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Project Summary

Irrigation Return Flow Water Quality Monitoring, Modeling and Variability in the Middle Rio Grande Valley, New Mexico

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A 250-acre (100 hectare) irrigated farm in the middle Rio Grande valley at San Acacia, New Mexico was intensively monitored for the five-year period from 1977 through 1981. The quantity and quality of the applied irrigation water and the drainflow leaving the farm were observed, and 39 observation wells were installed to monitor ground-water levels and quality. The data indicate that there has not been a statistically significant change in the total dissolved solids concentration in the shallow ground water underlying the site during the monitoring period. A significant increase in nitrate concentration in the shallow ground water and the drains was observed as portions of the farm were converted from alfalfa to corn.

The observations also included extensive systematic measurements of the temporal and spatial variability of chemical and physical parameters at the site. The spatial observations, which included measurements of infiltration rate, grain size distribution, electrical conductivity and chloride concentration, showed substantial variability, with correlation scales on the order of 10m in the horizontal direction and less than 1m in the vertical. The temporal data show major weekly variations in composition of the irrigation water, ground water, and drainflow.

The data from deep wells demonstrated the layered structure of the aquifer underlying the site and pointed to the possibility that upwelling regional ground-water discharge was producing a major influx of relatively high salinity water beneath the site.

The data collected at the San Acacia site were used to test two computer-based models which simulate the flow and water quality behavior. A two-cell lumped-parameter model, which emphasisesthe dynamic nature of the water and mass balances, adequately simulated the average monthly chloride concentration of the drain water.

A modified version of the U.S. Bureau of Reclamation (USBR) hydrosalinity model, which incorporates the layered structure of the aquifer and the contribution from high salinity regional inflow, was used to simulate a 30-year period under steady state average flow conditions, and the four-year monitoring period under transient flow conditions. The results of the 30-year simulation are in reasonable agreement with the monitored water quality of the drain flow at the end of the period. However, the modified model was not able to simulate the observed seasonal variation of salinity emissions from the site during the monitoring period. The chemical reactions included in the USBR model did not have a significant effect on the model predictions for the San Acacia site.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Pollution from irrigated agriculture has presented a difficult problem in the national water quality strategy. Irrigated agriculture occupies large land areas, and as a result its impact on water quality is extensive, but at the same time rather diffuse. Furthermore, control of pollution from irrigated agriculture requires the simultaneous cooperation of many different land users, irrigation districts and state and federal institutions. Such a process necessitates careful planning and organization. Although it is generally recognized that irrigated agriculture contributes to degradation of water quality, the extent of such pollution varies from location to location and is frequently ill-defined. For example, in some western states suspended and settleable solids are the major causes for degradation of water quality, while in the arid southwest increases in the salinity of streams by salt-loading and salt concentrating mechanisms are the main reasons for water quality degradation. In some areas water quality is degraded by nutrients from fertilizer discharged in soil water, and in other areas irrigation return flow has increased levels of phosphates or nitrates originating from natural deposits. Thus in order to define the impacts of irrigated agriculture on water quality it appears necessary to perform field monitoring studies under various environmental conditions and at various locations.

The general objectives of this project are: (1) to monitor irrigation return flow quality on a 250-acre (100 hectare) test site in the Middle Rio Grande Valley at San Acacia, New Mexico, (2) to use data obtained at this site to test the Bureau of Reclamation-EPA irrigation return flow model, and (3) to evaluate the effects of spatial and temporal variability of flow and water quality. The following detailed subobjectives will be required:

1. To evaluate the effects of irrigation on water quality in the Middle Rio Grande Valley of New Mexico through intensive monitoring of a farm operation at San Acacia, New Mexico.
2. To evaluate the predictive capabilities of the Bureau of Reclamation hydrosalinity model applied to the San Acacia site, and to consider modifications necessary to improve this model.
3. To evaluate the spatial and temporal variability of flow and water quality inputs and parameters at the San Acacia site and apply stochastic analyses which incorporate data on the variability of chemical and flow parameters at the San Acacia site.

