Report for 2001CO881B: Description and Interpretation of Salinization in the Lower Arkansas River Valley, Colorado

- Other Publications:
    - Valliant, Jim, 2001, An Overview of Water Outreach Activities in the Arkansas River Basin, in October 2001 Colorado Water, Newsletter of the Colorado Water Resources Research Institute, Colorado State University, Fort Collins, CO, pp. 9-11.
- Articles in Refereed Scientific Journals:
    - Gates, T.lK., J.P Burkhalter, J.W. Labadie, J.C. Valliant, and I. Broner; 2001, Monitoring and modeling flow and salt transport in a salinity-threatened irrigated valley, in Journal of Irrigation and Drainage Engineering, ASCE, 128(2):87-99.
- unclassified:
    - Gates, Timothy, 2001, Evaluating Strategies to Mitigate Waterlogging and Salinization in Colorado’s Lower Arkansas River Valley, Progress Report presented at the CWRRI Advisory Council on Water Research Policy (ACWRP) annual meeting, November 5, 2001, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, CO.

Report Follows:

SYNOPSIS

Project Number: 02 **Start:** 3/01
End: 2/02

Title: Description and Interpretation of Salinization in the Lower Arkansas River Valley, Colorado

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Congressional District: 4th

Focus Categories: WQL, GW, AG

Descriptors: Salinity, Drainage, Irrigation, Water Quality, Groundwater Quality, Saline Soils, Data Analysis, Data Storage

Problem and research objectives

There is growing evidence that the irrigated lands of the lower Arkansas River Valley in Colorado are suffering from severe waterlogging and salinization. Informal and anecdotal evidence abounds: salt crusting on soil surfaces, seepage and wet spots in selected fields, stunted growth of crops, and reduced crop yields. There is an acute need to place the diagnosis of salinity and waterlogging problems in the Arkansas Valley on a sound scientific footing. Over the last few years, we have initiated scientific investigations with the objectives of accurately diagnosing these problems.

Beyond the need to accurately describe the problems for farmers and for state and regional agencies, a reliable database is needed to aid in prescribing solutions. This project proposes to strengthen the data foundation needed to characterize salinization problems in the lower Arkansas River Valley and to guide the search for answers. The output of this project will be a report that assesses the scope and severity of the problems. The report will consider soil salinity, water table depth and salinity; river level, flow, and salinity; water levels, flows, and salinity in canals and drains; irrigation practices; hydraulic conductivity of surface soils; well pumping; and crop yields. Plausible causes and promising directions for addressing the problems also will be addressed. The report will be accompanied by a digital spatially-referenced (ArcView™ GIS format) database.

The results of the proposed project should prove a valuable resource in support of decision-making and intervention in the Valley. Without sound and timely intervention, it appears that the Valley will eventually succumb, at least in a large part, to the ill effects of salinization. Solutions based upon accurate knowledge of field conditions will be needed to insure sustainability of the Valley's productive agricultural base and preservation of its rural communities.

Methodology Synopsis

Project activities include compilation and evaluation of data from past studies, as well as collection of new field data. Data from past studies in the Valley are being pulled together, transformed into a compatible and accessible format, compared, and interpreted. Historic data considered include land topography and topology of hydraulic systems, field and crop layouts, general hydrology, subsurface geology and lithology, water table depth and salinity, groundwater well locations and pumping rates, river water levels and salinity, soil textures and classifications, irrigation practices, and county-wide crop yields. Extensive field data have been collected in 1999, 2000, and 2001 under this and related projects. The data collection effort focuses on a representative subregion of the Valley that extends eastward about 62 km along the Arkansas River in Colorado, from the town of Manzanola in Otero County to Adobe Creek in western Bent County, encompassing about 26,400 hectares of irrigated land. Data have been collected and analyzed on water table depth and salinity; water levels and salinity in the river, irrigation canals, drains, and reservoirs; soil salinity; hydraulic conductivity of near-surface soils; land topography; and crop yields.

Principal findings and significance

More than 100 monitoring wells have been installed and are routinely measured in the study subregion. Preliminary results from the 2001 season indicate an average water table depth of about 2.7 m. The average measured salinity (as electrical conductivity, EC) of the water table in the study region was about 3.0 dS/m (2700 mg/l) in 2001. Average depths and salinities were 2.1 m and 3.5 dS/m in 1999, and 2.5 m and 3.2 dS/m in 2000, respectively. Surface-water salinity is routinely measured at more than 170 locations, including points in the Arkansas River, in six major canals, in twelve drainages, and in two reservoirs. The average salinity of the water in the irrigation canals was about 1.03 dS/m (900 mg/l) in 2001, indicating low to moderate restriction in use for irrigation. This compares to averages of 0.93 dS/m (812 mg/l) in 1999 and 1.12 dS/m (978 mg/l) in 2000. Global positioning equipment has been used to accurately locate each of the ground-water and surface-water sampling sites for use in a geographic information system. About 15 deep exploratory boreholes were drilled to describe aquifer lithology and to locate the aquifer base. Analysis of 1999 data indicated that the seasonal average rate of groundwater return flow to the river (directly and through tributary drainages) was about $5.5 \bullet 10^6$ m^3/week, with an accompanying diffuse salt loading rate of $16.2 \bullet 10^6$ kg/week (about 740 kg/week per irrigated hectare).

Soil salinity (to a depth of about 1 m) was measured in early June and in mid August on 80 fields in 2001. On each field, soil salinity (as electrical conductivity of saturated extract, EC_e) was estimated using electromagnetic induction probes at an average of 62 locations (about 1 to 10 locations per acre) for each sampling. In addition, about 6000 soil samples have been collected for use in calibrating the electromagnetic probes over the period 1999-2001. Analysis has yielded preliminary relationships between electromagnetic inductance and EC_e for the soils in the Valley. The average soil salinities measured in 2001 were 2.8 dS/m in the early season and 2.5 dS/m in the late season. For the late-season readings in 2001, about 70% of the study subregion had soil salinities that exceeded 2 dS/m (threshold level above which crop yield reductions are expected for corn and alfalfa), indicating significant soil degradation and declining yield. Crop yield reduction due to salinization has been estimated to range between 0 and 75% on fields spread over the subregion, averaging about 10%. This indicates a total revenue averaging $70/ha - $100/ha over the subregion (1999 crop prices). Additional losses are likely occurring due to waterlogging.

The developed database is being used in a related project to support a computational model of the study subregion. The model is being developed to help assess possible solution strategies.

Steady-state modeling, to estimate long-term equilibrium conditions, indicates that increased pumping of existing well facilities would result in only limited localized improvement. Reduced recharge through increased irrigation efficiency would provide more extensive benefits, especially in much of the area south of the river. However, lowering the saline water table in the most severely-affected areas will require more than simply increasing irrigation efficiency or increasing pumping rates. Costlier strategies will need to be considered, such as canal lining, horizontal subsurface drainage, and lowering of the river level. Unsteady modeling of flow and salt transport under these strategies is currently underway. With guidance from Valley agencies and farmers, alternative solution strategies will be assessed by predicting how well they will control waterlogging and salinity, the impact they will have on time-varying return flows to the river, and their cost-effectiveness.