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MONITORING SOFTWARE FOR POLLUTANT COMPONENTS IN FURROW-IRRIGATION RUNOFF

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ABSTRACT

Non-point source pollution from furrow-irrigated agriculture threatens surface water quality throughout irrigated regions of the world. For example, sediment or dissolved chemicals contributed by irrigation return-flows can degrade habitats and increase user costs downstream. The threat from these pollutants has been fully appreciated only recently, resulting in an increased interest in runoff monitoring. However, analysis of runoff data from furrow-irrigation is cumbersome and time consuming. Calibration functions relating measured quantities to desired water-component concentrations must be obtained for each treatment (e.g. a calibration function relating measured component volumes to runoff component concentration). It is awkward and tedious to plot or analyze constituent runoff data by treatment. The PASCAL program described here reads inflow and runoff data from an ASCII text file and derives, displays, and statistically compares calibration functions for treatments or any other user-defined furrow group. It employs the computed or a user-supplied function to calculate infiltration, runoff, and component loss for each furrow. In addition, the software computes and plots group-averaged values for inflow, outflow, infiltration, runoff constituent loss, and outflow constituent concentration as a function of irrigation duration.

Keywords: Furrows, Irrigation, Runoff, Sediment discharge, Field losses, Infiltration.

INTRODUCTION

Several field constituents are lost from furrow-irrigated fields in tailwater, including eroded sediment (Berg and Carter, 1980, mineral and fertilizer salts (Carter, et al., 1973), pesticides (Hall, et al., 1991), weed seeds, and disease organisms (e.g. nematodes). When these displaced materials enter the return flow, the stream becomes a potential non-point pollution source of surface waters.

Some 1.5 million ha of highly erodible soils are furrow irrigated in the Pacific Northwest. Soil-losses ranging from 5 to 50 t ha^{-1} yr^{-1} occur on many ha in South-Central Idaho (Berg and Carter, 1980). Soil erosion is a critical process because other field components such as total phosphate and pesticides are closely associated with fine soil particles, hence, phosphate or pesticide losses are directly related to amount of sediment removed from fields in irrigation runoff.

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WASHOUT is a comprehensive Pascal program that may be used to compute and plot irrigation inflow, runoff, and infiltration values, and ongoing pollution-component-losses (e.g. sediment) in furrow tailwater. Calibration functions relating measured component indexes to runoff component concentration (e.g. functions relating volume of settled sediment in Imhoff cones to mass of sediment per unit volume runoff) are computed by WASHOUT. Calibration functions can be computed separately for different furrow conditions and statistically compared to determine whether the individual functions are required to compute field component losses. Net infiltration is calculated, and calibration functions are employed to estimate the runoff constituent and its net loss for each furrow. WASHOUT computes and plots group-averaged values of cumulative constituent loss, outflow constituent concentration, and flow rate as a function of irrigation duration.

USING *WASHOUT* TO MONITOR FURROW SOIL LOSSES

We used WASHOUT to monitored furrow-irrigation induced sediment losses in Southern Idaho. Sediment content in furrow tailwater was measured using the Imhoff cone method. The technique employs a calibration function that correlates the sediment volume settled in an Imhoff cone after 30 min, with sample sediment concentration (weight per unit volume runoff).

Field measurements were made on each experimental furrow. These included irrigation inflow, out-flow, and settled sediment volumes from 1-L runoff samples collected in Imhoff cones. Identifying codes, furrow spacing and length were noted for each furrow. Time and inflow rate were recorded whenever furrow inflow was adjusted. Time, outflow rate, and sediment volume were recorded at each sampling interval. Outflow rate and sediment volume were measured at 5 and 15 min after furrow advance, then every 30 min during the next 3 h. From then on, measurements were made hourly, with a final appraisal made just prior to inflow shut off. Four to ten runoff samples, representing the sampling range were collected from Imhoff cones for each treatment. These were filtered in the laboratory and sediment mass was used to compute calibration functions (see following section). Details on furrow monitoring and filtering techniques were reported previously (Lentz and Sojka, 1994).

