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Project Summary

Irrigation Tailwater Management

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This investigation was undertaken to obtain information and data on irrigation tailwater and other components of irrigation return flows from two representative sites in the Central Valley of California. Field studies were conducted in the Sacramento Valley where irrigators divert water from the Sacramento River and discharge return flows back into the river, and in the west side of the San Joaquin Valley where irrigators import water from the Sacramento River Basin and discharge return flows into the San Joaquin River.

This report contains extensive data on the quantity and quality of supply and drainage waters for the 1975-77 period. The study sites include the 664 km² (164,076 ac) Glenn-Colusa Irrigation District and the 113 km (70 mile) Colusa Basin Drain in the Sacramento Valley, and the 1619 km² (400,059 ac) Mendota-Crows Landings Return Flow Group in the San Joaquin Valley. Within these large spatial units specific water district and farm level studies were also conducted in regard to tailwater production, irrigation and drainage practices and extent of reuse of return flows by agriculture and wildlife areas. Surface irrigation return flows vary widely in both quantity and quality. Site specific conditions and factors contributing to such variations are noted.

The results of this investigation were evaluated to develop conclusions and recommendations on the control and management of irrigation return flows, particularly tailwater. These findings, which were reviewed by local, state and federal water agencies, will contribute to the Section 208 Water Quality Management Planning now being conducted for nonpoint sources of pollutants. Because irrigation return flows may be highly variable and their impacts on receiving waters may be variable, it is suggested that due considerations be given to their site specific nature when developing best management practices.

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

Introduction

Irrigation tailwater control and reuse appears to be a deceptively simple management practice, but in fact may be a very complex practice because of the many factors contributing to and/or affecting tailwater and its quality. To understand more fully this potential control technology, field studies were conducted in association with two of California's first and largest NPDES permittees· the Mendota-Crows Landing Return Flow Group (MCLRFG) in the San Joaquin Valley and the Sacramento Valley Water Quality Committee in the Sacramento Valley. These selected operating systems provide case study information and data to the public and policy makers for developing better guidelines for the management of tailwater.

The objectives of this project were:

(1) to identify and evaluate factors contributing to or affecting irrigation tailwater production and its quality,

(2) to perform field studies in selected areas in the Sacramento and San Joaquin River Basins,

(3) to determine the least-cost combination of agricultural production and labor, capital, irrigation water, and tailwater management and reuse; and

(4) to integrate scientific, engineering, and economic appraisals for the recommendation of guidelines for best practical technology for irrigation tailwater management.

Prior to the completion of this report, PL 92-500 was amended by the Clean Water Act of 1977 (PL 95-217). The new amendments affecting irrigated agriculture include: 1) Irrigation return flows are reclassified from point to nonpoint sources of pollutants, and hence are exempted from NPDES permits; 2) Irrigation return flows and their cumulative effects are considered under Section 208 Areawide Waste Treatment Management Plans along with other nonpoint sources of pollutants; and 3) a cost-sharing program to be administered by the U.S. Department of Agriculture (USDA) in cooperation with the USEPA will be established to provide technical and financial assistance to landowners and operators in rural areas for implementing Section 208 management plans.

Figure 1 identifies the various components of irrigation return flow with a focus on the crop root zone portion of irrigated lands. The "collected" surface irrigation return flow may be comprised by both surface runoffs and collected subsurface drainage. The former may contain irrigation water surface runoff commonly referred to as "tailwater," operational spills from irrigation distribution systems, and runoffs from precipitation during the irrigation season. The latter may contain collected subsurface effluents from tile drainage and drainage wells, and interception of subsurface water flows by natural and man-made open channels.

Irrigation tailwater in some quarters, is considered to be the easiest component of surface irrigation return flow to manage and control. It is said that if tailwater is controlled and/or reused, irrigation application efficiency would be improved, water and energy would be conserved, and at the same time discharge of pollutants would be substantially reduced. Although tailwater management appears to be a logical and practical control technology, it has not been thoroughly evaluated with regards to economic, legal, institutional, and physical constraints. Before a blanket recommendation on irrigation tailwater management is made, there is a need to investigate more fully such a management/control policy.

Conclusions

The results of this field study can be presented in three parts: 1) quantity of tailwater production, 2) quality of tailwater produced, and 3) control and management of tailwater quantity and quality.

