CONVEYANCE LOSS MODELING OF TWO WYOMING RIVERS

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ABSTRACT

Conveyance loss modeling was performed on the Greybull River and the Wind River in Wyoming using the USGS hydrologic computer model J349. The conveyance losses determined by the model present values which water regulators can use to more accurately assess downstream water users their proportionate share of the conveyance loss encountered by reservoir releases. A method is presented which estimates incremental conveyance losses for difference incremental flows on the Greybull River.

The model was found to most accurately simulate conveyance losses where flows in the river do not change more than 300 cfs during any given time simulation period and the total flow is in the range of 300 to 600 cfs. It was also found that the model is sensitive to transmissivity and storativity in determining conveyance losses which means that accurate field data is needed in calibration of this type of model.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

BACKGROUND

Today, water in the west and in the state of Wyoming is a scarce resource, a resource which must be accounted for and conserved. Water in Wyoming has many uses, including: recreation, wildlife habitat, power generation, municipal, domestic and agricultural. With so many uses placed upon Wyoming's water, it becomes obvious that there is a real need for an accurate accounting of this precious resource.

Water in the State of Wyoming is accounted for by several means. Measuring mountain snowpack, water removed from groundwater wells or the quantity of water a given residence uses every month are a few of these means. One important process which continues to require accurate measurement and research is conveyance loss.

At its simplest, conveyance loss refers to the amount of water a stream or canal naturally loses in being conveyed between two points along its course. Conveyance loss is crucial to all appropriators. Most appropriators, including farmers and ranchers, need an accurate accounting of conveyance loss especially if they have rights in a reservoir. This is because they need to know how much total water to order from the reservoir (amount of water needed at the farm or ranch plus the conveyance loss amount).

There are many factors affecting conveyance losses in streams or canals. Pahl (1985) presents the following list of possible causes for conveyance loss:

Length of reach,
Natural flow of the river,
Size of increase in flow,
Precipitaticn,
Elevation and slope of water table,
Stream channel characteristics,
Silt layer characteristics,
Evaporation,
Evapotranspiration,
Hydraulic characteristics of the aquifer,
Irrigation return flows,
Diversions, and
Valley cross sections.

Until recently, the methods most commonly used to determine conveyance losses of a stream or river were based on a water budget analysis. The concept of a water budget analysis is that the difference between the flow of water into a reach and the flow of water out of the same reach is the conveyance loss. The major drawback to this method of analysis is that a stable flow period over a long time interval is required (Hanlin 1988). Today, however, computer models are available which estimate conveyance losses without the requirement of a stable flow period. One such model is the J349 conveyance loss model (Farber 1992).

Farber obtained the source code for the J349 computer model from the United States Geological Survey (USGS) and modified the code so that it would run on a 286 or higher personal computer. Farber applied streamflow data collected by Pahl(1985) and Hanlin(1988) to the model. In his thesis, Farber concludes that the J349 model is capable of modelling actual streamflow data and would provide reasonable estimates of conveyance losses.

PURPOSE AND OBJECTIVES

The purpose of this research is to apply the J349 model to streamflow data collected on reaches of the Greybull and Wind Rivers to accurately estimate conveyance losses in these reaches. The results of this modelling will help local water commissioners, hydrographers and water appropriators to properly quantify conveyance losses. Appropriators will then be able to more accurately release the correct amount of water from storage. The objectives to accomplish the above purpose are:

1) Create a streamflow database of flow values for reaches on the Greybull River and Wind River.
2) Develop a methodology for determining incremental conveyance losses utilizing the J349 model.

CHAPTER II

REVIEW OF LITERATURE

The literature review covers the past history of conveyance loss studies on perennial streams in the intermountain western region. It summarizes the computer model J349 with its associated advantages and limitations for the analysis of conveyance loss modeling.

HISTORY OF CONVEYANCE LOSS STUDIES

Other States

Concerns over conveyance losses date back to the 1930's when the Twin Lakes transmountain diversion project was completed in Colorado. After completion of the diversion project, Hinderlinder (1938) began investigating conveyance losses on a 175 mile portion of the Arkansas River which extended from Leadville, Colorado to the Colorado Canal near Pueblo, Colorado. Hinderlinder encountered problems in determining conveyance loss because the reach in question experienced gains. He concluded that this gain was due to the rivers flowpath through an irrigated region.

Lacey (1941) continued the study on this river reach. The study included seven reservoir releases in which flow through the river as well as diversions along its flowpath were taken into account. Lacey too discovered that the gaining nature of this river reach made determining an accurate conveyance loss very difficult. The result of these two studies did lead the State of Colorado to assess a loss value of 0.07% on total flow per mile of stream in the Arkansas River for releases from Twin Lakes Reservoir.

Wright Water Engineers (1970) attempted to determine conveyance losses for the above 175 mile reach with data collected from a series of 30 reservoir releases performed between 1966 and 1970. The study was based upon an incremental type approach. Losses to evaporation, inadvertent diversions and bank storage were considered in this study. The study suggested that a varying conveyance loss should be assessed dependent upon the magnitude of reservoir release. Additionally, the study showed that the actual conveyance loss due to reservoir water was less than the 0.07% per mile previously suggested.

Livingston (1973) conducted another conveyance loss study on the same 175 mile reach of the Arkansas River. Livingston utilized an incremental conveyance loss approach and considered four primary losses in his study. These losses included the three previous losses (evaporation, inadvertent diversions, and bank storage) as well as channel storage. Losses were found to be dependent upon the duration and rate of reservoir release, as well as the time of year of the reservoir release. The results of this investigation yielded a conveyance loss which ranged from 0.03 % per mile to 0.16 % per mile.

Lucky and Livingston (1975) created a routing model which accounted for water wave time of travel, bank storage, channel storage and inadvertent diversions. This model was applied to the same 175 mile reach of the Arkansas River as previously mentioned. Results from the model yielded similar results to those found by Livingston in 1973. The model was found to be most accurate during relatively steady flow periods.

Livingston (1978) also modeled a different reach on the Arkansas River. The reach extended 142 miles from the Pueblo Reservoir to the John Martin reservoir. The model developed in 1975 was altered so that a greater emphasis could be placed on evaporation loss. Additionally, the portion of the model that accounted for inadvertent losses was eliminated. The results of this study showed that for a ten day release of 100 cfs, incremental conveyance losses ranged from 0.05% to 0.35% per mile. Livingston concluded from this study that 80% of the total conveyance loss could be attributed to bank storage while 10% could be accounted for in channel storage and the remaining 10% could be accounted for through evaporation.

Wright Water Engineers (1982) conducted a conveyance loss study on an 80 mile reach of the Fryingpan River between Ruedi Reservoir and Parachute, Colorado. A series of theoretical equations was used to estimate losses due to bank storage, channel storage and inadvertent diversions. Conveyance losses on this reach were estimated to range between 0.02% to 0.18% per mile.

Several models have been developed which account for conveyance loss using various relationships between flowrate and aquifer parameters. Pinder and Sauer (1971) and Zitta and Wiggert (1971) developed computer models which simulate the effect that flood waves has on bank storage. Moench (1974) developed a model that compares stream and aquifer parameters in routing reservoir releases on the North Canadian River in Oklahoma. Cunningham (1977) developed a model that correlates groundwater depth and corresponding streamflow to model conveyance losses on the Truckee River in Nevada.

Wyoming

Basin Electric Power Cooperative in 1975 (Wyoming State Board of Control, 1976) requested of the Board of Control a transfer of 98.73 cfs through 110 miles of river reach on the Laramie River. The route extended from the Laramie River diversion of the Boughton Ditch to Grayrocks Reservoir. The Board of Control granted a transfer of 41.86 cfs with an annual maximum of 3117 acre-feet. Conveyance loss values were estimated such that existing users were protected from loss. Conveyance losses assigned are as follows:

1) for a maximum daily diversion greater than 35 cfs, a value of 30% of total flow is assessed;
2) for a maximum daily diversion less than 35 cfs and greater than 22.5 cfs a value of 40% of total flow is assessed;
3) for a maximum daily diversion less than 22.5 cfs and greater than 5 cfs a value of 50% of total flow is assessed; and
4) for a maximum daily diversion rate less than 5 cfs, a value of 100% of total flow is assessed.

These conveyance losses average out to between 0.3% to 0.9% per mile of river.

In 1978, the Green River Development Company (Wyoming State Board of Control, February 1981) requested a transfer of 28.62 cfs to be routed 130 miles from the Green River and Cottonwood Creek through the Green River Supply Canal and Cottonwood Canal respectively. The Board of Control allowed a transfer of 14.31 cfs with an annual maximum of 2000 acre-feet. The Board of Control, basing the estimate solely on experience, placed a charge of 0.2% per mile to the transfer.

In 1985, Pahl completed a conveyance loss study on three Wyoming Rivers. A form of the mass balance equation was applied to streamflow data to determine incremental conveyance losses for the stream reaches in question. The equation applied in the determination was:

$$L = [\Delta I - \Delta D] - \Delta O$$

where L = Incremental loss,

ΔI = Increase in inflow,

ΔD = Increase in diversion, and

ΔO = Increase in outflow.

The major drawback to utilizing this equation is that steady flow periods are necessary for this method to predict conveyance losses accurately. A steady flow period is needed so that the stream-aquifer relationship is in equilibrium. Assuming that this is true, when flow is increased, all conveyance loss encountered would be due to that increase in flow.

Pahl determined that incremental conveyance losses are most likely to occur as a result of:

1) Evapotranspiration,
2) Bank storage,
3) Channel storage,
4) Inadvertent diversion, and
5) Reduction in groundwater inflow.

Research was conducted on three Wyoming rivers using the methods described. One reach modeled was Piney Creek from below Lake DeSmet to a USGS gaging station at Ucross, Wyoming. An incremental conveyance loss ranging between 0.76% to 1.66% per mile was calculated.

The second reach to be considered in this study was on the New Fork River. The reach in question ran from New Fork

Lake to a point approximately eight miles downstream. The incremental conveyance loss determined for this reach was 0.85% per mile.

The third study reach was on the Laramie River. The reach extended from Wheatland Reservoirs No. 2 and No. 3 to the confluence of the Laramie River and Sybille Creek, a distance of 51 miles. A conveyance loss of 0.34% per mile was calculated for this reach.

Pahl drew several conclusions from modeling the three stream reaches. First, the amount of conveyance loss in any reach is dependent on the amount of flow as well as the length of the flow period. Secondly, water lost to bank storage is not a true loss. When water stage within the reach recedes, most of the water stored as bank storage may return to the river system. Finally, this research determined average incremental conveyance losses ranging between 0.34% to 1.66% per mile.

In 1988, Hanlin completed a conveyance loss study on five Wyoming stream reaches. This study also used a form of the mass balance equation known as the net total loss type of conveyance loss. Net total conveyance loss is a method for assessing transfer charges to insure that water rights of existing users are not harmed. The net total loss equation takes the form:

(GAINS or LOSSES) = OUTFLOW + DIVERSIONS - INFLOW

The drawback to using this method for determining conveyance losses is that a steady flow period is needed to insure that the stream-aquifer relationship is in equilibrium.

Hanlin attempted to model five stream reaches. The first reach was a 52 mile segment of the North Platte River which extended from Guernsey Reservoir to the Tri-State Dam. Conveyance losses on the reach ranged from 0.3% per mile to 4.3% per mile. This compares reasonably well with the results of Livingston's (1973) research on the Arkansas River where losses were found to range between 0.02% to 4.3% per mile.

The second reach modeled was Piney Creek from Lake DeSmet to the Clear Creek at Carlock Ranch. A conveyance loss of 1.2% per mile was calculated for this reach. This compares well with conveyance losses determined by Pahl. Pahl found losses on this river to be within the range of 0.76% to 1.66% per mile.

The third reach to be modeled was 26 miles of Horse Creek from below the Woods and Lykins Diversion to just above the diversion into the Brown and Lagrange Canal. Conveyance losses for this reach ranged from 0.05% to 4.7% per mile. The upper value is high compared to the range of 0.34% to 1.66% per mile determined in earlier studies by Pahl.

The fourth reach to be modeled was on the Bear River between the USGS gaging station near Randolph, Utah to below

Pixley Dam. This study was discontinued however, due to lack of adequate streamflow data.

The fifth reach to be modeled was on the Green River from just below Fontenelle Dam to the town of Green River. This study too, was discontinued due to a lack of adequate streamflow data.

For each of the reaches modeled, Hanlin developed an equation of the form:

$$y=a+\frac{b}{x}$$

where y = stream gains or losses expressed as percent of inflow, and

x = average inflow.

This equation shows that there is a relationship between a stream's gains and flow in the stream. These equations can only be created for stream reaches with sufficient data such that the water balance approach may be used.

Farber (1992) completed research on conveyance loss modeling for two Wyoming rivers. Farber modeled the Green River from below Fontenelle Dam to the town of Green River. Additionally 50 miles of Piney Creek from Lake DeSmet to five miles east of Leiter, Wyoming were modelled.

Conveyance loss modeling for these reaches was accomplished using the computer model known as J349. Farber received the computer code for the J349 model from Gerhard

Kuhn of the United States Geological Survey. The code was initially written for use with mainframe computers and had to be altered for use with 286 or higher personal computers.

The J349 model was then utilized to determine conveyance losses on Piney Creek. Using the model on streamflow data collected in 1984, a conveyance loss of 0.65% per mile was calculated. Streamflow data for 1985 was separated into four sub-reaches. Conveyance losses were found to range between 0.011% to 0.52% per mile. These conveyance losses compare reasonably well with results determined by both Pahl and Hanlin.

The Green River reach could not be modeled in the same manner as the Piney Creek reach due to reservoir conditions at the time of the study. Flow was decreased on the Green River reach and then increased rather than just an increase.

The study revealed several interesting conclusions. First, the percent of the reservoir release lost to bank storage decreases as the reservoir release increases. Secondly, the percent of the reservoir release to bank storage decreases as the duration of the reservoir release increases. Perhaps the most important conclusion by Farber was that the J349 conveyance loss program is capable of providing reasonable estimates of conveyance loss to bank storage.

J349 HYDROLOGIC CONVEYANCE LOSS MODEL

The J349 model is a conveyance loss computer model which combines a streamflow routing component with a bank storage component to determine a total conveyance loss for a given reach. The program was published as a United States Geological Survey Computer Contribution (Land 1977). Equations inherent in the model allow for actual aquifer characteristics to be considered as part of the modelling.

Hall and Moench (1972) developed a system by which bank storage could be determined. The J349 hydrologic conveyance loss model utilizes this system in its code to calculate bank storage. Darcy's Law in combination with a one-dimensional confined aquifer equation are solved for flowrate either into or out of bank storage. Boundary conditions which can be applied to the equations are:

1) semi-infinite aquifer,
2) infinite aquifer, and
3) infinite aquifer with semi-permeable confining layer between stream and aquifer.

Keefer and McQuivey (1974) developed an equation to model streamflow based on the diffusion analogy. The J349 model routing component is based on this equation. This equation may be convolved in conjunction with upstream hydrograph data to determine the response of a stream channel. A multiple linear routing technique, used in the J349 model, is also described by Keefer and McQuivey. This option allows nonlinearities in the actual system to be segmented to better approximate a linear system with the computer model. The benefit of this is that the computer model, with these equations, has physical data as part of its routine.

