Report for 2002ND7B: Feedlot Runoff and Manure Management Modeling

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  - Kizil, Unal. 2003. Ph. D., "Development of a Software Program, Feedlot Hydrology/Nutrient Management, and GIS Database for the State of North Dakota." Agricultural and Biosystems Engineering Department,College of Engineering and Architecture, North Dakota State University, Fargo, ND 58105. Major Professor: Jim Lindley
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Report Follows:

Feedlot Runoff and Manure Management Modeling

ND WRRI Graduate Research Fellowship Project
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Abstract

The overall goal of this research is to develop a complete feedlot runoff and manure management model to predict runoff and its concentrations generated from feedlots, and develop an online GIS database. Preservation of environmental quality makes it essential that feedlot runoff be handled and controlled appropriately to prevent water contamination. Regulations, such as Clean Water Act, provide enforceable criteria for environmental protection from contamination by livestock production. Since the animal manure is exposed to the runoff, pollution potential of the feedlots depends on the size of operation, rainfall intensity, duration and frequency. According to data obtained from G. Haberstroh of North Dakota State Department of Health, there are 106,874 animal units (1 animal unit = 500 kg of live weight) of beef cattle have been growing in North Dakota. The importance of the feedlot operations in the State, pollution potential of feedlot runoff, and regulations make it imperative to pay more attention to animal operations, especially feedlots to protect water resources. Some watershed based hydrological and water quality models have been adapted to feedlot. A manure management plan model also has been decided to use in the study. A paper describing these models has been presented in ASAE Annual Meeting. In order to validate the hydrological and water quality models, field experiments have been conducted. Runoff measurements (quantity, quality), and manure sampling have been completed.

Critical state or regional water problem being investigated

In North Dakota for regulatory purposes a feedlot is defined as "any livestock feeding, handling, or holding operation or feed yard where animals are concentrated in an area which is not normally used for pasture or growing crops and where the space per animal unit is less than 600 ft^2 (56 m^2). Concentrating cattle in feedlots has numerous advantages in terms of productivity and quality control and is a practice widely accepted in North Dakota.

In the feedlots, large concentration of animals produces concentrated areas of manure production. Runoff from cattle feedlots contains relatively high concentrations of nutrients, salts, pathogens, and BOD demand. These nutrients, which are so beneficial to crops and soils, can have detrimental effects when carried into surface or groundwater. In surface waters they may cause large growths of algae, resulting in fish kills and decreased recreational opportunities. Nutrients in groundwater contaminate wells.

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Since the animal manure is exposed to the runoff, pollution potential of the feedlots depends on the size of operation, rainfall intensity, duration and frequency. According to data obtained from G. Haberstroh of North Dakota State Department of Health, there are 106,874 animal units (1 animal unit = 500 kg of live weight) of beef cattle have been growing in North Dakota. The importance of the feedlot operations in the State, pollution potential of feedlot runoff, and regulations make it imperative to pay more attention to animal operations, especially feedlots to protect water resources.

Anticipated results and benefits from the study

Considering the importance of livestock production and its potential affects on water quality in North Dakota there is a need to evaluate feedlot runoff. Anticipated benefits of the study can be summarized as follows:

a) Watershed based hydrologic and water quality models will be modified to predict feedlot runoff and its constituents.

b) Design criteria for ND feedlots will be developed as a result of the field experiments

c) The user friendly computer program will enable the producers to design runoff control structures, make manure management plans

d) Use of the computer program will reduce the overall risk of water pollution due to improper handling and management of runoff and manure.

e) North Dakota feedlots will be spatially evaluated using GIS and evaluation results will be provided online.

f) These results will demonstrate the critical watersheds in North Dakota from the viewpoint of feedlot runoff.

g) Feedlot owners will be able to evaluate their feedlots online to see if their feedlot meets the State criteria

h) Using the computer technologies, such as Internet and GIS, it will be possible and easy to reach the producers, and update information.

i) The results will provide a good base for the future studies.

Scope and objectives of the research

The overall goal of this research is to develop a complete feedlot runoff and manure management model to predict runoff and its concentrations generated from feedlots, and develop an online GIS database. The corresponding objectives to achieve the goal are to:

- define the hydrologic models for feedlots, and conduct field experiments to validate these models
- develop a user friendly computer program that will help users to predict runoff and its characteristics, design runoff management structures, and make manure management plans.
- develop an online GIS database for North Dakota feedlots that will help scientists for Nonpoint Source (NPS) evaluation, and estimate the overall pollution risk which might be generated from the feedlots.

The first objective of the study has already been completed. Some watershed based hydrological and water quality models have been adapted to feedlot. A manure management plan model also has been decided to use in the study. A paper describing these models has been presented in ASAE Annual Meeting. In order to validate the hydrological and water quality models, field experiments have been conducted. Runoff measurements (quantity, quality), and manure sampling have been completed. Flowcharts of the proposed computer program are ready. Fellowship study included the development of computer program, and validation of the results. Feedlot database that was obtained from the ND Health Department were converted to GIS format. For different rainfall events such as 10 year-24 hour, 25year-24 hour, the developed computer program was run, and results published online along with database in GIS format. An ArcView extension was used to achieve it.