Tailwater Quantity

Tailwater (irrigation surface runoff) is only one of several components

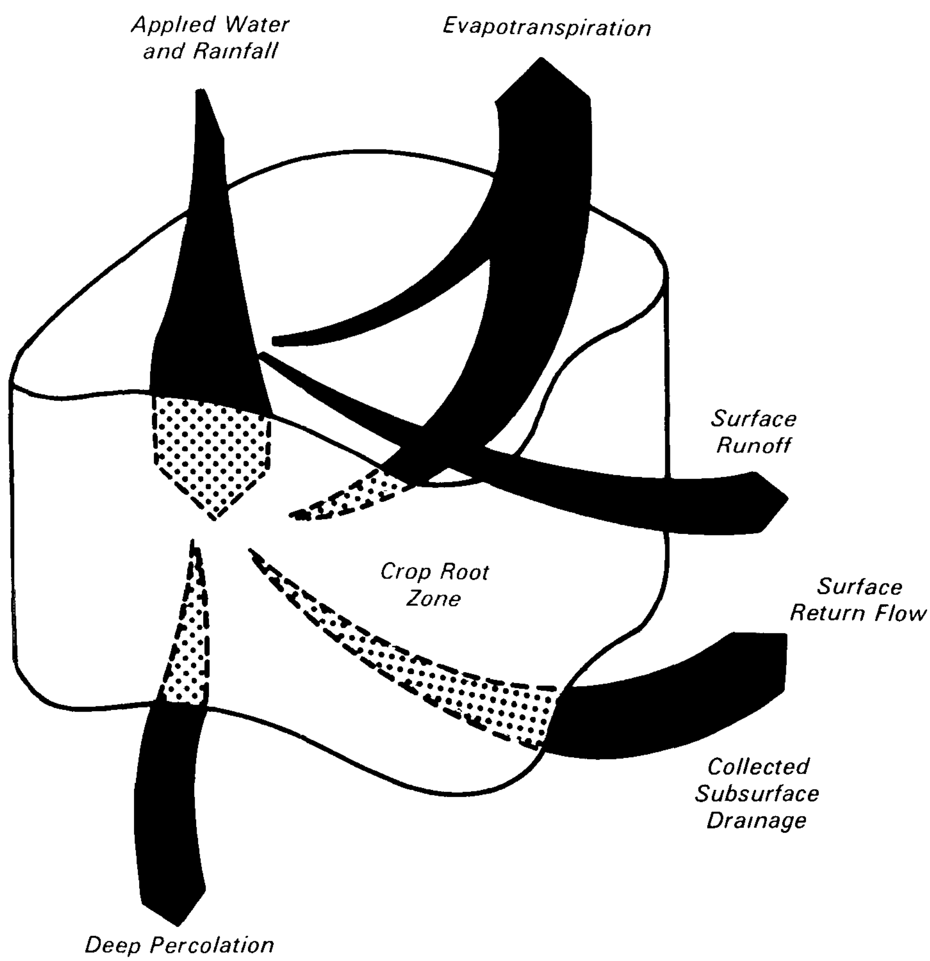

Figure 1. *The major water-flow pathways in the root zone portion of irrigated lands*

comprising surface irrigation return flows Other components "collected" surface return flows from irrigated lands are precipitation runoff, operational spills from distribution systems, effluents from tile drainage and drainage wells, subsurface waters intercepted by natural and man-made open channels, and discharges into irrigation drains by other sectors of society, for example, municipal storm water runoffs and treated sewage effluents Tailwater is not usually collected in a drain separate from other collected return flows. In the Central Valley of California the 2.43 x 10^3-km^2 (0 6 million ac) Westlands Water District is the only large irrigation project that is developing a drainage collection system that separates surface runoff from tile drainage

Tailwater discharged from irrigated lds may not always reach a receiving surface water body due to evaporation losses, infiltration into the land surface, evapotranspiration by phreatophytes and other vegetation, and recovery and reuse by downstream irrigators and other sectors of society. In areas where precipitation occurs during the irrigation season, it is difficult to differentiate the magnitudes of runoffs between rain-fed and applied irrigation waters. In most instances it is difficult to accurately measure tailwater production from a given field because tailwater is produced intermittently, coinciding with irrigation schedules. Unless tailwater is collected in a sump or drain it is usually discharged diffusely as a nonpoint source.

The factors contributing to and/or affecting on-farm tailwater production are manifold. In areas where water is scarce or expensive, tailwater is seldom discharged or, if produced, is generally reused at or close to the site of production. Although the price of water is not the only factor dictating water reuse, a general observation indicates that as irrigation water costs increase tailwater recovery systems become economically advantageous. Also in time of drought conditions, such as the 1977 drought in California, irrigation water is more carefully managed and reuse is more extensively practiced. In areas where water is plentiful or inexpensive, there is a tendency for large water applications and production of tailwater. The production of tailwater, however, does not necessarily mean inefficient water management since reuse is commonly practiced.