Assumptions to the J349 Model

There are four basic assumptions inherent to the J349 computer model. The first is that the convolution technique presented by Keefer and McQuivey (1974) assumes that the hydrologic system is linear. The J349 model allows for the actual system being modeled to be segmented into smaller sub-reaches which may better approximate a linear system.

The second assumption is that the stream fully penetrates the aquifer. This assumption is important because it assumes a conservative approach to conveyance loss to bank storage. Looking at Darcy's Law:

$$Q=k*i*a$$

where k is the aquifer hydraulic conductivity, i is the hydraulic gradient of the aquifer and a is the flow cross-sectional area. When hydraulic gradient 'i' decreases, flowrate also decreases. Hydraulic gradient decreases as the length of flowpath increases. When the stream channel fully penetrates the aquifer the length of flowpath is at its smallest and the hydraulic gradient is at its largest. When the hydraulic gradient is large, the flowrate into the aquifer (by Darcy's Law) is at its greatest making loss to bank storage its greatest.

The third assumption is that the stream flows through the center of the aquifer. The model has components, as described earlier, developed by Hall and Moench (1972) which account for various aquifer types. This assumption is important because the model is designed to simulate losses to bank storage based on boundary conditions that are equal on each side of the stream in the transverse direction from the river channel.

The fourth assumption is that ground water in the aquifer is level with the system at the beginning of the modeling. This assumption is critical because water lost to bank storage may not be indicative of the actual amount of water lost for an incremental increase in flow if water levels are not stable prior to simulation.

Limitations to the J349 Model

Aside from the basic assumptions to the J349 model, there are also limitations to its use. One limitation is that the model does not account for evaporation losses within a study reach. Farber (1992) thoroughly develops a method for calculating evaporation losses for river reaches which includes use of evaporation data collected at nearby National Weather Service stations.

A second limitation to the model is that the model is limited to 399 time steps. This equals approximately 33 days given a two hour time step. This is not limiting, unless the travel time for the study reach is small, because the time step is normally set at the travel time for the river reach so that changes in the upstream hydrograph can be observed in the subsequent downstream hydrograph.

The most limiting factor, in terms of input structure, is that the model is limited to twenty-five changes in diversion values. A constant diversion rate may last through the entire length of the simulation, however if a diversion rate varies, each change in rate accounts for one of the twenty-five total diversions allowed. The result of this limitation is that if the diversion rates vary, for example, every four hours than the length of the study period could last only six days.

The model is also limited in that surface infiltration into the stream aquifer system from precipitation, irrigated lands, or from any other type of surface infiltration is not accounted for in the J349 computer model. The model also does not account for return flows from irrigation canals or introduction of water through precipitation events. The model also does not account for any flowrate in the aquifer parallel to the stream channel. The only aquifer parameter the J349 model accounts for is flow transverse from the stream directly into the aquifer.

Advantages of the J349 Model

The major advantage to the J349 computer model is that periods of steady flow are not required in order to determine conveyance losses. As discussed earlier in this paper, conveyance loss analysis generally requires a steady flow period in order to apply forms of the water budget analysis to determine conveyance loss. The results of Farber (1992), Livingston (1978), and others indicate that conveyance loss can theoretically be determined for any period of streamflow data.

A second advantage to this computer model is that a conveyance loss analysis can be accomplished with accurate streamflow data and only some physical information. For example, information on aquifer width and length of channel can be collected from USGS 7.5 minute quadrangle maps. All other data pertinent to the models operation, such as transmissivity and storativity, can be determined during the calibration process using the measured streamflow and diversion data.

A third advantage is that the J349 model consists of three hydrologic components. These components account for different aspects of conveyance loss. These aspects make the program applicable to situations where variables differ. These components are:

1) Streamflow routing component. This feature allows the user to segment the river reach when aquifer characteristics do not remain uniform for the entire length of the reach.
2) Bank storage component. This option allows actual aquifer characteristics, such as transmissivity,

to be considered as part of the calculations.

3) A stream depletion coefficient. This option allows the user to account for water being removed from the system through groundwater production wells.

A fourth advantage that the J349 model has over incremental or net total loss approaches is that physical properties of the aquifer are part of the J349 model.

CHAPTER III

STUDY AREAS

SITE SELECTION

The Wyoming State Board of Control, State Engineers Office and the Wyoming Water Development Office, over the years, have developed a list of potential study areas for conveyance loss analysis. The following criteria are used to select study reaches:

1) Stream reaches which have a significant amount of historical streamflow data.
2) Stream reaches which have a specific need for the determination of conveyance losses.
3) Stream reaches whose conveyance losses could be correlated to other similar streams in the same area or other areas of the State of Wyoming.

From this list, two areas were selected as the basis for this paper. Reaches selected for study were:

1) GREYBULL RIVER: from USGS Station Number 086276500 located at Meeteetsee, Wyoming to the Farmers and Bench Canals southwest of Burlington, Wyoming.
2) WIND RIVER: from USGS Station Number 06227600

near Kinnear, Wyoming to USGS Station Number 06228000 near Riverton, Wyoming.

A map showing the location of both study areas is given on Figure 1.

SITE SETTING

Greybull River Study Reach

The Greybull River has its headwaters in the Carter Mountains of the Absaroka Range in northwestern Wyoming. The streamflow of the Greybull River is produced mainly by runoff from snowmelt with some as a result of rainfall. The river flow is also augmented by several small springs and streams along its course. The one tributary within the study reach of significance is Meeteetsee Creek. The Greybull River reach is approximately twenty-four miles in length.

The Greybull River floodplain alluvium consists of pebbles with small boulders which in some places is overlain by a one to three foot layer of silt and sand. Occasional sedimentary rocks outcrop at the edge of the flood plain alluvium. Terrace deposits consist mainly of rounded pebbles to small cobbles and are overlain by a layer of one to three feet of thick silt and sand. Alluvial deposits range from sandy clay to silty sand and are anywhere between five and sixty feet thick (Cooley and Head 1979).

Water from the Greybull and Wood Rivers is stored in the Sunshine Reservoirs and discharges when needed into the

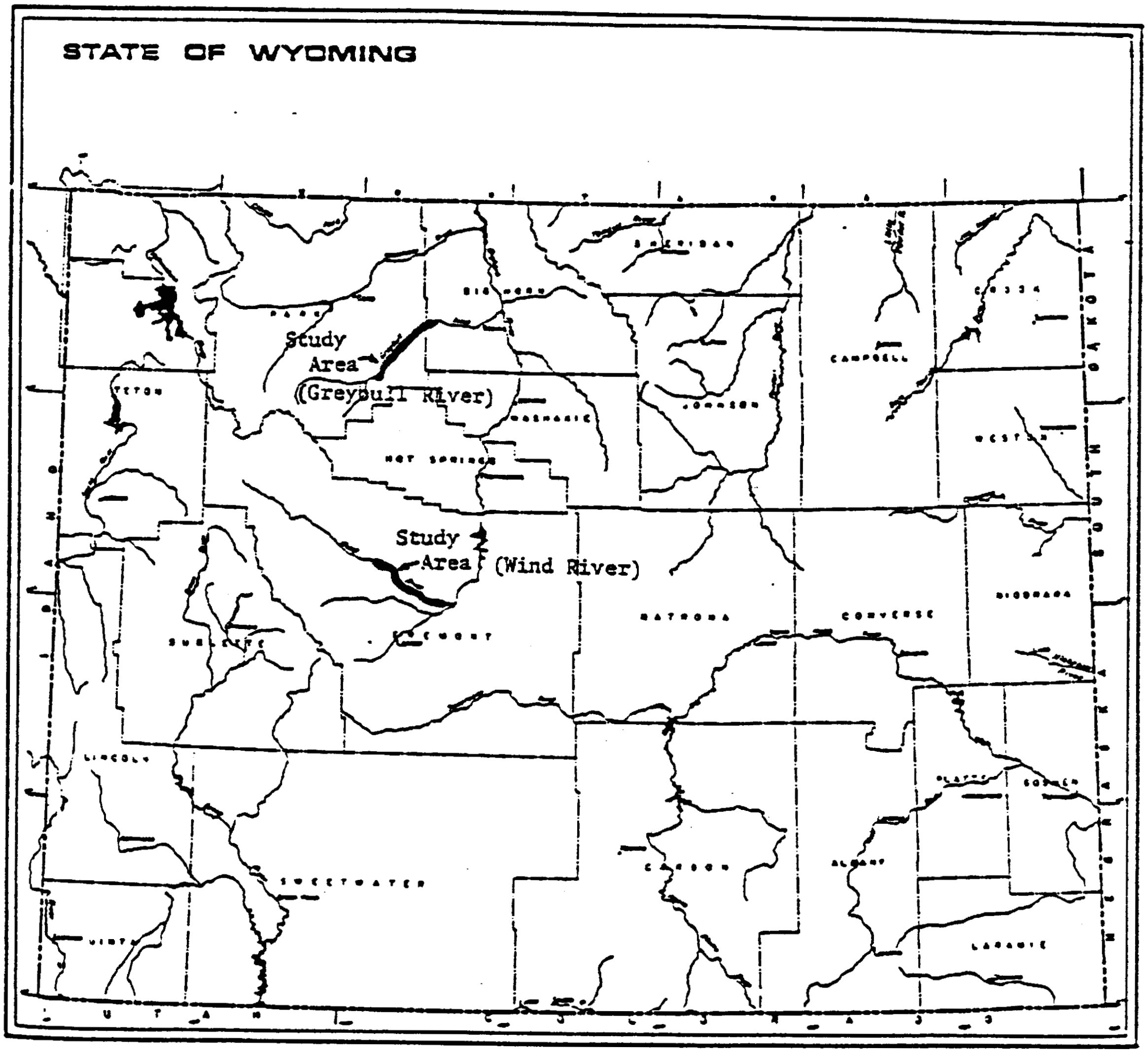


Figure 1. Location of Study Areas.

Greybull River for use by downstream irrigators. The main crops in the area include: hay, corn, alfalfa, sugar beets and soybeans. Farmed lands are irrigated mainly by flood irrigation with a small amount of sprinkler irrigation.

Wind River Study Reach

The Wind River has its headwaters in the Wind River Mountains of central Wyoming. Streamflow in the Wind River can be accounted for mainly by runoff from snowmelt with some rainfall events. There are many small tributaries that flow into the Wind River along its flow path but they are all ephemeral streams which had no flow during the study period within the study reach. The length of the Wind River study reach is approximately 24.1 miles.

Water is diverted from the Wind River for use by farmers. Farmed lands are irrigated mainly by flooding methods with some sprinkler irrigation. Crops in the area include: sugar beets, hay, corn, and soybeans.

CHAPTER IV

METHODOLOGY

SITE INSTRUMENTATION AND DATA COLLECTION

In order to determine conveyance losses in a reach using the J349 conveyance loss computer model, it is necessary to have stream flow data on the reach in question as well as flow records from the major diversions or tributaries along that reach.

Greybull River Study Reach

Along the Greybull River study reach, there were a total of twenty-two gaging stations installed to monitor flow and diversions. Each station was fitted with a stilling well, recorder stand, staff gauge and a continuous stage recorder. Two types of recorders were used in this survey, the Stevens Type F and the Stevens Type A-35. A table of recorders, and their locations on the reach are presented in Table 1. The purpose of these gaging stations was to accurately measure (using the mid-section method described in Rantz, et.al. (1983)) the amount of surface water flowing past that point. Figure 2 illustrates gaging station locations along the Greybull River.

Once the network of gaging stations was installed,

TABLE 1

DESCRIPTION OF GREYBULL RIVER STREAMFLOW GAGING STATIONS

Recorder Location	Control Section	Recorder
USGS Station 06276500	Natural	
T Ditch	2 foot Parshall	Type F
Dotterer Ditch	18 inch Parshall	Type F
Meeteetsee Creek	Natural	Type F
Wyoming Manning Ditch	18 inch Parshall	Type F
Winkle-Benbrooke Ditch	18 inch Parshall	Type F
Dyer Ditch	3 foot Parshall	Type F
Cheeseman Ditch	3 foot Parshall	Type F
Dodge Ditch	2 foot Parshall	Type F
Arnold Ditch	4 foot Parshall	Type F
Myers Ditch	2 foot Parshall	Type F
Snyder Ditch	2 foot Parshall	Type F
Blackstone Ditch	Natural	Type F
Keystone Ditch	4 foot Parshall	Type F
Jimmerfield Ditch	4 foot Parshall	Type A-35
Jimmerfield & Roach Ditch	3 foot Parshall	Type A-35
Smith Ditch	18 inch Parshall	Type A-35
Avent Ditch	3 foot Parshall	Type F
Greybull River	Natural	Type F
Return Flow	8 foot Parshall	Type F
Farmer's Canal	20 foot Parshall	Type A-35
Bench Canal	20 foot Parshall	Type A-35

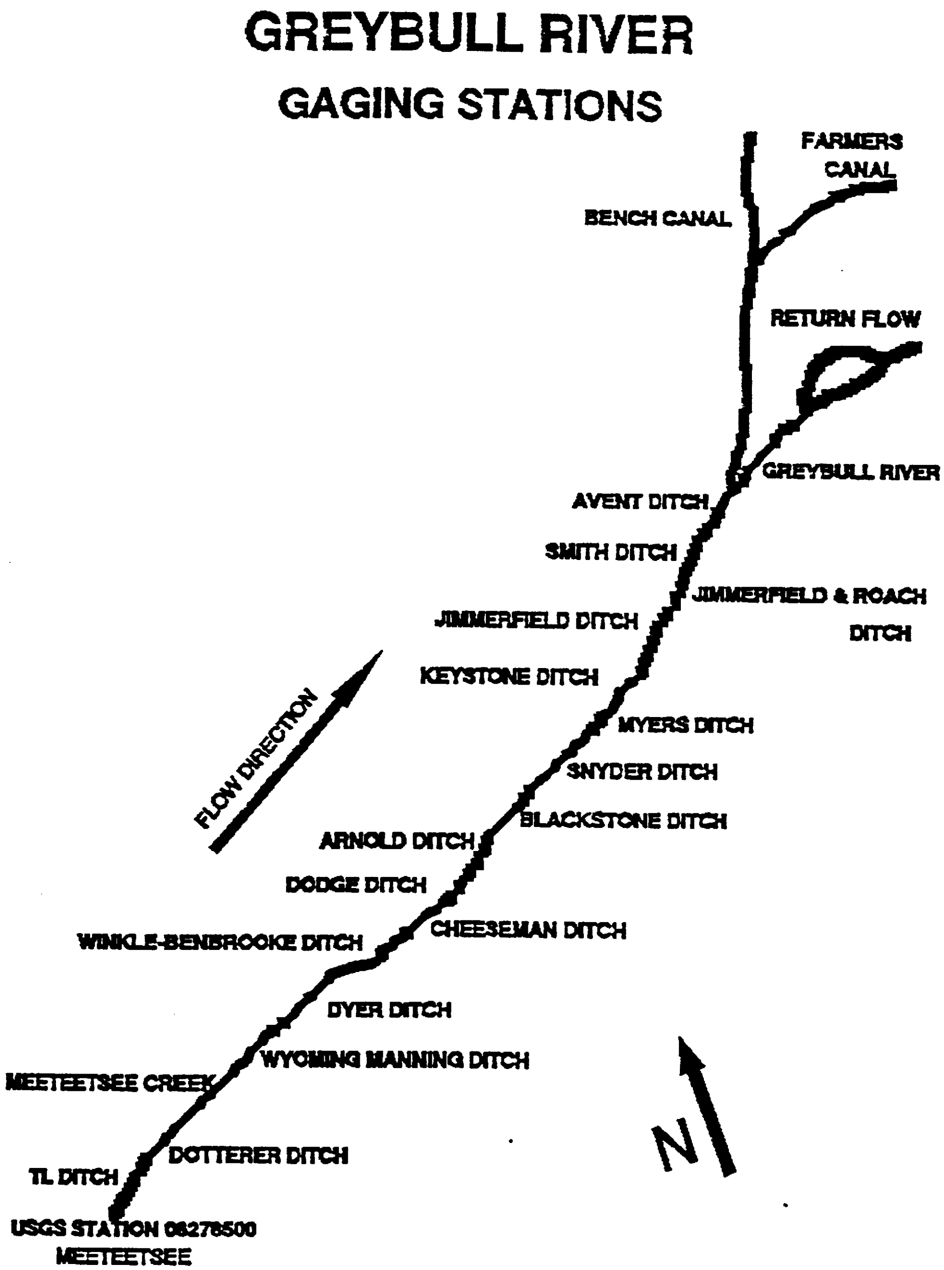


Figure 2. Gaging Stations on the Greybull River Study Reach.

rating curves were developed for each of the locations where a stream cross-section was required (using the methods in Rantz, et.al. (1983)). On canal diversions where Parshall Flumes were present, the flumes theoretical rating curve was used. Flow measurements were made with a current meter at each of the diversions to compare a gaged flowrate to the calibrated flow of the Parshall Flumes rating curve. All current meter flow measurements were found to be within ten percent of the calibrated flow values.