WASHOUT reads the raw data from an ASCII text file. Information for each furrow is entered as a block, beginning after the initial data file title record. Computer data entry is simplified because the field data sheet format closely matches that of the input file (e.g. see Sojka et al., 1994).

Imhoff Cone Calibration Functions

The program computes Imhoff cone calibration functions for up to 20 different groups defined by one or more of the furrow identifiers. The ability to declare group types permits one to determine those treatments or factors that require unique calibration functions. Sediment mass of collected calibration samples are regressed on the corresponding Imhoff settled-sediment volumes using the least squares method. Sediment concentration ($\mathbf{SCONC}_i$), in g L^{-1} for each irrigation interval (i), is estimated from the calibration equation: $\mathrm{SCONC}_i = \mathbf{B} \cdot \mathrm{SVOL}_i + \mathrm{C}$, where **B** is the slope, **C** is the Y-intercept, and $\mathbf{SVOL}_i$ is the Imhoff cone settling volume (mL).

WASHOUT then tests for similarity among calibration functions using an ANOVA F-test . Up to four of any of the groups can be tested at one time. After defining groups to be employed in the analysis. WASHOUT asks for the number and identification of groups to analyze. Regression functions for each group are computed and both lines and data points are displayed (Fig. 1), permitting a rapid graphic assessment of regression fit. Next, a statistical comparison between group calibrations is completed; and the functions are displayed on screen, along with F-test statistics (Fig. 2). This analysis determines whether unique calibrations are required for each group.

Infiltration and Sediment Loss Calculations

When calibration function analysis is complete, the program requests the user to specify which calibration function to apply to each of the previously selected furrow groups. Output values are then calculated for all furrows in each group. At this point a program prompt permits the user to request a data display for individual furrows (Fig. 3).

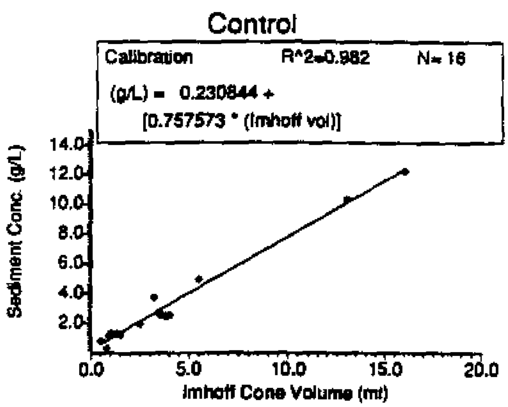

Fig. 1. Calibration function and data points. Four functions per page.

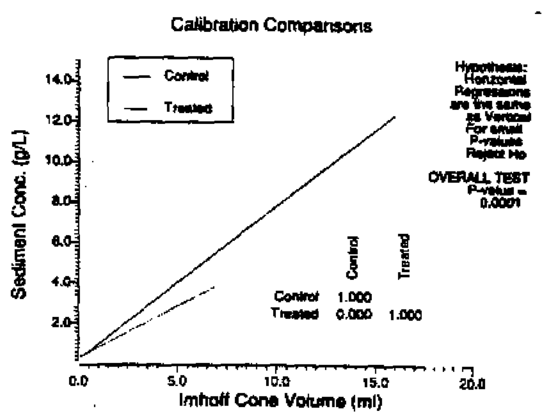

Fig. 2. Display of compared calibration functions and F-test statistics.

The software outputs computed values to an ASCII text file, which is readily imported into statistical or graphics software. Furrow identifiers are included to aid in sorting data. Each data column in the output file is labeled. Calculated outputs include mean outflow in L min^{-1}, total sediment loss in kg/ha, total inflow in mm, total outflow in mm, total infiltration in mm, mean sediment concentration in g/L, depth of soil loss in mm, infiltration in inches, and furrow advance time in minutes (time required for the water to traverse the dry furrow).