The tailwater produced is usually captured and reused, either by plan or incidentally, at the site of production or downstream. The reuse of tailwater and other collected return flows may occur at several spatial levels, for example, within an individual irrigated field, on-farm (i.e., capture and reuse in downslope field by landowner), district level (irrigation, drainage, reclamation), and up to river subbasin, river basin, and interbasin levels.

The types of beneficial uses made of tailwater and other collected irrigation return flows include irrigation of crops and pasture, maintenance of wetland/waterfowl habitats, livestock water supply, groundwater recharge, maintenance of summer (low) flows in stream beds which would otherwise become dry, repulsion of salinity in tidal estuaries, fish migration and spawning, warm water fish habitat, navigation, recreation and aesthetics, and municipal/industrial water supply

One of the major factors contributing to the production of tailwater is irrigation application method. Surface flood irrigation methods (basin, border, furrow), have inherent limitations, making it difficult to attain high application efficiencies. The slope of the irrigated field, length of run, size of stream used, and water intake (infiltration) rates are some of the critical factors affecting tailwater production. These critical factors must be balanced within a system to obtain efficient water application. Tailwater is less frequently produced in well-designed and properly managed sprinkler and drip irrigation systems. In surface flood irrigation, however, it is difficult to attain application efficiencies in excess of 85% for basin and border methods and 90% for furrow method. It is exceedingly difficult to completely eliminate runoffs from flood irrigation methods other than from level borders and basins or level furrows. These estimated runoffs and attainable irrigation system efficiencies are dependent not only upon system design but also upon technical skills of irrigators.

Tailwater Quality

The quality tailwater usually is similar to that of the applied water but could be quite variable, sometimes an improvement and other times a deterioration in overall quality and/or specific parameters. The quality of applied water usually has a strong influence on the quality of tailwater. In some instances, tailwater quality may be considerably degraded because of the pickup of dissolved mineral salts, sediments, and agricultural chemicals

In other instances, tailwater quality may be improved over that of the applied water. This is possible because of the deposition of suspended solids which may contain sorbed agricultural chemicals as well as the potential reduction of degradable pollutants as in flooded rice fields.

Significant changes in tailwater quality may occur abruptly over a short time period or over an extended period For instance, aerial applications of ammonium sulfate fertilizer in rice fields may result in a pulse of ammonia (NH_3) and nitrates (NO_3) in the runoff waters over a two-to-four-day period whereas suspended solids in the flood waters are significantly reduced by sedimentation over the rice growing season.

Suspended matter is frequently the quality parameter of most concern in tailwater. Water passing over the land surface has a tendency to erode the soil and to transport both mineral and organic matter in a suspended form Associated with the suspended matter are several classes of water quality constituents such as sorbed pesticide residue and other toxicants like certain metals and boron (B), nutrients like phosphorus (P) and nitrogen (N), and certain soil minerals like gypsum ($CaSO_4 \cdot 2H_2O$) which may later dissolve in the water contributing to a rise in salinity. Thus, the reduction of sediments in tailwater will not only help in minimizing the undesirable impacts of sediment per se, but also decrease the discharge of pollutants associated with the sediments.

Other pollution and/or quality parameters in tailwater may be of importance for site-specific conditions and practices. Nitrogen may be picked up by tailwater in both organic and inorganic forms as well as dissolved and particulate forms. In general, runoff waters from close-growing crops (e g , rice and pasture) contain a predominance of organic nitrogen over that of inorganic forms (NH_3, NO_3, NO_2) and vice versa from widely-spaced crops (e.g., row crops).

In the reuse or renovation of high nitrogen-containing wastewaters, however, large reduction in nitrogen in the effluent may be achieved by passing water overland on grasslands or in anaerobic ponds. The reduction is attributed to denitrification and assimilation by plants.

Phosphorus, like nitrogen, exists in many forms. In general, the concentration of dissolved phosphorus is low in tailwater due to the low solubility of phosphorus compounds However, significant amounts associated with mineral and organic matter may be discharged in runoff

Pesticide residue may be present in tailwater, but the concentrations of pesticides are highly variable both in time and location. This is due to the wide variability in mode of applications, formulations, soil interactions, and chemical properties such as solubility, volatility, and biodegradability.

Tailwater Control and Management

There appears to be no one universal control technology for tailwater and other collected surface irrigation return flows due to the wide variability in the quantity and quality of supply waters and return flows. The various management practices may include one or more of the following: improve irrigation application efficiencies to attainable levels, capture usable irrigation return flows, discharge tailwater only as required by cultural practices, install sediment retention sumps or other facilities, install tailwater recovery system and reuse at farm site, allow for limited tailwater discharge under either low stream flow conditions to augment/maintain flow when it is desirable or under high stream flow conditions to minimize impact of pollutants discharged, and elimination of discharge of tailwater. The above technology is available,but in some, the systems or water controls needed are so costly that current conditions do not justify them. For instance, to allow for limited tailwater discharge under either low or high stream flows may require large holding reservoirs if the timing between tailwater production and discharge allowed into streams do not coincide.