The recorders were in operation for the late summer of 1992 and spring of 1993.

Wind River Study Reach

Along the Wind River study reach, a total of six gaging stations were in operation. Four of these stations were operated in cooperation with the Wyoming State Board of Control and the USGS and two of these stations were operated for the Shoshone and Arapahoe Indian Tribes by the USGS. Table 2 lists each canal and the operator. Figure 3 shows a schematic of the reach and its diversions. Both the Board of Control and the Shoshone and Arapahoe Indian Tribes were responsible for placement and supervision of their gaging stations. Surface flow records for the spring, summer and fall of 1992 were received for analysis from each organization.

DATA REDUCTION

Greybull River Study Area

TABLE 2

WIND RIVER CANAL OPERATORS

STATION	OPERATOR
Station 086276500	USGS (for Board of Control)
Johnstown Canal	USGS (for Shoshone and Arapahoe Tribes)
LeClair Canal	Board of Control
Lefthand Ditch	USGS (for Shoshone and Arapahoe Tribes)
Wyoming Central Canal	Board of Control
Station 0622800	USGS (for Board of Control)

The process of reducing the streamflow data involved reduction of the charts from each of the gaging points in the study area. The data were reduced into two hour water stage increments. This time increment was selected to keep the increments smaller than the flood wave time of travel for the reach. These stage values were placed on a spreadsheet where an equation for the proper size of Parshall Flume for each diversion was applied to the stage data to obtain a flowrate. When the data came from a section without a flume, a rating curve was developed and applied to the spreadsheet stage values to obtain flowrates.

One method for developing a rating curve is to plot river stage versus measured discharge on a log-log graph.

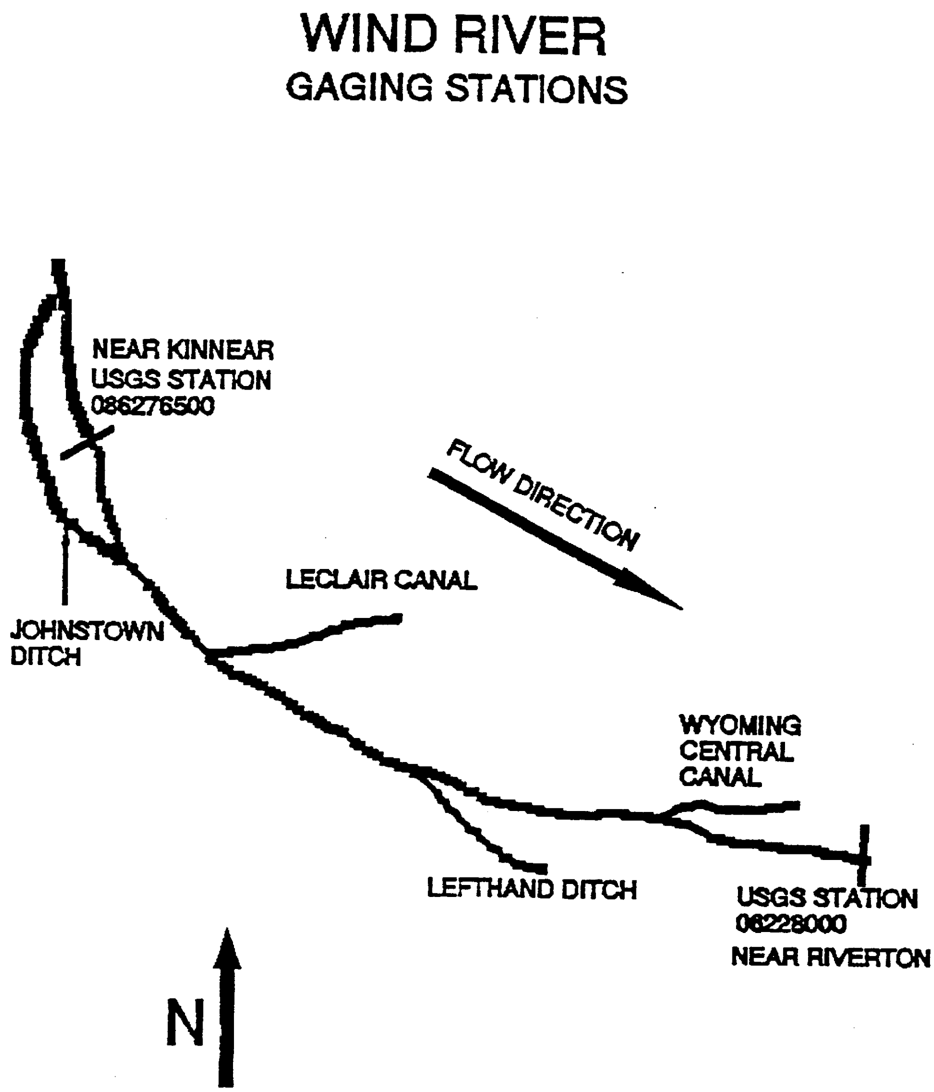


Figure 3. Gaging Stations on the Wind River Study Reach.

An equation of the form

$$Q=k*H^b$$

can be developed to fit the plotted data where:

Q = Discharge (cubic feet per second),

k = Coefficient,

H = Water stage (feet), and

b = Exponent.

A rating curve for Meeteetsee Creek is shown on Figure 4.

Wind River Study Area

The continuous streamflow data for the Wind River study reach provided by the United States Geological Survey were reduced by them and made available through the Wyoming Water Resources Data Group at the University of Wyoming's Water Resource Center. Charts for the LeClair Canal and the Riverton Valley Canal were provided by the State Board of Control and were of the A-35 continuous stage type. These charts were reduced in the same manner as the Greybull River charts on an hourly basis for water stage levels. These water stage levels were applied to rating curves developed by the Board of Control to obtain discharge values.

ADDITIONAL DATA NEEDED

In order to run the J349 program, additional information was required. The additional information includes:

flood travel time for the reach,

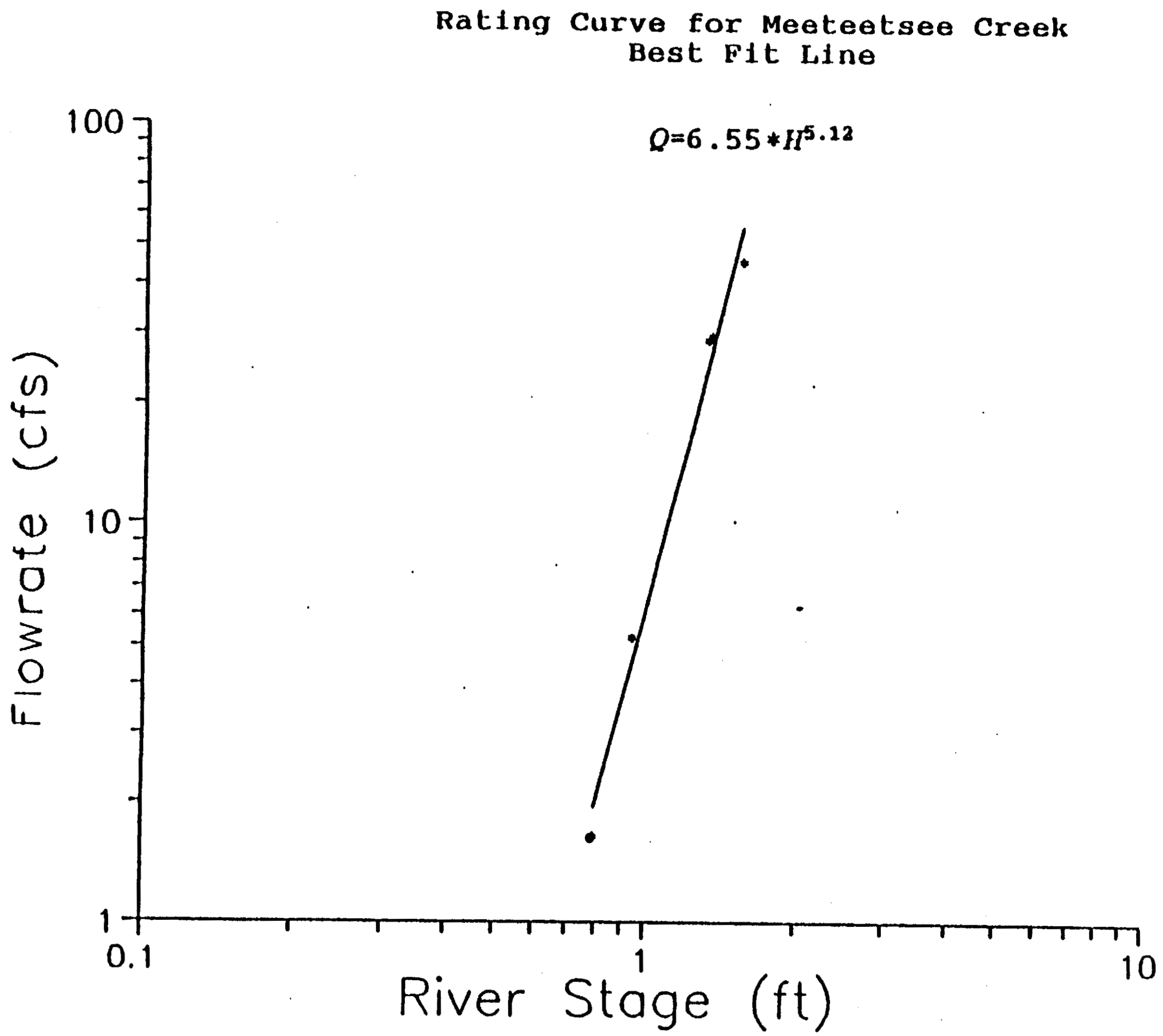


Figure 4. A Rating Curve for Meeteetsee Creek.

aquifer transmissivity,
storage coefficient,
wave dispersion coefficient,
wave celerity,
length of channel, and
length of alluvium.

Travel time was determined by subtracting when a flood wave reached the beginning of the study reach from when the same flood wave reached the end of the reach using river stage data collected from the recorder charts to determine these times. Figure 5 shows a plot of flood wave travel on the Greybull River. Point A on the plot represents the point at which the flood wave reaches the upstream gaging station. Point A-A represents the point where the same flood wave reached the downstream gaging station. Points B and B-B represent the point of the peaks of the flood wave at the respective stations.

Points C:C-C and D:D-D represent similar points for other flood waves. From the plot, it can be seen that the flood wave time of travel is dependent on the magnitude of the flood wave. An average time of travel of eight hours was selected for the Greybull River after analysis of several flood waves. Figure 6 represents a similar plot of flood wave travel time for the Wind River. An average travel time of eight hours was selected from analysis of the data for the Wind River.

Aquifer transmissivity and storativity were determined for the study area during model calibration. Length of

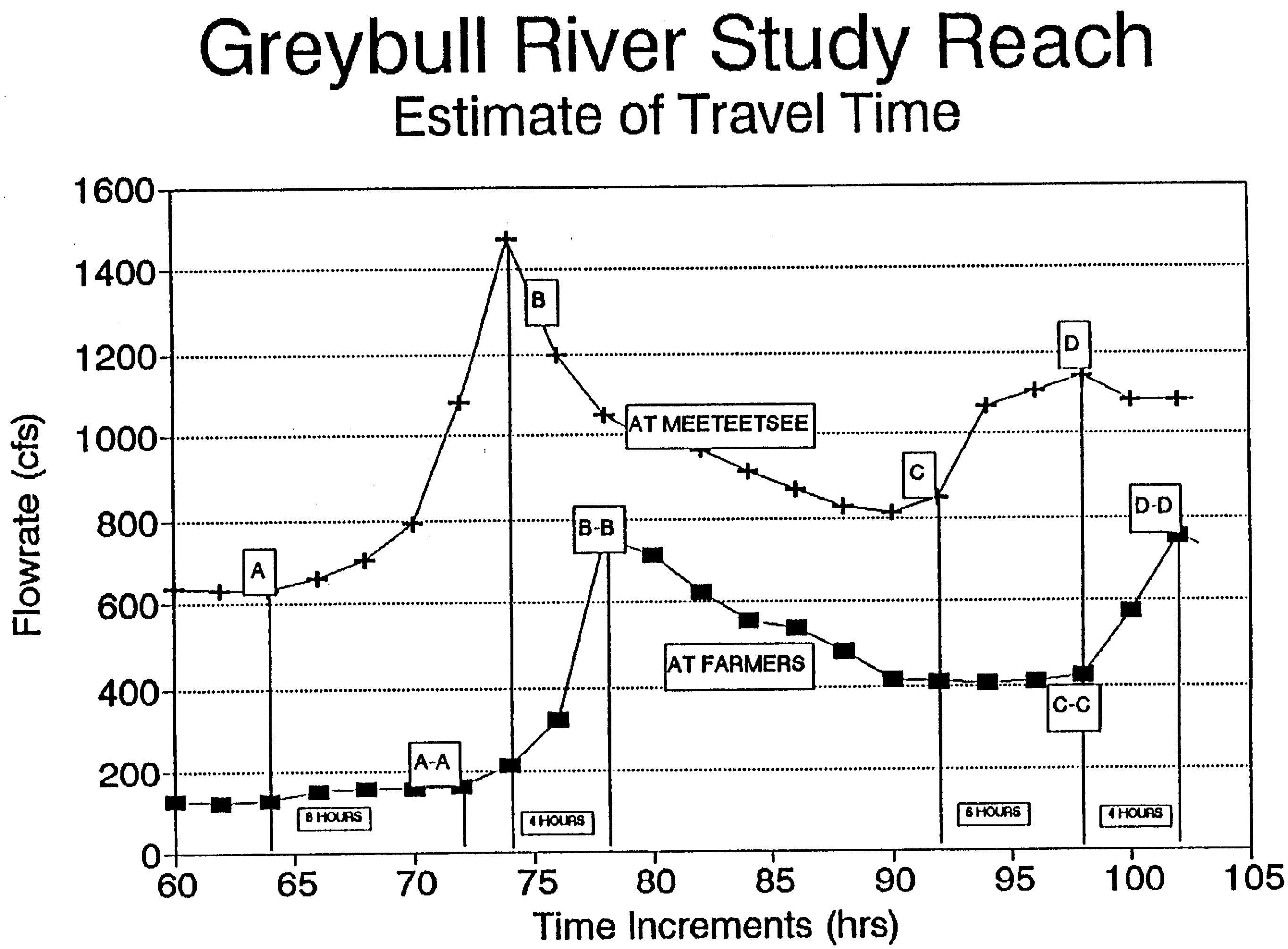


Figure 5. Greybull River Water Wave Travel Time Representation.

channel and length of alluvium give the model a measure of channel sinuosity and were determined from USGS 7.5 minute quadrangle maps using a digitizer. Wave celerity and wave dispersion were determined from methods detailed by Farber (1992).