Monitoring and Variability

Monitoring information provided an extensive data base on the irrigated hydrologic system at the San Acacia site over four complete irrigation seasons. These observations provided a unique data base for comparative testing of the USBR-EPA irrigation return flow model.

The temporal variability observations emphasized that water quality parameters of the irrigation water, the ground water and the drainflow are subject to significant short-term (weekly) variations which can easily mask any long-term trends. These observations demonstrate that the irrigated hydrologic and water quality system is highly dynamic and point to the difficulty of coming to any definitive conclusions about water quality trends in such systems from only occasional (annual or semi-annual) observations.

Similarly the spatial variability observations demonstrated that the flow and water quality parameters at the San Acacia site are highly variable in both the horizontal and vertical direction. Generally the correlation scales in the horizontal (on the order of 10 m) are significantly larger than the scales in the vertical (a meter or less). The correlation scale of water quality parameters tends to be larger than that of the infiltration rate. These observations also demonstrated the difficulty of realistically characterizing the properties of such an irrigated system from a small number (2 or 3) of observation wells or soil samples.

Modeling

Two modeling approaches were used in this study to determine the characteristics of the middle drain flow system at the San Acacia site. The first approach employed multiple-celled lumped-parameter models, and the second consisted of a profile finite element flow model coupled with the U.S. Bureau of Reclamation hydrosalinity model. The results of the modeling studies indicated that the mixing process producing observed drain concentrations involves a complex transient relationship between the irrigation recharge and a poor quality regional inflow.

The application of these models at the San Acacia site demonstrated the dynamic structure of the irrigation return flow system. The observations of flow and water quality showed a high degree of temporal and spatial variability. A simple lumped-parameter water and mass balance model adequately reproduced the dynamic effects, but the USBR-EPA model failed to represent the observed temporal system. We do not recommend modification of the USBR-EPA model to represent unsteady conditions with regional inflow. This would require complete revision of the modeling approach and would greatly increase data requirements. The need to simulate dynamic water quality changes in irrigated systems would, in our opinion, be better served by improving the lumped-parameter model to include the effect of chemical reactions. The data requirements of the lumped-parameter model are less severe, parameter estimation is systematic, and the simple structure is easily modified to reflect site specific conditions. In any case, we recommend that a systematic lumped-parameter water and mass balance model be used initially to evaluate overall hydrologic conditions and provide regional management-oriented predictions.

Conclusions

Intensive monitoring of the irrigation system established that the San Acacia site, which originally appeared to be hydrologically isolated from the surrounding area, was, in fact, significantly influenced by the surrounding regional ground-water flow system. This is especially true in relation to salinity, where over 50 percent of the total dissolved solids emission in drains originates from sources outside the farm. The models were modified to account for this external contribution.

Analysis of total dissolved solids data obtained from monitoring shallow wells underlying the irrigated area of the San Acacia site shows that there has not been a statistically significant change in the salinity of the shallow ground water over the duration of the project. A significant increase in nitrate concentration in the shallow ground water and the drains was observed as portions of the farm were converted from alfalfa to corn.

Extensive systematic observations of chemical and physical parameters of the subsurface flow system at the site show that these parameters are highly variable in time and space. The correlation scale of spatial variability is generally observed to be an order of magnitude larger in the horizontal direction than in the vertical.

A two-cell lumped-parameter model, which emphasizes the dynamic nature of the water and mass balances, was found to adequately simulate the average monthly chloride concentration in the middle drain, despite the complexities of the real flow system.

A modified version of the Bureau of Reclamation model adequately simulated steady-state average water quality at the end of a 30-year period but the modified model was not able to simulate the observed seasonal variation of salinity emissions from the site during the monitoring period. The chemical reactions included in the Bureau of Reclamation model did not have a significant effect on the predictions at the San Acacia site.

In this and other applications of lumped-parameter models, it has been shown that these simple models adequately simulate the behavior of conservative solutes. It is recommended that the lumped-parameter models be generalized to include the effect of chemical reactions.

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The complete report, entitled "Irrigation Return Flow Water Quality Monitoring, Modeling and Variability in the Middle Rio Grande Valley, New Mexico," (Order No. PB 83-261 719; Cost: $37.00, subject to change) will be available only from:

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