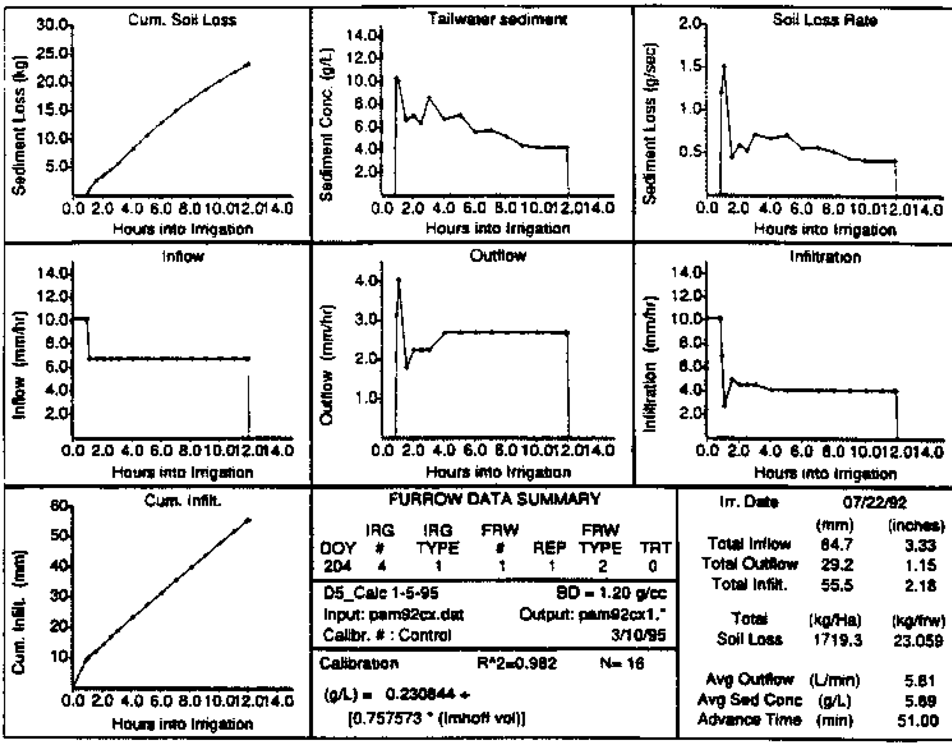

Fig. 3. Display option for individual furrow output.

The program also outputs a second file, which contains irrigation duration data. WASHOUT can tabulate furrow data based on group or furrow identifier. Compiled irrigation parameter values, cumulative soil loss, runoff sediment concentration, and outflow rate are averaged within the defined groups and plotted as functions of irrigation duration (Fig. 4).