MODEL CALIBRATION

Field data were input into the J349 model following the input structure provided by the USGS for the model. The input structure as well as an example input and output for a trial run on the Greybull River are presented in Appendix A. The calibration process involved varying transmissivity, storativity, wave dispersion coefficient, wave celerity and base flow until predicted downstream discharge calculated by the J349 program simulated actual discharge at the downstream point.

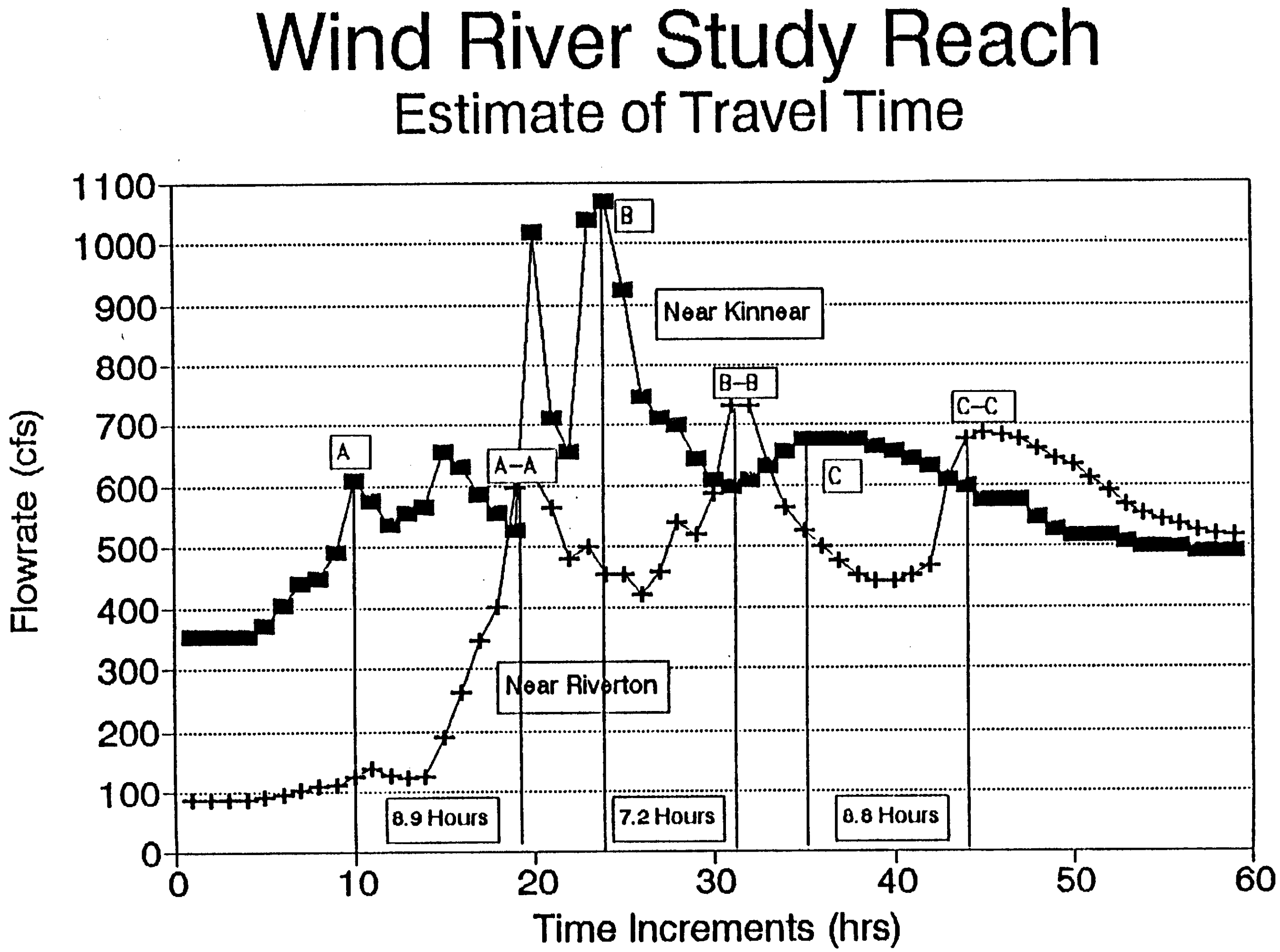


Figure 6. Wind River Water Wave Travel Time Representation.

CHAPTER V

RESULTS AND DISCUSSION

GREYBULL RIVER STUDY AREA

The period of analysis to be discussed in this thesis for the Greybull River study reach extends from July 17, 1992 to September 30, 1992.

The Greybull River study reach was separated into two sub-study reaches for input into the J349 model. Diversion flow data from Meeteetsee to the Arnold Ditch made up the first reach (Reach 1) while flow data from the Arnold Ditch to the Farmers and Bench Canals was the second study reach (Reach 2).

Conveyance loss analysis was also separated into monthly trial periods. Monthly periods were chosen since the model, as discussed earlier, allowed for only twenty-five changes in diversion values. Monthly study periods also allowed for a comparison between conveyance loss values on a monthly basis. The first study period analyzed was July of 1992. The model was calibrated, as discussed in Chapter 4, to the point where the predicted downstream hydrograph calculated by the J349 model simulated the actual downstream hydrograph for the month of July (Figure 7).

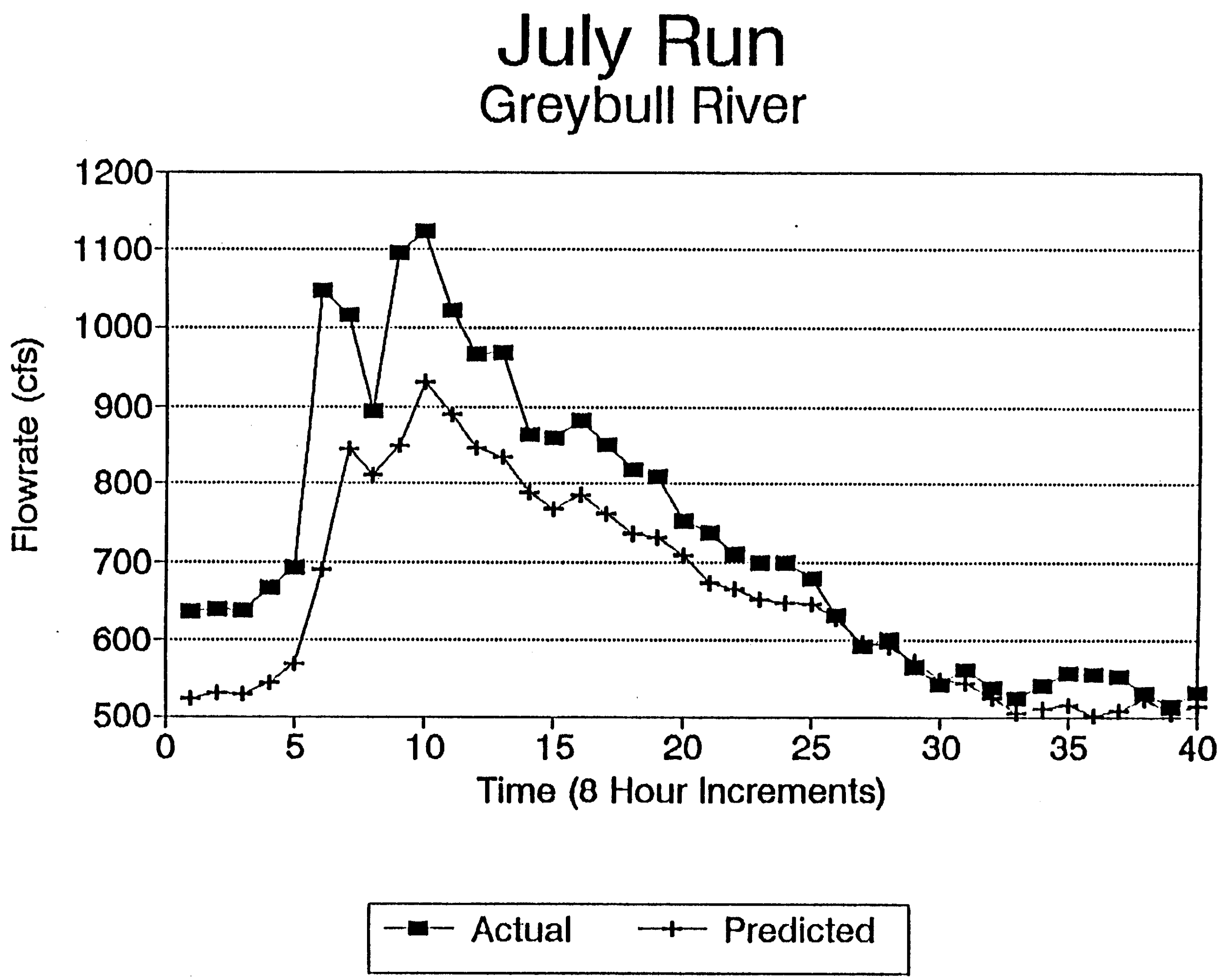


Figure 7. Greybull River (July 1992) Calibration Comparison of Actual Flows and Modeled Flows.

Table 3 presents the final stream and aquifer parameters determined from the calibration process. Final transmissivity for the aquifer determined by calibration was estimated to be 14,000 ft^2/day. Transmissivity was estimated for the Greybull River area to range between 2,000 ft^2/day and 18,000 ft^2/day by Libra, Doremus and Goodwin (1981).

In the calibration process, it was found that transmissivity and storativity had a great influence on conveyance losses calculated by the J349 model. Figure 8 illustrates the effect of varying transmissivity and storativity on the conveyance losses predicted by the model using July flow data. Transmissivity was increased from 50 to 20,000 ft^2/day for three different storage coefficients. Increase in transmissivity between 500 and 2000 ft^2/day showed the most marked increase in conveyance loss.

TABLE 3

FINAL MODELING PARAMETERS FOR THE GREYBULL RIVER STUDY REACH.

INPUT PARAMETER	VALUE	
	REACH 1	REACH 2
Transmissivity (ft^2/day)	14,000	14,000
Storativity	0.45	0.45
Aquifer Width (ft)	2155	3265
Wave Dispersion (ft^2/sec)	475.0	475.0
Wave Celerity (ft/sec)	7.3	7.3
Base Flow (cfs)	50.0	50.0
Length of Channel (miles)	13.6	14.4
Length of Alluvium (miles)	11.5	12.3
Time of Travel (hrs)	4	4

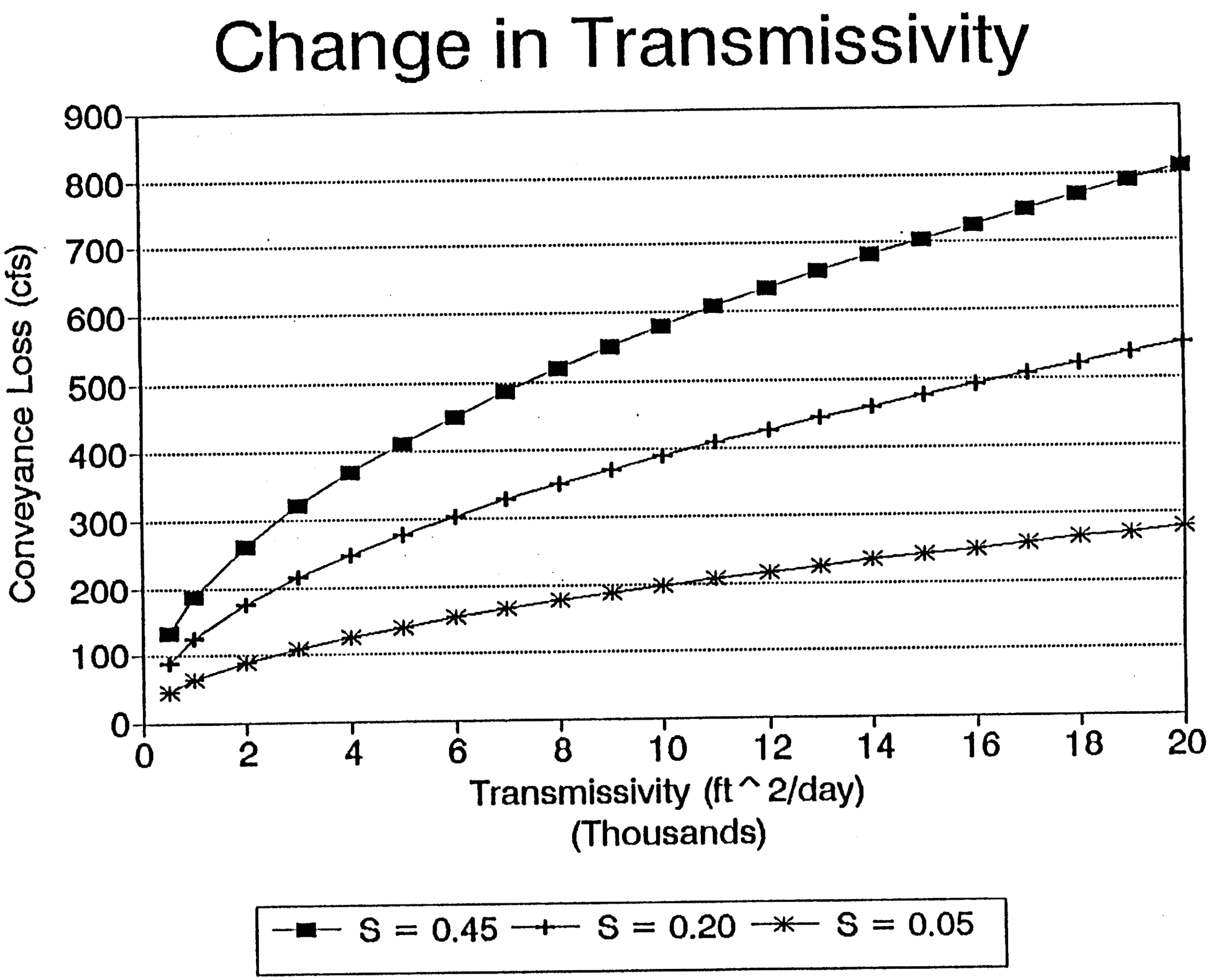


Figure 8. Greybull River Modelling Results, Conveyance Loss versus Transmissivity for Three Different Storage Coefficients.

