adjacent to and below the pond indicate that, when operational, interceptor drains surrounding the pond partially contain seepage and confine it to the area below the pond.

Mark E. Grismer is Assistant Professor, and Blake L. McCullough-Sanden is Postgraduate Researcher, Department of Land, Air and Water Resources, University of California, Davis.