Methods, procedures, and facilities

In this study, Bison Feedlots of Carrington Research Center of North Dakota State University were chosen. Carrington is 40 miles NW of Jamestown, ND and 134 miles West of Fargo, ND. Runoff from 2 lots were measured. Each 4 lots drain into a runoff storage pond. There are 2 storage ponds of size 64x16 m (1024 m^2). Size of each lot is 22x21m (462 m^2); drainage area of each runoff storage pond is 67x54 m (3618 m^2) including the pond surface area. Two flowmeters, 2 runoff samplers, and 1 water sampler (from the storage pond) were installed.

The following procedure was followed to accomplish the objectives and associated tasks of the study:

Objective 1: To define the hydrologic models for feedlots, and conduct field experiments to validate these models

a) Definition of Hydrologic Models for Feedlot Runoff: The preliminary objective of this study is to define the hydrologic models for the estimation of feedlot runoff. Although, some studies have been conducted to predict feedlot runoff, results vary widely.

b) Determination of Runoff Curve Number for Feedlots: The key factor in the estimation of runoff is curve number. To determine the curve number for North Dakota conditions runoff data were collected from 2 feedlots.

c) Prediction of Runoff Characteristics: Using nutrient and sediment transport equations it is possible to predict amount of NO_3-N lost from the first layer, organic N runoff lost, soluble P lost in runoff, sediment phase of P in runoff, and sediment yield etc. In the study, collected feedlot soil, runoff, and manure samples were sent to a commercial labs. Lab results will provided data for required variables, and feedlot runoff characteristics. Then, nutrient and sediment transport equations were calibrated for feedlots.

Objective 2: To develop a user-friendly computer program that will help users to predict runoff and its characteristics, design runoff management structures, and make manure management plans

a) Hydrology and Nutrient Transport Module: After finding the required variables for hydrology and nutrient transport model in Objective 1, Visual Basic programming language was used to develop a software program.

b) Manure Management Module: The procedure used in this module provides step-by step plan development instructions and worksheets. Entering the required information a complete manure management plan can be prepared. This module balances the plant nutrient requirements, available soil nutrients, and feedlot runoff/manure nutrients. A proper manure management prevents excessive nutrient load to the field, therefore reduces the water pollution risk.

c) Runoff Control Facilities Design Module: This module will design runoff control facilities, such as settling basin, runoff and manure holding ponds, for a given feedlot operation.

Objective 3: To develop an online GIS database for North Dakota feedlots that will help scientists for Nonpoint Source (NPS) evaluation, and estimate the overall pollution risk which might be generated from the feedlots

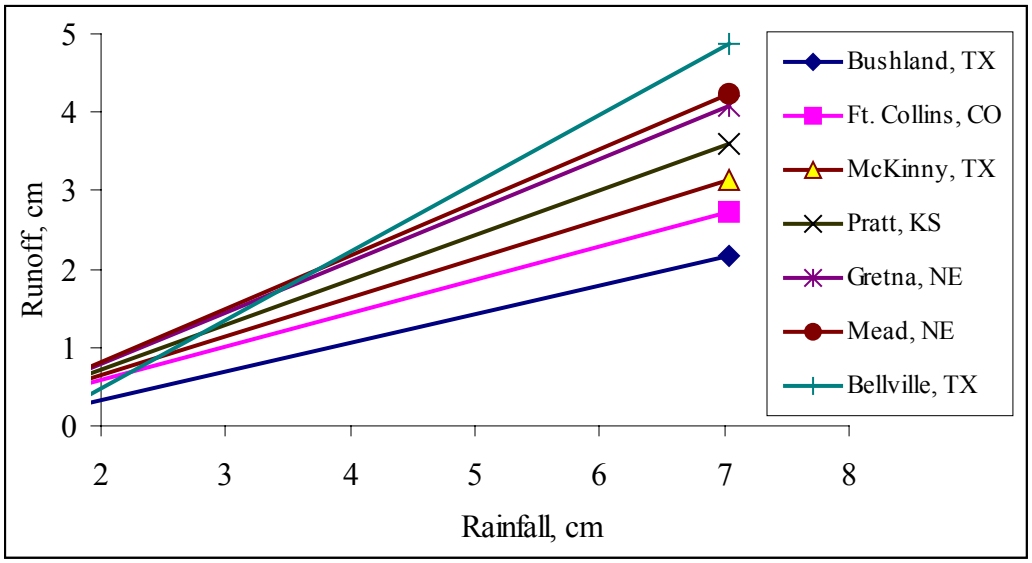
a) Development of On-line GIS Database: A complete feedlot database for the State of North Dakota has been obtained from Health Department. The database includes the coordinates of feedlots, number of animals, status (active or not), county, animal type, watershed etc. In ArcView GIS software a GIS-based feedlot database was developed. GIS-based database includes the mentioned information about the feedlots. Feedlots can be evaluated on-line considering the State Laws and literature.