Increases in transmissivity between 2000 and 20,000 ft^2/day shows successively smaller increases in conveyance loss as transmissivity was increased. The plot (Figure 8) illustrates, for example, that given an increase in transmissivity from 2000 to 4000 ft^2/day and a storage coefficient of 0.20, the conveyance loss increases from 176 cfs to 248 cfs, an increase of forty-one percent.

Streamflow data for the months of August and September were then modelled using the same stream and aquifer parameters that accurately simulated flow for the month of July. Predicted flow calculated by the computer program versus the actual flow measured for August and September are illustrated on Figures 9 and 10, respectively.

Figures 7, 9 and 10 illustrate that for several time increments near the start of the month, the model is inaccurate in predicting actual flow. Farber (1992) thoroughly discusses and explains the reasons for this inaccuracy. The main cause is due to the models' inability to obtain closure between streamflow, diversions and bank storage during the initial time steps (model needs a start up period to cause the model to synthesize correctly).

These figures also reveal that for July when flow values exceed 1000 cfs, the model consistently predicts a flowrate significantly (up to eighteen percent) lower than actually existed. Throughout the study period, approximately 2000 acre-feet (af) of water was not accounted for by the models predicted flow. This is approximately 9.7% of the total flow for the July simulation period.

In August, when flowrates ranged between 500 and 600 cfs, the model predicts flows lower than actually existed. Predicted values were up to eighteen percent lower than actual flow data for the first several time increments at the beginning of the simulation, and then stayed within five percent for the remainder of the study period. Approximately 1380 af of water is unaccounted for by the models predicted flow, or about 9.1% of total flow for the August simulation period.

The plot of September data shows that as actual flow data dips below 300 cfs, the model predicts flows higher than actually existed. Modelled flow data ranged between zero and ten percent higher than actual data. For the September study period, approximately 850 af of water, or 6.3% of total flow was not accounted for by the model.

In general, Figures 7, 9 and 10 show that the model can produce output that accurately simulates actual flow data for the Greybull River. Together with research conducted on the J349 program by Farber (1992), and the ability of the model to simulate actual flow data for the Greybull River, conveyance losses as calculated by the model are felt to be reasonably accurate for this study reach.

With the model theoretically calculating conveyance loss within accuracy limits of most gaged measurements, it

Figure 9. Greybull River (August 1992) Calibration Comparison of Actual Flows and Modeled Flows.

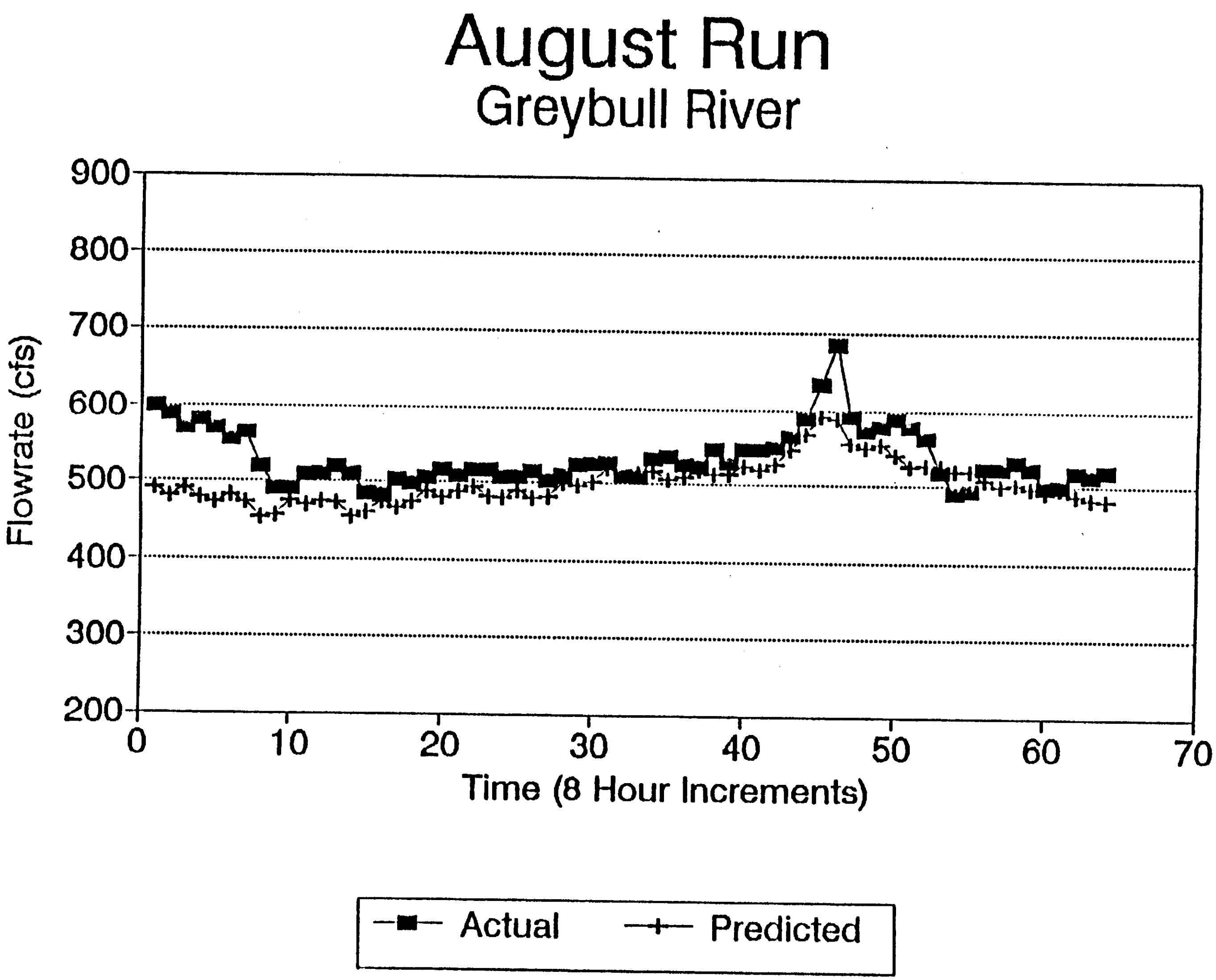
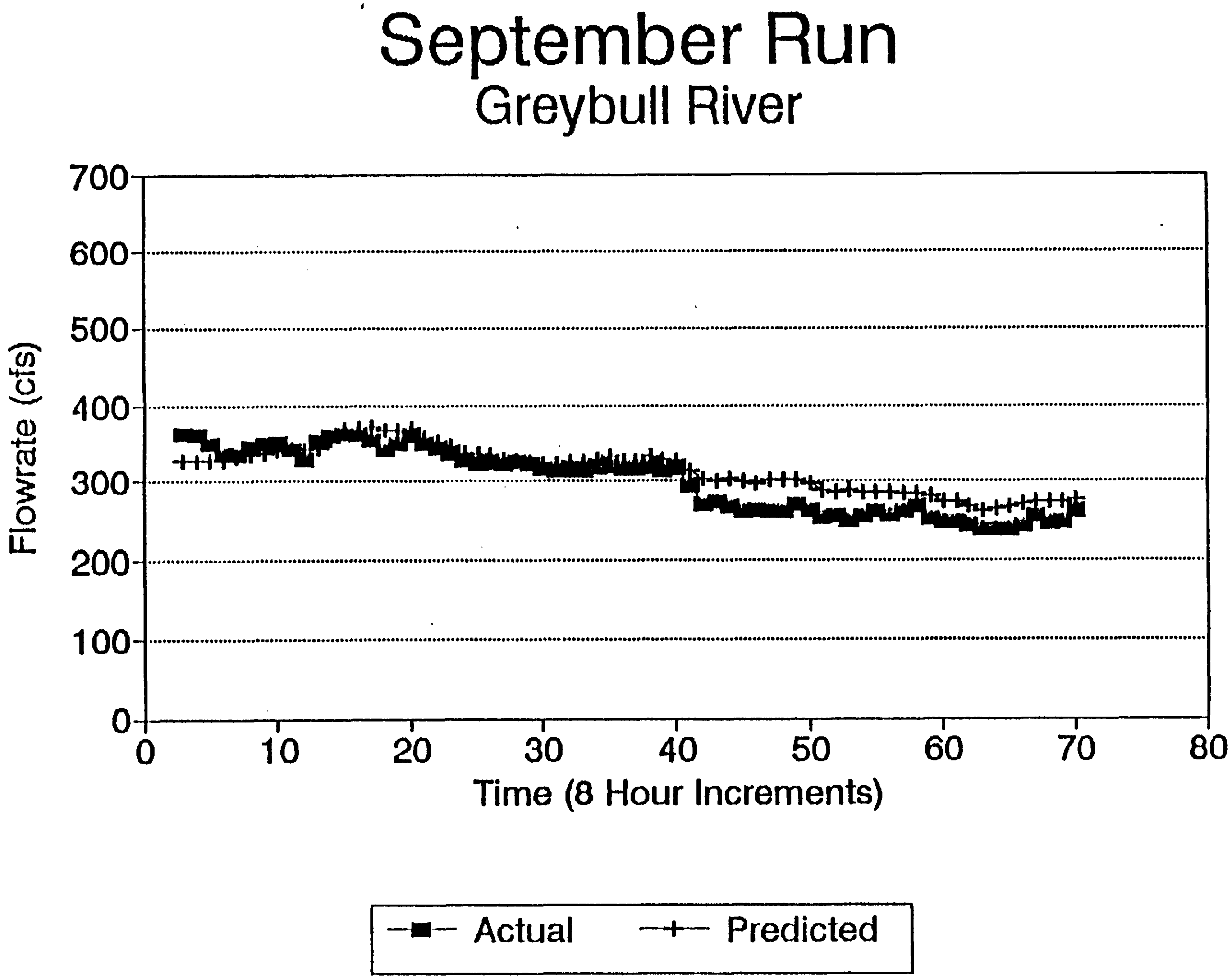


Figure 10. Greybull River (September 1992) Calibration Comparison of Actual Flows and Modeled Flows.



is possible to determine an incremental conveyance loss for increases in flowrate. This is accomplished with the model by coding an upstream hydrograph with a constant flowrate into the working model for a one day period and letting the model determine a total conveyance loss for that upstream hydrograph as it passes down the river reach. The upstream hydrograph is then increased by increments of 50 cfs and the total conveyance loss for the new upstream hydrograph is determined. This process is repeated until the upstream hydrograph is at the highest expected flowrate for which conveyance loss estimates are generally needed. This procedure was performed for all three study months for the Greybull River study reach.

The daily diversion rate used in this process is the average daily diversion rate. An average daily diversion rate for each month is used in an effort to simulate conveyance loss for that month assuming that the diversions are representative of the same time periods for other years.

The results for the conveyance loss determination for each month and the average of all three months are shown in Table 4. The numbers indicate the total conveyance loss incurred in the Greybull River for a given flowrate for one day. Figure 11 illustrates a comparison between monthly conveyance losses. This figure (Figure 11) shows that total conveyance loss rises sharply initially and then levels off as the flowrate approaches 1500 cfs. Also there is little change in total conveyance loss between any month. Table 5 indicates the percent difference for each months total conveyance loss with respect to the three month average for each flowrate considered. With the exception of flowrates ranging from 50 to 150 cfs, all values are within ten percent of the three month average. Figure 12 illustrates the three month average of total conveyance losses, and is a reasonable representation of what should probably be used as the basis for determining incremental conveyance loss.

Conveyance losses determined using this method range from 0.40% to 0.62% per river mile of the incremental flow increase. This compares favorably with losses determined by Hanlin (1988), which were in the range of 0.3% to 4.7% loss per river mile. Losses determined for the Greybull River by the J349 model also fell within the 0.34% to 1.66% loss per river mile determined by Pahl (1985) for several streams in Wyoming.

The process for determining incremental conveyance loss involves using Figure 12 to determine the difference in total conveyance loss for two given flowrates. This difference in total conveyance loss is called an incremental conveyance loss. An example of the method used to determine this conveyance loss using Figure 12 is demonstrated on Figure 13. Figure 13 illustrates that at a flowrate of 400 cfs there is a total conveyance loss of 57.8 cfs, and at a flowrate of 200 cfs there is a total conveyance loss of 25.2

TABLE 4

MONTHLY TOTAL CONVEYANCE LOSS FOR GREYBULL RIVER STUDY AREA

Flowrate (cfs)	July Loss (cfs)	August Loss (cfs)	September Loss (cfs)	Average Loss (cfs)
50	5.65	3.94	4.76	4.78
100	13.26	8.77	12.04	11.36
150	20.91	16.01	19.64	18.85
200	28.51	23.49	27.3	26.43
250	36.3	31.07	34.88	34.08
300	44.13	38.72	42.53	41.79
350	51.96	46.73	50.2	49.63
400	59.79	54.02	58.03	57.28
450	67.62	61.67	65.87	65.05
500	75.46	69.32	73.7	72.83
550	83.29	76.97	81.53	80.60
600	91.14	84.62	89.37	88.38
650	98.83	92.47	97.14	96.15
700	106.25	100.15	104.72	103.71
750	113.33	107.61	111.92	110.95
800	120.11	114.73	118.79	117.88
850	126.56	121.58	125.4	124.51
900	132.78	128.11	131.7	130.86
950	138.72	134.33	137.75	136.93
1000	144.42	140.36	143.55	142.78
1050	149.93	146.08	149.15	148.39
1100	155.26	151.63	154.55	153.81
1150	160.44	157.01	159.79	159.08
1200	165.44	162.19	164.86	164.16
1250	170.3	167.26	169.78	169.11
1300	175.03	172.12	174.56	173.90
1350	179.6	176.9	179.19	178.56
1400	184.05	181.46	183.7	183.07
1450	188.41	185.96	188.08	187.48
1500	192.65	190.31	192.37	191.78
1550	196.05	194.46	195.82	195.44
1650	201.08	199.73	200.92	200.58
1750	205.7	204.58	205.63	205.30
1850	210.11	209.06	210.05	209.74
1950	214.31	213.39	214.3	214.00