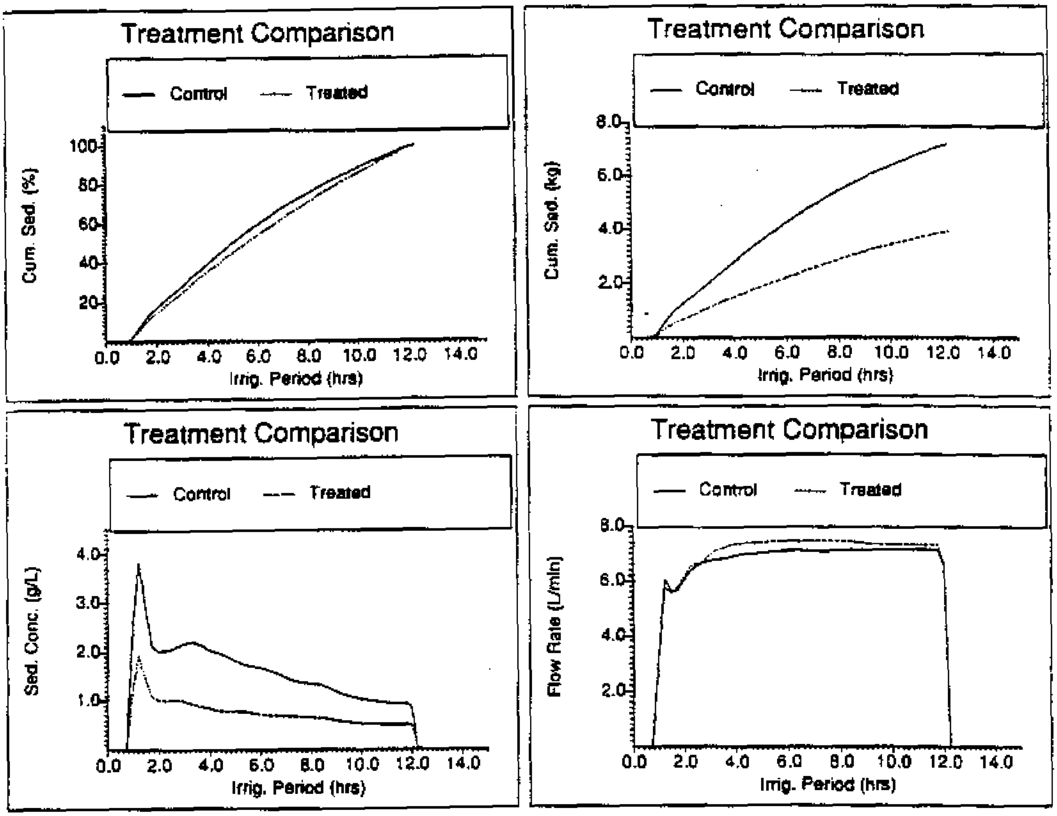

Fig. 4. Display of group-averaged irrigation parameter values plotted as a function of irrigation duration.

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Water-Alluvium-Solute Hydrographic OUTflow

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Developer

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Description

The Water-Alluvium-Solute Hydrographic OUTflow (WASHOUT) program automatically analyzes furrow flow and runoff component data. The objective of the program is to compute and plot irrigation inflow, runoff, and infiltration values, and ongoing pollution-component-losses in furrow tailwater. Subsequently, WASHOUT computes net values for the above variables.

WASHOUT can optionally compute net application of a liquid additive (from a stock solution) that is injected into the furrow stream at the furrow head.

Program inputs are irrigation interval measurements of inflow and runoff rates, and outflow pollutant concentration. Input measurements and output data are processed for individual furrows.

Water Quality Applications

WASHOUT can calculate the loss of sediment, fertilizer nutrients, pesticides, and other components in tailwater leaving irrigated furrows.

Features

- The Datachk3 utility examines data input files, ensuring that file format is correct and parameter values fall within an appropriate range. When errors are discovered, Datachk3 automatically loads the offending data segment into a text editor for correction, and replaces the original data with the modified text.
- Calibration functions relating measured component indexes to runoff component concentration (e.g. functions relating volume of settled sediment in Imhoff cones to mass of sediment per unit volume runoff) are automatically computed.
- Optionally, the user may request a piece-wise linear regression, entering the component index value at which slope transition occurs.
- Calibration functions can be computed separately for different furrow conditions and statistically compared to determine whether the individual functions are required to compute furrow component losses.

- Inflow, runoff, infiltration and component loss rates are computed for each measurement interval during the irrigation. Irrigation duration may be given in hour units, or as a percent of the total irrigation set.

- Cumulative component loss (kg) and component concentration (g/L) in tailwater are computed for each measurement interval during the irrigation.

- Net component loss is computed by integrating the interval component loss-rate over the irrigation period.

- Net outflow is calculated by integrating outflow rate over the entire irrigation

- Graphical output may be displayed on-screen or printed to a variety of printers. Furrow output is plotted as a function of irrigation duration. Seven graphs and a data summary are displayed on-screen simultaneously.

- Furrow groups in the input data file can be identified and their output characteristics computed using data-base searching and averaging programs.

Limitations

- Component concentration in inflowing water is not directly addressed in the program.

- A maximum of 30 irrigation measurement intervals is allowed.

- A maximum of 20 irrigation inflow rate changes allowed per irrigation set.

- A maximum of 1000 monitored furrows allowed per input data file.

- Output is in metric units

Support

Program diskettes, documentation, and limited technical support are available through the USDA Agricultural Research Service, Northwest Irrigation and Soils Research Laboratory, Kimberly, Idaho.

Future Developments

- Directly include inflow component concentrations in calculations.

- Improve the program interface.

- Develop a Windows version of the program.

Resource Requirements

WASHOUT requires a MS-DOS compatible system with 640K of memory and 1 megabyte of disk storage space. A math coprocessor is not required.