Results

Objective 1:

Runoff generated from the feedlot and contributing areas, was calculated using SCS Curve Number method. This method is based on a number called "runoff curve number". Determination of runoff curve number is the key factor in the prediction of runoff, and nutrient transport from a feedlot. There is literature reporting the curve numbers for feedlot operations. However, this number is dependent on soil characteristics, soil cover and use, and rainfall intensity etc. Therefore, the literature values vary significantly.

The other technique has been used in the runoff prediction is developing linear relationship between rainfall and runoff. Relationships between rainfall and runoff at different locations in the USA are given in the following figure (1).



As can be seen from the figure, slopes of the linear equations are different at each location. Therefore it is essential to determine the linear relationship for the study area of interest.

The estimation of runoff quality and quantity is critical. Design of runoff containment structures, nutrient budgeting, and pollution discharge to a water body – if no containment structure available – are dependent on a good estimation of runoff depth. Therefore, developing rainfall-runoff relationship and/or determining runoff curve number for North Dakota is highly important from the view point of pollution transport from feedlot operations to the water resources of the State.

In our study we found that a curve number of 93 can be used to estimate runoff amount, and the following relationship gives the highest R^2-value of 73 between rainfall and runoff events.

$$R = 0.57P - 1.16$$

Where:

R = runoff, mm

P = rainfall, mm

Another goal of the Objective 1 was to evaluate some hydrology/nutrient transport models, such as EPIC and AGNPS. The EPIC model is a watershed-based model that can be used to predict runoff and nutrient transport along with the runoff from a particular watershed. Soil nutrient concentrations, such as N, P should be known to estimate runoff nutrient transport.

In the AGNPS model a simpler approach is used in the prediction of nutrient transport from a feedlot. Average feedlot runoff N, P, or COD concentrations should be provided to the model. Proportional to the percent manure pack on the feedlot surface, the default nutrient concentrations are changing for a particular feedlot operation. For example, if the percent manure pack is 100, it is assumed that runoff nutrient concentrations will be equal to the default values. If it is less than 100, the actual nutrient concentration of the runoff will be decreased proportional to the percent manure pack.

The purpose of our study is to see if the EPIC model approach, which is a watershed-based model, can be used to estimate nutrient transport from the feedlots. The AGNPS approach was supported with EPIC model approach. Because each model is specific to certain nutrient compounds.

The EPIC and AGNPS models were adapted to feedlot hydrology in order to predict runoff quality and quantity. Organic-N and P were predicted with high correlation coefficients of 0.89 and 0.81 respectively. Hence, the model can be used in the prediction of Org-N and P transport. Use of model will provide an opportunity to evaluate overall pollution potential of a feedlot operation if no runoff confinement systems exist.

Even though the model did not provide a good coefficient of correlation for other nutrient compounds, still the predicted results are a good representation of actual data. The runoff collected from the feedlot is not applied to field as it is generated. Stored runoff characteristics change significantly during rainy weeks, but during storage period the average pond characteristics stay stable. This implies that accurate estimation of runoff characteristics is not necessary for waste management purposes. As discussed above, average predicted and observed runoff characteristics are satisfactorily close to each other. Therefore knowing the average runoff characteristics and storage losses might be good enough to manage the feedlot runoff.

The EPIC model uses the soil nutrient characteristics as inputs and predicts the amount of nutrient transport by runoff. In this study manure samples that were collected from the feedlot surface were used as source of nutrients. The manure samples were a mixture of

soil, feces, urine, water, and spilled feeding materials. During the study the animal density was high enough to provide evenly distributed and compacted manure. It is showed that manure analysis results provide data not only for manure management planning but also nutrient transport models.

Carrington Research Center of the North Dakota State University (NDSU) University provided the feedlots, and information about the animals, operation period, etc. An automatic liquid sampler was obtained from the Civil Engineering Department of NDSU.

Objective 2:

The second objective of this study is to develop a user-friendly computer program. The program has 3 modules as follows:

1- Hydrology/nutrient module: In this module runoff quality and quantity is calculated using the models explained in the previous objective. Amount of nutrient loading to a water body (if there is no runoff containment structure, or in case of a failure of the containment structure) is estimated in this module. Also, runoff quality and quantity data is used in the second module to make a manure management budget.

2- Manure management module: Mass balance approach is used in the program to predict the nutrient fate of the manure. Manure and/or runoff application rate, required commercial fertilizer amount, and commercial value of the produced manure are some of the outputs of this module. Over application of manure and/or runoff might create water pollution due to the excess amount of nutrient build up in the soil followed by surface runoff or leaching. Therefore it is essential to apply optimum amount of manure/runoff to the field. This module can be used as a tool that provides environmentally sound waste management plans.

3- Storage or treatment system design module: The last module of the program provides a tool to design waste storage and treatment systems. To protect water resources from feedlot related pollution, manure/runoff should be controlled. Generally control means containment of the waste material and application of it to the field when the soil, and weather suitable. The design criteria were taken from the Agricultural Waste Management Field Handbook of USDA Natural Resources Conservation Service. The software was written in Visual Basic programming language.

Feedlot Runoff Measuring System

Sampling System