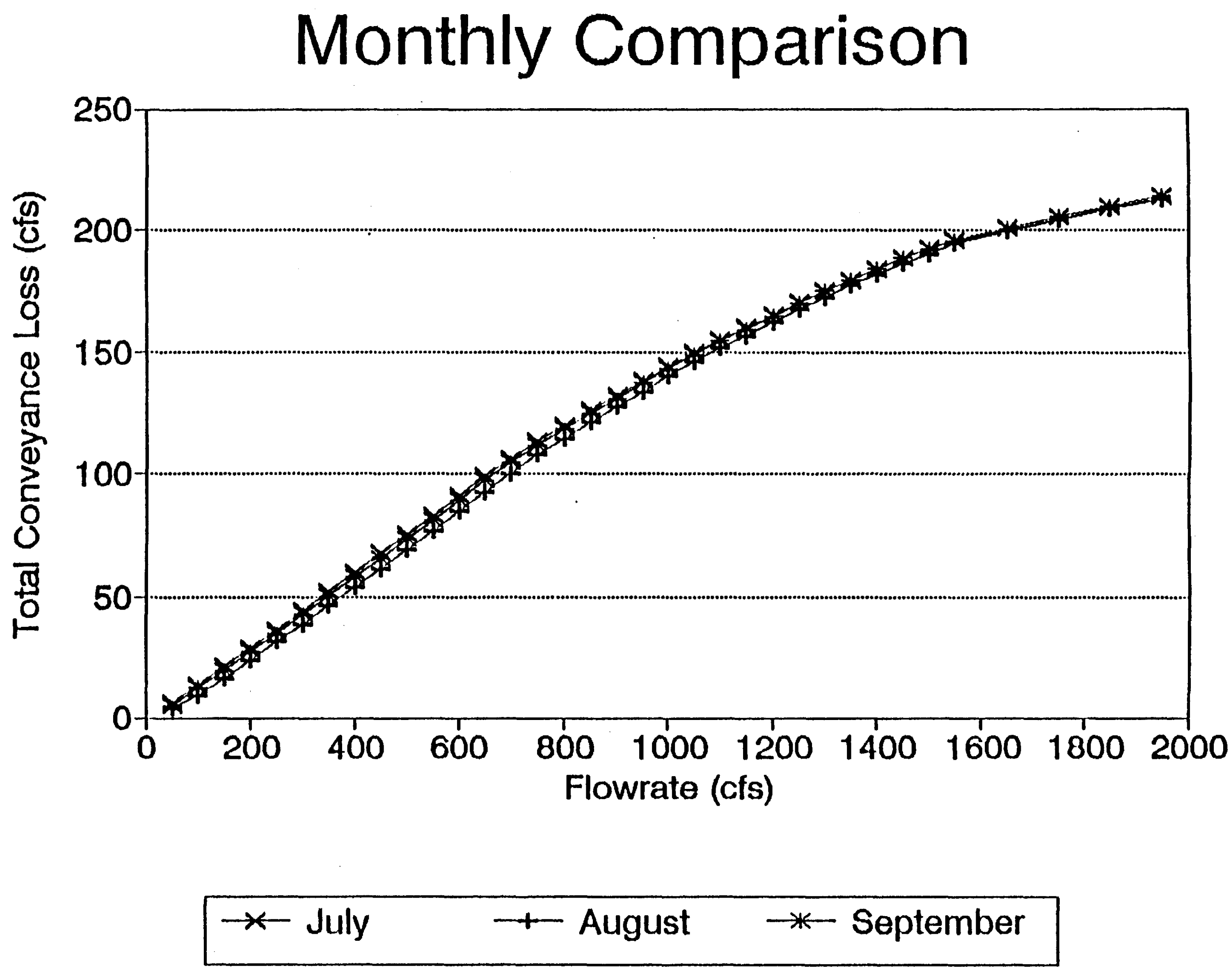


Figure 11. Greybull River Modeling Results Comparison Between the Monthly Conveyance Losses.

cfs. The incremental conveyance loss for an increase from 200 to 400 cfs for one day is 32.6 cfs.

The incremental conveyance loss determined by the preceding procedure can be used to determine an incremental conveyance loss for each following day, assuming that the flowrate remains constant. Table 6 presents the results of running the J349 model to determine total conveyance loss, for between one and ten days with a constant flowrate of 500 cfs. A flowrate of 500 cfs was used because it falls within the 300 to 600 cfs range at which the river was flowing for most of the summer. This analysis was also performed at flowrates of 1000 and 1500 cfs for comparison. The results for flowrates of 1000 and 1500 cfs varied less than five percent on a day to day comparison with the 500 cfs flow.

Table 6 gives the daily conveyance loss for that given flowrate for the first day and the following ten days. The table also indicates the percent of the original conveyance loss determined for each of the days. The data in this table is illustrated on Figure 14. Figure 14 indicates that conveyance loss on the second day is nearly identical to the loss on the first day. By the third day, however, the conveyance loss drops sharply to approximately 70% of the original conveyance loss. From the third day on, the percentage drops gradually and levels off at approximately 35% of the original conveyance loss by the 10th day.

Using Table 6 and the previous example where a

TABLE 5

PERCENT DIFFERENCE OF MONTHLY CONVEYANCE LOSS FROM THREE MONTH AVERAGE.

Flowrate (cfs)	July (%)	August (%)	September (%)
50	18.12	17.63	0.49
100	16.76	22.78	6.02
150	10.91	15.08	4.17
200	7.86	11.13	3.28
250	6.50	8.84	2.34
300	5.59	7.35	1.76
350	4.69	5.84	1.15
400	4.38	5.69	1.31
450	3.95	5.20	1.26
500	3.62	4.82	1.20
550	3.34	4.50	1.16
600	3.13	4.25	1.12
650	2.79	3.82	1.03
700	2.45	3.43	0.98
750	2.14	3.01	0.87
800	1.89	2.67	0.77
850	1.64	2.36	0.71
900	1.46	2.10	0.64
950	1.30	1.90	0.60
1000	1.15	1.69	0.54
1050	1.04	1.55	0.51
1100	0.94	1.42	0.48
1150	0.85	1.30	0.45
1200	0.78	1.20	0.42
1250	0.70	1.10	0.39
1300	0.65	1.03	0.38
1350	0.58	0.93	0.35
1400	0.54	0.88	0.34
1450	0.49	0.81	0.32
1500	0.46	0.76	0.31
1550	0.31	0.50	0.19
1650	0.25	0.42	0.17
1750	0.19	0.35	0.16
1850	0.18	0.32	0.15
1950	0.14	0.29	0.14

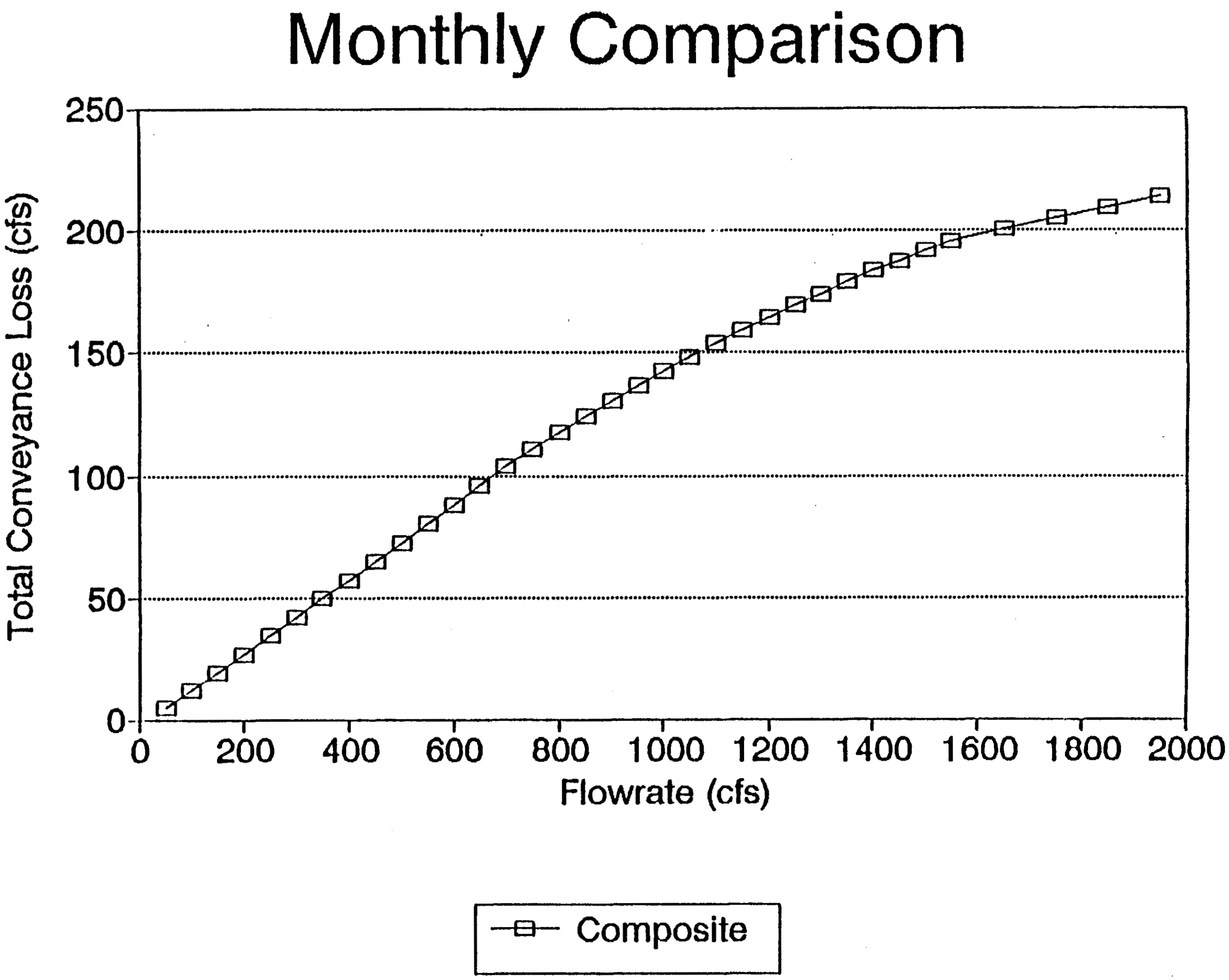


Figure 12. Greybull River Modeling Results Showing Monthly Average of Total Conveyance Loss versus Flowrate.

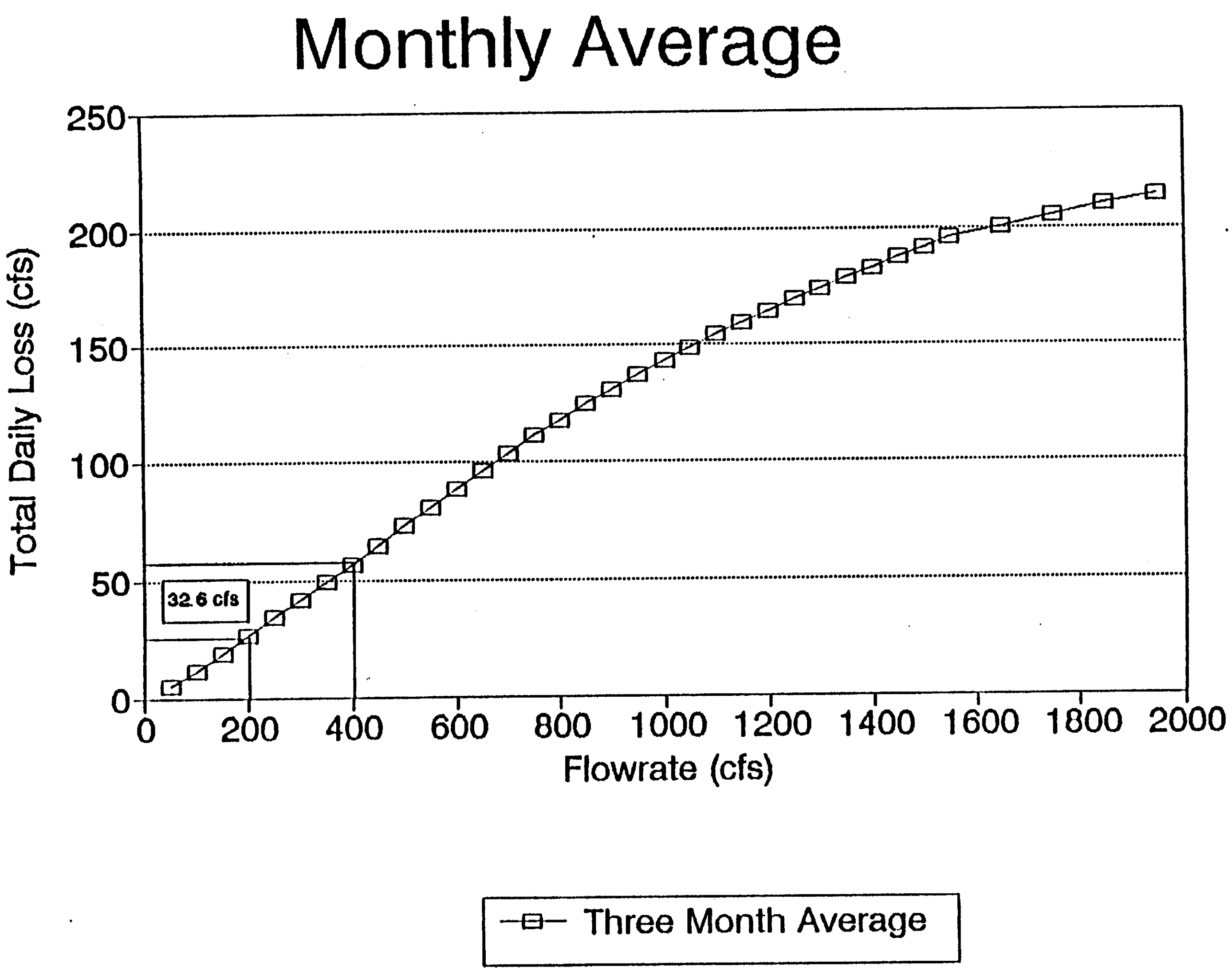


Figure 13. Greybull River Modeling Results Using Total Conveyance Loss to Determine Incremental Conveyance Loss.

TABLE 6

TOTAL CONVEYANCE LOSS DETERMINED BY J349 MODEL AT A CONSTANT FLOWRATE FOR ONE TO TEN DAYS

Day	Total Conveyance Loss (cfs/day)	Percent of Original Loss
1	75.46	100.0
2	73.43	96.0
3	52.79	68.9
4	43.60	56.8
5	37.99	49.5
6	34.13	45.2
7	31.24	41.4
8	28.99	38.4
9	27.15	36.0
10	25.64	34.0

conveyance loss of 32.6 cfs was determined for one day, the loss for the second day would be 96.0% of 32.6 cfs or 31.3 cfs given a constant flowrate. The conveyance loss for the third day would be 68% of 32.6 cfs or 22.5 cfs, given that the flowrate remained constant at 500 cfs.

Using Figure 12, the preceding process can be used to determine incremental conveyance loss for any increase in flowrate from 0 to 1950 cfs, but is most accurate between 300 and 600 cfs. A flow of 1950 cfs was chosen because it was approximately 50 percent higher than any flowrate measured during the study period. The practical value of

Figure 12 is that hydrographers on the Greybull River can use it to quickly estimate a conveyance loss for any given increase in flowrate so that downstream users can be properly assessed that loss.

WIND RIVER STUDY AREA

The period of analysis to be discussed in this thesis for the Wind River study area begins June 1, 1992 and ends September 30, 1992. Average daily diversion values were chosen for the same reasons indicated in discussion of the Greybull River study reach.

The first period in the study of the Wind River reach extended from June 15, 1992 to July 9, 1992. During this period of record, high flowrates were recorded and the model was calibrated to the actual flow records. Figure 15 illustrates the results of this calibration which shows that for high flowrates, the model simulated actual data moderately well. However, when the flow data immediately following the first study period were analyzed, a disparity was encountered. The modelled data indicated that the river was flowing on average approximately 100 cfs more at the downstream end of the study reach than could be accounted for by the model.