The application of the foregoing array of possible technology should be site-specific. Although there may be some that can be broadly applied, there is no single, universally-applicable control technology for irrigated agriculture. Elimination of tailwater at all sites is not practical or feasible. These control technologies also may be viewed in terms of source control, effluent treatment, and reuse.

The least-cost combinations of agricultural production and labor, capital, irrigation water, and tailwater management and reuse were analyzed for a variety of alternative on-farm irrigation systems of varying sizes. Economic-engineering cost studies of several field-level (0.688 km^2, 170 ac) alternative irrigation systems indicate that systems designed to minimize tailwater discharge will lower annual irrigation costs compared to a conventional furrow method These cost savings are primarily due to the low water and labor requirements. These studies were based on the 1976 interest rates, input prices, and water application rates for a 0 688 km^2 tomato field in the San Joaquin Valley study area The alternatives considered are as follows:

(1) side-roll sprinkler system

(2) furrow irrigation with gated pipe and a tailwater reuse system

(3) a hand move sprinkler system

(4) variable interest and labor cost rates

(5) differential water costs

Recommendations

Mitigation of the impacts of irrigation tailwater can be accomplished by both technical and managerial methods. Improved irrigation efficiencies should be achieved by adopting improved application methods, irrigation scheduling and training of irrigators.

Tailwater and other usable collected irrigation return flows should be recovered and reused whenever this practice will be a cost effective method of improving water quality.

For locations where the collected subsurface waters are considerably more degraded in quality than the surface runoff, attempts should be made to keep these two types of irrigation return flows separate so that the surface runoffs will have greater reuse potential for all sectors of society.

Under certain conditions, it may be more operationally efficient to capture and reuse water at larger spatial levels than field-site and farm-site, e.g., water district, irrigation project, or basin.

Where there are detrimental impacts due to the sediment load in tailwater, sediment source control practices and/or sediment removal operations should be considered

(1) Under conditions of moderate to high erosion hazards, particularly with surface irrigation methods such as wildflooding, corrugations and furrows, source control practices should be implemented, including better control of water by reducing the length of run and slope, or contouring

(2) Where the sediment load in tailwater is a problem, sediment retention facilities should be built. Sediment removal may consist of sedimentation tanks or ponds, vegetated buffer strips at the end of irrigated fields and water spreading over contiguous grasslands and ponds.

The discharge of tailwater should be minimized during and immediately after the application of agricultural chemicals (for instance, injection of anhydrous ammonia in irrigation water, aerial top-dressing of fertilizers and herbicides on flooded rice fields, etc.) to prevent pulses of pollutants from being discharged into receiving waters.

Wherever possible, the resources and expertise available in line agencies (USDA-Science and Education Administration-Agricultural Research, USDA-Economics, Statistics and Cooperative Service, Soil Conservation Service, Water and Power Resources Services, Agricultural Experiment Stations and Cooperative Extension Services, and other state agencies) should be utilized to develop and implement Best Management Practices.

Where there appears to be no incentives or tangible benefits for irrigators to implement water quantity/quality control measures, cost sharing, low-interest loans,and other incentive programs should be explored in order to equitably distribute the financial burden of maintaining water quality.

Due to the site variability of receiving waters,and of tailwater production and quality, the authors do not recommend any single universally applicable control technology. The effect(s) of tailwater discharge into surface waters may be either beneficial, detrimental or both, depending on the quality constituents of interest and water flow A practice that is effective in one location may not be as effective in another

Irrigation return flows and the resulting waste loads range widely in controllability. Management and controls should be adopted on the basis of both cost and technical efficiency

Site-specific factors and conditions on a case-by-case basis should be considered in developing regulatory guidelines, controls, or standards. Local, as well as state-wide, standards should be developed which are in conformance with the national goals These site-specific plans and management, however, should be compatible and mutually beneficial at the basin and interbasin levels.

Additional information on the subject of irrigation tailwater management is available through the National Technical Information Service as.

EPA-600/2-81-034b, "1975-1976 Annual Report on Irrigation Tailwater Management," (Order No. PB 81-200 545; Cost· $17.00)

EPA-600/2-81-034c, "1976-1977 Annual Report on Irrigation Tailwater Management," (Order No PB 81-200 552; Cost. $18.50)

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***Arthur Hornsby** is the EPA Project Officer (see below).*

The complete report, entitled "Irrigation Tailwater Management," (Order No. PB 81-196 925; Cost: $12.50, subject to change) will be available only from:
National Technical Information Service
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Springfield, VA 22161
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