The problem was most likely with the actual data. The first problem uncovered with the actual data was that the Johnstown ditch which diverts flow above the upper gaging station on the study reach actually returns ungaged flows

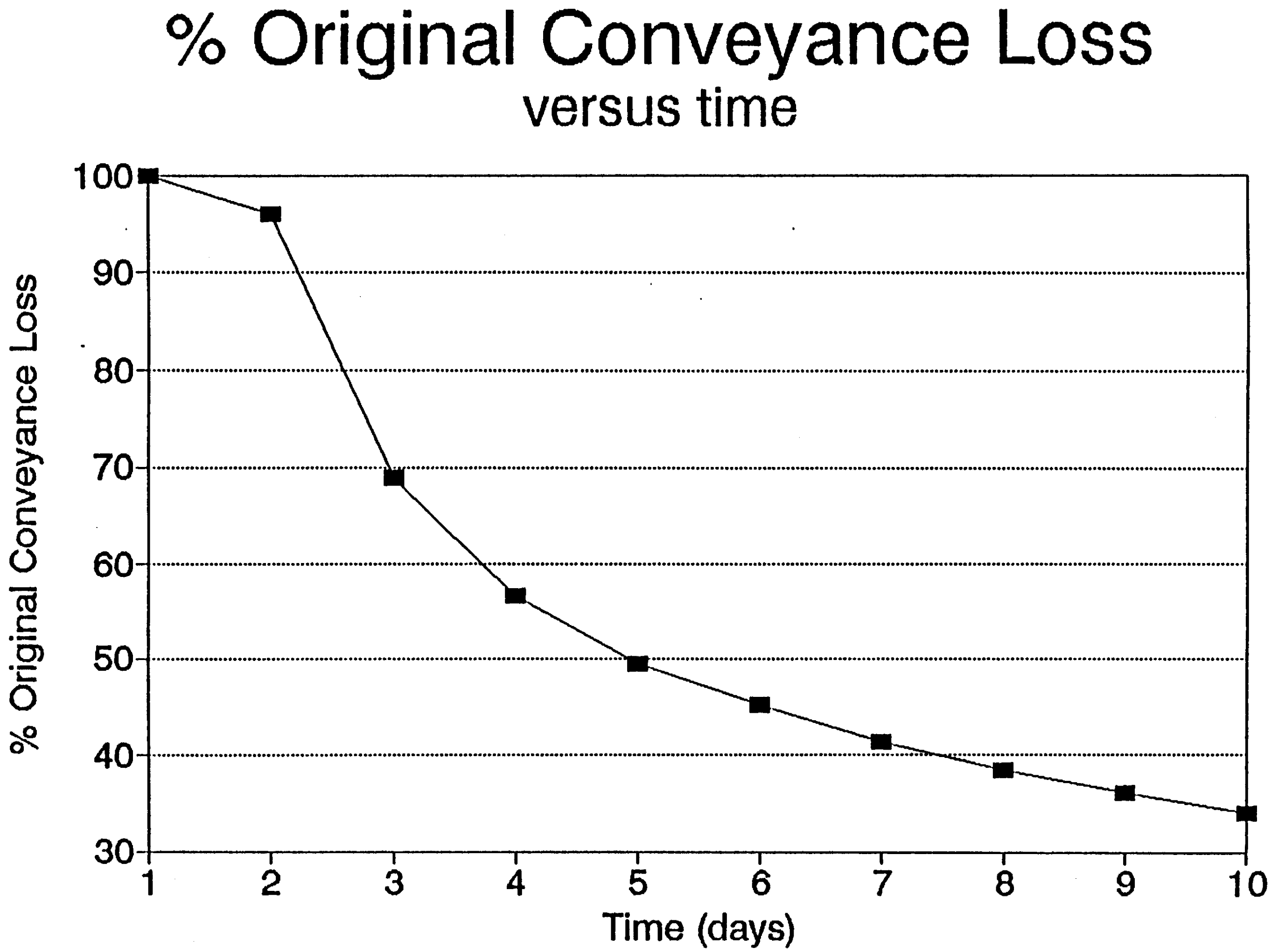
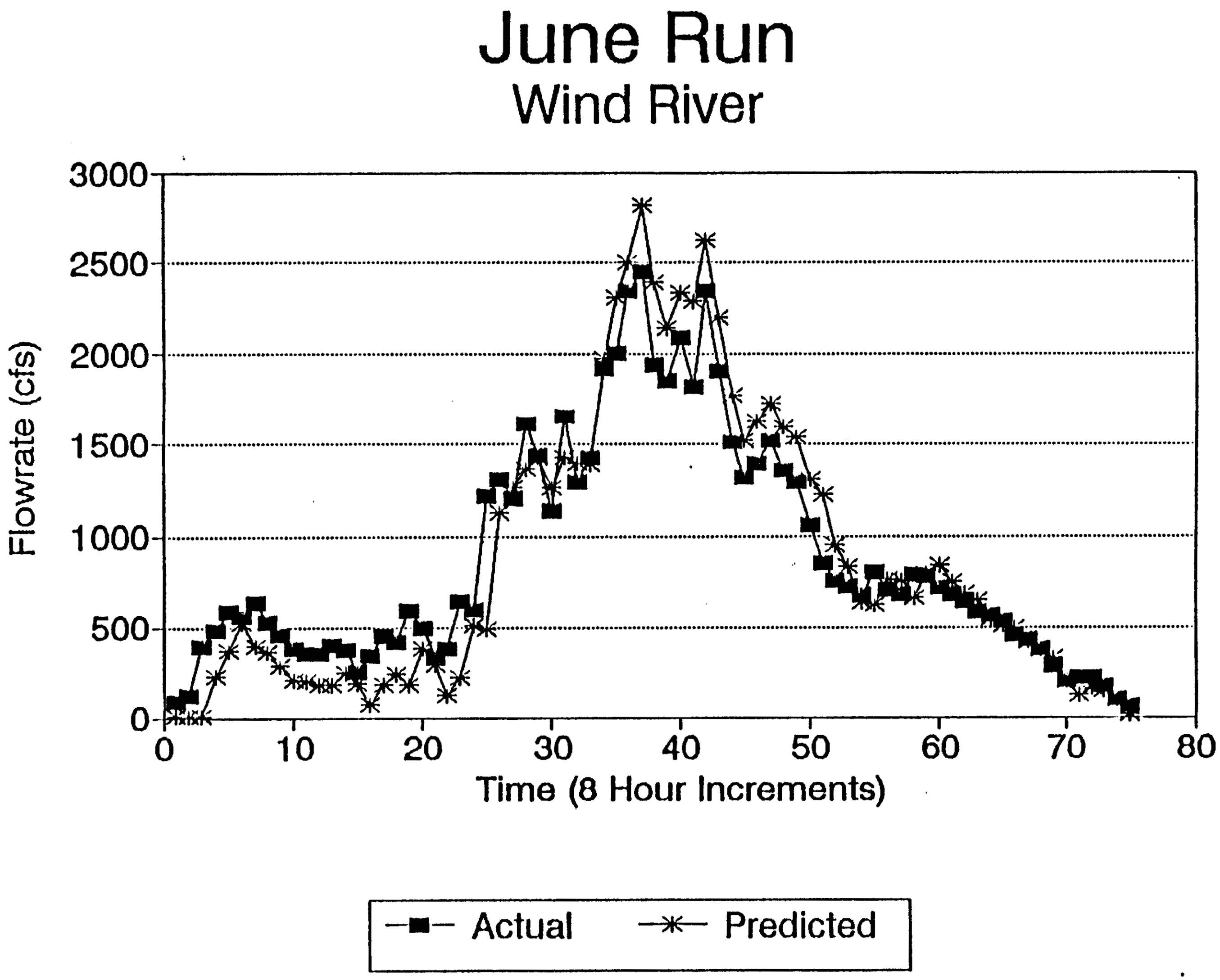


Figure 14. Greybull River Results, Total Conveyance Loss as a Percent of Original Conveyance Loss with Time.

Figure 15. Wind River (June 1992) Model Calibration Comparison of Actual Flows and Modeled Flows.



directly into the Wind River in the study reach. The ditch diverts water from the Wind River approximately 200 yards upstream of the Kinnear gaging station and the wastewater re-enters the Wind River within the study reach possessing at times a significant amount of the flowrate that was originally diverted. Secondly a canal that starts in the Little Wind River drainage and ends up irrigating land within the Wind River drainage has a spill system that allows excess canal water to flow into the Wind River. This spill system was unknown when the study was initiated and was not brought to our attention until August, 1993. Water of an unknown flowrate was entering the Wind River within the study reach. At times this wastewater was estimated to be in the neighborhood of 60 to 80 cfs. The consequences of these ungaged flows is that flow measured at the Riverton gaging station was higher than a mass balance of the flows in the reach would indicate. This discovery caused the Wind River analysis for 1992 to be highly suspect and no further analyses were performed.

It is important to note that while the J349 model successfully modelled the first study period for the Wind River reach, these results cannot be accepted as valid. The reason is that the high flowrates that were encountered during this study period masked the gains incurred in the study reach. Flows during this time period ranged between 2000 and 3500 cfs at the Riverton gage. A gain of 100 cfs during this time period is a small difference of between three and five percent of the total flowrate. However, the flowrate for much of the remainder of the summer averaged between 200 cfs and 500 cfs at the Riverton gage. A gain of 100 cfs during this time period results in a difference of between twenty and fifty percent. A difference in flowrate of five percent would be within the measurement accuracy for the gaging station. An error of twenty percent, however, is too extreme to say that model results are simulating flows in the Wind River. The study on the Wind River reach to estimate conveyance losses was suspended as a result of these discoveries. It will require another season of measurements which will include canal wastewater return flow measurements into the Wind River before estimates can be made on conveyance losses using the modelling approach presented. The model did, however, indicate the return flow problem.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The results of the research presented in this paper and research conducted by Farber(1992), Hanlin(1988) and Pahl(1985) are the basis for the following conclusions.

First, the J349 hydrologic computer model was able to accurately simulate fluctuations in stream stage. However the model predicted flows lower than actually existed during high flowrate periods and predicted higher flow values than actually existed during low flowrate periods. This trend is also observed in research conducted by Farber (1992). These results show that the J349 model is able to reliably simulate flow changes in the range of 200 to 400 cfs. In areas where flows deviate by more than 300 cfs, the model loses some accuracy in simulating actual flowrates. Using the J349 model to determine conveyance loss on reaches where streamflow data has high variability was beyond the scope of this study.

Secondly, the J349 model produced conveyance loss estimates on the Greybull River between Meeteetsee and the Farmers and Bench Canals which are reasonable and realistic when compared with other streams in Wyoming utilized by Pahl (1985) and Hanlin (1988). Hydrographers and others should be able to use Figure 12 provided in this thesis to determine incremental conveyance losses to be assessed downstream users for any arbitrary increase in flow between 50 and 1950 cfs. However, the results produced by the model are most accurate for flows ranging between 300 and 600 cfs.

Verification of data collected from outside agencies is essential. All sources and diversions within the reach under consideration must be accounted for in order to use the J349 model to the best of its ability. An accurate accounting of wastewater flow from canals and ditches re-entering the river within the study reach is key to making the J349 model simulate actual flows.

The J349 model is very sensitive to increases in transmissivity and storativity. Small changes in these variables resulted in large changes in predicted downstream flow values calculated by the model. Changes in these variables in either direction also made a marked difference in conveyance loss calculated by the model. When storativity and transmissivity were increased, the conveyance loss calculated by the model also increased.

RECOMMENDATIONS

First, it is recommended that a visual survey of any reach be conducted before any streamflow data is collected where conveyances losses are to be estimated. A visual survey would provide valuable knowledge of the flow data that would be required to be collected to make the J349 model function correctly. A visual survey would also allow for a better understanding of aquifer characteristics in the area under consideration.

Secondly, it is recommended that storage and groundwater/surface water interactions present in the model be altered so that actual flowrates with high variation can be more accurately simulated. The J349 model should also be modified to allow for more than 25 changes in diversion values during the time period to be modelled.

Since transmissivity and storativity have such a great influence on the results determined by the computer model, a more accurate estimate of these parameters is needed. Well tests could be performed near the river to better define these aquifer characteristics.

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APPENDIX A
GREYBULL RIVER OUTPUT FILE EXAMPLE

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                           GREYBULL RIVER 1992 RUN 11


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0PROPERTIES AND CHARACTERISTICS OF MODEL RUN
 -------------------------------------------
          BEGINNING DATE
 7/17/1992
          ENDING DATE
 7/31/1992
          OBJECTIVES ARE TO COMPUTE - FOR EACH REACH
1) DOWNSTREAM HYDROGRAPH

2) BANK STORAGE DISCHARGE HYDROGRAPH
          LENGTH OF TIME STEP   (HOURS)
   8.0
          NUMBER OF REACHES IN THIS RUN
   2
          NUMBER OF UPSTREAM REACHES
   0
          BASE FLOW AT UPSTREAM STATION   (CFS)
    .0
0

 UPSTREAM STATION DATA
RATING TABLE
 ---------------------
------------
                                                         STAGE
          DISCHARGE
                                                          3.00
            450.00
                                                          3.10
            500.00
                                                          3.20
            550.00
                                                          3.30
            604.00
                                                          3.40
            658.00
                                                          3.50
            715.00
                                                          3.60
```

780.00
3.70
847.00
3.80
918.00
3.90
990.00
4.00
1065.00
4.10
1142.00
4.20
1221.00
4.30
1303.00
4.40
1388.00

1--

GREYBULL RIVER 1992 FROM MYER DITCH TO FARMERS AND BENCH (REACH NO. 1)

PROPERTIES AND CHARACTERISTICS OF REACH

LENGTH OF CHANNEL (MILES)
14.6
LENGTH OF ALLUVIUM (MILES)
11.5
TRAVEL TIME (ESTIMATED HOURS)
4.0
TRAVEL TIME TO BEGINNING OF RESPONSE (HOURS)
5.6 Cumulative from start of first reach = .23 DAYS
TRAVEL TIME TO CENTER OF RESPONSE (HOURS)
8.3
TRAVEL TIME BETWEEN BREAKS IN HYDROGRAPHS (HOURS)
6.9
NUMBER OF SUBREACHES USED IN COMPUTATIONS
1
TRANSMISSIVITY OF AQUIFER (SQ.FT./DAY)
14000.0
STORAGE COEFFICIENT OF AQUIFER (CU.FT./CU.FT.)
.45
AQUIFER IS ASSUMED TO BE 1000. (FT) WIDE (STREAM TO BOUNDARY)

CASE 2

SOIL RETENTION FACTOR

.00

BASE FLOW AT DOWNSTREAM STATION

50.0

MINIMUM EXPECTED DISCHARGE TO BE ROUTED

50.0

MAXIMUM EXPECTED DISCHARGE TO BE ROUTED

3000.0

CELERITY AND DISPERSION RATING TABLE W.

CELERITY	DISCHARGE	DISP. COEF.	DISCHARGE
2.00	50.0	235.0	50.0
3.45	300.0	890.0	300.0
3.50	600.0	1675.0	600.0
3.55	900.0	2460.0	900.0
3.60	1200.0	3245.0	1200.0
3.65	1500.0	4030.0	1500.0
3.70	1800.0	4815.0	1800.0
3.75	2100.0	5600.0	2100.0

FAMILY OF FLOW ROUTING UNIT-RESPONSE FUNCTIONS

NO. W. CELERITY DISP.COEF TRAVEL TIME
DISCHARGE ORDINATES
FT/SEC SQ FT/SEC TIME STEPS CU
FT/SEC

1 2.00 235.0 1
1525.0 1) .6617 2) .3383
2 3.90 7955.0 0
3000.0 1) .3172 2) .6793 3) .0034

STREAM-AQUIFER UNIT-RESPONSE FUNCTION

NOTE: THIS RESPONSE FUNCTION (EXPONENTIAL
DECAY TYPE IS EVALUATED FOR 18.5 HALF-LIVES.
IT HAS 45 ORDINATES.

1) -.007835 2) -.004524 3)
-.003504 4) -.002961 5) -.002612 6)
-.002362
7) -.002173 8) -.002023 9)
-.001900 10) -.001797 11) -.001709 12)
-.001633
13) -.001566 14) -.001505 15)
-.001451 16) -.001402 17) -.001356 18)
-.001314
19) -.001274 20) -.001237 21)

-.001201 22) -.001168 23) -.001136 24)
-.001105
25) -.001076 26) -.001047 27)
-.001020 28) -.000993 29) -.000967 30)
-.000942
31) -.000918 32) -.000895 33)
-.000872 34) -.000850 35) -.000828 36)
-.000807
37) -.000786 38) -.000766 39)
-.000747 40) -.000728 41) -.000710 42)
-.000692
43) -.000674 44) -.000657 45)
-.000641
0

DOWNSTREAM STATION DATA
RATING TABLE

DISCHARGE	STAGE
549.00	9.30
600.00	9.40
654.00	9.50
713.00	9.60
776.00	9.70
844.00	9.80
917.00	9.90
996.00	10.00
1081.00	10.10
1172.00	10.20
1269.00	10.30
1374.00	10.40
1486.00	10.50
1606.00	10.60
1735.00	10.70
	10.80

```
          1872.00
                                                              10.90
          2019.00
1
0 SUMMARY OF ITERATION DATA FOR ROUTING OPTION
  --------------------------------------------

                                  CHANGES BETWEEN ITERATIONS
     VOLUMES AT END OF ITERATION
                      --------------------------------------------

  -----------------------------------

  ITERATION         MAXIMUM CHANGE           ABSOLUTE CHANGE
   NET VOLUME          VOLUME OF FLOW
     NO.                  IN                       IN
       OF                    AT
               BANK STORAGE DISCHARGE    BANK STORAGE VOLUME
  BANK STORAGE       DOWNSTREAM STATION
                           (CFS)              (CFS - DAYS)
    (CFS - DAYS)           (CFS - DAYS)
0     1                   78.1                     273.
     -191.                  10960.
0     2                    4.4                      13.
     -189.                  10961.
0     3                     .4                       1.
     -189.                  10961.
0 CLOSURE WAS OBTAINED AFTER  3 ITERATIONS
     CRITERIA FOR CLOSURE                          1.0 CFS
     GREATEST CHANGE IN LAST ITERATION              .4 CFS

  BANK STORAGE DISCHARGE AFFECTED DOWNSTREAM ROUTED DISCHARGE
1 TIME STEPS LATER.
1------------------------------------------------------------
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  REACH NO.  1:          BEGINS AT GAGING STATION 0000001
GREYBULL RIVER BELOW MEETEETSEE, WYOMING

                           ENDS AT GAGING STATION 000002
ARNOLD DITCH


  TOTAL STUDY PERIOD:    BEGINS  7/17/1992
                           ENDS  7/31/1992

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THIS SIMULATION PERIOD BEGINS 7/17/1992 AND ENDS 7/31/1992

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0

SUMMARY OF STREAMFLOW DIVERSIONS AND DEPLETIONS

DISCHARGE	STARTING DAY	ENDING DAY	DISTANCE FROM STREAM
CFS	NUMBER OF DAY FROM BEGINNING OF MODEL RUN		FEET
-.10	1	1	.00
-6.40	2	2	.00
-8.60	3	3	.00
-14.70	4	4	.00
-3.40	5	5	.00
-3.80	6	6	.00
-1.80	7	7	.00
-6.10	8	8	.00
-11.50	9	9	.00
-7.60	10	10	.00
-11.60	11	11	.00
-13.70	12	12	.00
-17.70	13	13	.00
-37.00	14	14	.00
-48.40	15	15	.00

0

SUMMARY OF DATA AND RESULTS

DATE	TIME	UPSTREAM DISCHARGE	OBSERVED DOWNSTREAM DISCHARGE	PREDICTED DOWNSTREAM DISCHARGE	DOWNST. Q W/O BANK STORAGE AND LOSSES	BANK STORAGE DISCHARGE	DIVERSIONS AND DEPLETIONS	UPSTREAM STAGE	DOWNSTREAM STAGE	CHANGE IN DOWNSTREAM STAGE
7/17/1992	800	676.00	.00	49.90 *	50.00	-8.48	-.10	3.43	8.32	.05
7/17/1992	1600	659.00	.00	488.72	497.29	-49.89	-.10	3.40	9.18	.29
7/17/1992	2400	614.00	.00	664.76	714.75	-36.45	-.10	3.32	9.52	.04
7/18/1992	800	654.00	.00	636.38	679.22	-26.36	-6.40	3.39	9.47	-.01
7/18/1992	1600	638.00	.00	657.71	690.47	-25.75	-6.40	3.36	9.51	.02
7/18/1992	2400	604.00	.00	661.27	693.41	-16.85	-6.40	3.30	9.51	-.03
7/19/1992	800	638.00	.00	640.05	665.50	-15.95	-8.60	3.36	9.47	-.00
7/19/1992	1600	635.00	.00	651.94	676.50	-18.70	-8.60	3.36	9.50	.02
7/19/1992	2400	809.00	.00	658.71	686.01	-33.54	-8.60	3.64	9.51	.11
7/20/1992	800	1176.00	.00	751.89	800.13	-75.03	-14.70	4.14	9.66	.32
7/20/1992	1600	892.00	.00	1012.11	1101.83	-66.51	-14.70	3.76	10.02	.10
7/20/1992	2400	957.00	.00	956.88	1038.08	-37.02	-14.70	3.85	9.95	-.09
7/21/1992	800	1127.00	.00	944.59	985.01	-53.33	-3.40	4.08	9.93	.11
7/21/1992	1600	1004.00	.00	1062.76	1119.48	-50.59	-3.40	3.92	10.08	.05

7/21/1992	2400	919.00	.00	1041.62	1095.61	-27.93	-3.40	3.80	10.05	-.10
7/22/1992	800	932.00	.00	966.02	997.76	-22.37	-3.80	3.82	9.96	-.05
7/22/1992	1600	867.00	.00	951.43	977.60	-19.67	-3.80	3.73	9.94	-.03
7/22/1992	2400	818.00	.00	915.52	938.99	-11.46	-3.80	3.66	9.90	-.07
7/23/1992	800	893.00	.00	871.32	884.58	-16.53	-1.80	3.76	9.84	.00
7/23/1992	1600	849.00	.00	899.29	917.63	-20.20	-1.80	3.70	9.88	.02
7/23/1992	2400	801.00	.00	891.88	913.89	-11.42	-1.80	3.63	9.87	-.05
7/24/1992	800	822.00	.00	849.72	867.24	-10.39	-6.10	3.66	9.81	-.02
7/24/1992	1600	781.00	.00	848.40	864.90	-10.27	-6.10	3.60	9.81	-.02
7/24/1992	2400	720.00	.00	828.50	844.87	-1.89	-6.10	3.51	9.78	-.06
7/25/1992	800	732.00	.00	777.25	790.64	-.13	-11.50	3.53	9.70	-.04
7/25/1992	1600	713.00	.00	766.31	777.94	-2.57	-11.50	3.50	9.68	-.01
7/25/1992	2400	702.00	.00	755.36	769.43	-1.75	-11.50	3.48	9.67	-.02
7/26/1992	800	720.00	.00	746.37	755.72	-4.32	-7.60	3.51	9.65	.00
7/26/1992	1600	686.00	.00	751.99	763.91	-3.52	-7.60	3.45	9.66	-.01
7/26/1992	2400	627.00	.00	736.38	747.50	5.44	-7.60	3.34	9.64	-.07
7/27/1992	800	638.00	.00	690.80	696.96	7.49	-11.60	3.36	9.56	-.04

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 7/27/1992  1600     636.00          .00        680.17
684.28        3.13       -11.60       3.36          9.54
 -.00
 7/27/1992  2400     578.00          .00        678.20
686.68        8.11       -11.60       3.25          9.54
 -.04
 7/28/1992   800     594.00          .00        642.03
647.62       10.11       -13.70       3.28          9.48
 -.04
 7/28/1992  1600     593.00          .00        635.00
638.59        5.46       -13.70       3.28          9.46
  .00
 7/28/1992  2400     550.00          .00        635.10
643.34        9.19       -13.70       3.20          9.46
 -.03
 7/29/1992   800     566.00          .00        606.04
614.55       10.23       -17.70       3.23          9.41
 -.03
 7/29/1992  1600     607.00          .00        603.12
610.59        1.54       -17.70       3.31          9.41
  .04
 7/29/1992  2400     586.00          .00        626.97
643.13         .78       -17.70       3.27          9.45
  .01
 7/30/1992   800     600.00          .00        606.89
643.10        2.95       -37.00       3.29          9.41
 -.01
 7/30/1992  1600     614.00          .00        611.21
645.26        -.80       -37.00       3.32          9.42
  .02
 7/30/1992  2400     577.00          .00        621.46
659.26        3.04       -37.00       3.25          9.44
 -.02
 7/31/1992   800     593.00          .00        594.16
639.52        5.42       -48.40       3.28          9.39
 -.02
 7/31/1992  1600     641.00          .00        594.61
637.59       -3.06       -48.40       3.37          9.39
  .04
 7/31/1992  2400        .00          .00        623.30
674.76       42.50       -48.40       2.10          9.44
 -.28
                  -------     -------      -------
-------     -------     -------
 COLUMN TOTALS:
+                 32038.00    34071.14     32884.10
34071.14     -567.34     -577.20
0FOOTNOTE: *  DOWNSTREAM DISCHARGE IS LESS THAN SPECIFIED
MINIMUM FLOW.
                  THIS MAY BE CAUSED BY THE MODEL WHEN A
SHARP RISE IN STAGE OCCURS.
                  OR
```

THIS MAY ALSO BE CAUSED BY A HIGH
DIVERSION OR DEPLETION.

** DIVERSIONS AND DEPLETIONS WERE REDUCED TO
PREVENT NEGATIVE FLOW AT ONSET.
DOWNSTREAM DISCHARGES SHOWN RESULT FROM
BANK STORAGE.
1 VOLUME OF
FLOW (CFS-DAYS)

UPSTREAM STATION REACH
DOWNSTREAM STATION

0TOTAL 10679.33
TOTAL (W/O BANK STORAGE + LOSSES)
11357.05

TOTAL (W/ BANK STORAGE + LOSSES)
10961.37
BASE FLOW .00
BASE FLOW
750.00
RELEASE OR FLOOD 10679.33 STREAMFLOW LOSS OR GAIN
-381.51 RELEASE OR FLOOD
10211.37

BANK STORAGE:
FLOW FROM STREAM
227.58
STORED IN AQUIFER
189.11
LOST TO SOIL
.00
RETURNED TO STREAM
38.46
NET BANK STORAGE
DISCHARGE -189.11

DIVERSIONS AND WELL
LOSSES -192.40
FIRST REACH RELEASE OR FLOOD VOLUME
= 10679.3 CFS-DAYS
0 WELL LOSS, CUMULATIVE FROM FIRST REACH
= .00 CFS-DAYS
CUMULATIVE TOTAL
LOSS = -381.51 CFS-DAYS

CUMULATIVE LOSS EXCLUDING WELL LOSS = -381.51
CFS-DAYS = -3.57 PERCENT OF FIRST-REACH RELEASE OR
FLOOD VOLUME
0 NOTE: UNLESS STATED OTHERWISE
(-) INDICATES FLOW FROM STREAM
(+) INDICATES FLOW INTO STREAM
1---

GREYBULL RIVER 1992 FROM ARNOLD
(REACH NO. 2)

PROPERTIES AND CHARACTERISTICS OF REACH

LENGTH OF CHANNEL (MILES)
15.4
LENGTH OF ALLUVIUM (MILES)
12.3
TRAVEL TIME (ESTIMATED HOURS)
4.0
TRAVEL TIME TO BEGINNING OF RESPONSE (HOURS)
2.3 Cumulative from start of first reach = .33
DAYS
TRAVEL TIME TO CENTER OF RESPONSE (HOURS)
6.5
TRAVEL TIME BETWEEN BREAKS IN HYDROGRAPHS (HOURS)
4.4
NUMBER OF SUBREACHES USED IN COMPUTATIONS
1
TRANSMISSIVITY OF AQUIFER (SQ.FT./DAY)
14000.0
STORAGE COEFFICIENT OF AQUIFER (CU.FT./CU.FT.)
.45
AQUIFER IS ASSUMED TO BE SEMI-INFINITE
CASE 1
SOIL RETENTION FACTOR
.00
BASE FLOW AT DOWNSTREAM STATION
50.0
MINIMUM EXPECTED DISCHARGE TO BE ROUTED
50.0
MAXIMUM EXPECTED DISCHARGE TO BE ROUTED
3000.0
CELERITY AND DISPERSION RATING TABLE W.

CELERITY	DISCHARGE	DISP. COEF.	DISCHARGE
3.55	50.0	235.0	50.0

3.56	300.0	890.0	300.0
3.57	600.0	1675.0	600.0
3.58	900.0	2460.0	900.0
3.59	1200.0	3245.0	1200.0
3.60	1500.0	4030.0	1500.0
3.61	1800.0	4815.0	1800.0
3.62	2100.0	5600.0	2100.0

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            FAMILY OF FLOW ROUTING UNIT-RESPONSE FUNCTIONS
                 NO.  W. CELERITY  DISP.COEF  TRAVEL TIME
DISCHARGE                           ORDINATES
                        FT/SEC     SQ FT/SEC   TIME STEPS  CU
FT/SEC
                  1      3.65        7955.0        0
3000.0      1) .2390    2) .7486    3) .0124
            STREAM-AQUIFER UNIT-RESPONSE FUNCTION
                  NOTE: THIS RESPONSE FUNCTION (EXPONENTIAL
DECAY TYPE IS EVALUATED FOR 18.5 HALF-LIVES.
                        IT HAS  45 ORDINATES.
                     1)  -.007835       2)  -.004524       3)
-.003504       4)  -.002961       5)  -.002612       6)
-.002362
                     7)  -.002173       8)  -.002023       9)
-.001900      10)  -.001797      11)  -.001710      12)
-.001634
                    13)  -.001567      14)  -.001508      15)
-.001455      16)  -.001407      17)  -.001364      18)
-.001324
                    19)  -.001288      20)  -.001255      21)
-.001224      22)  -.001195      23)  -.001168      24)
-.001143
                    25)  -.001119      26)  -.001097      27)
-.001076      28)  -.001056      29)  -.001038      30)
-.001020
                    31)  -.001003      32)  -.000987      33)
-.000972      34)  -.000957      35)  -.000943      36)
-.000930
                    37)  -.000917      38)  -.000905      39)
-.000893      40)  -.000882      41)  -.000871      42)
-.000860
                    43)  -.000850      44)  -.000840      45)
-.000831
0
```

DOWNSTREAM STATION DATA
RATING TABLE

DISCHARGE	STAGE
412.00	6.50
457.00	6.60
506.00	6.70
559.00	6.80
617.00	6.90
681.00	7.00
750.00	7.10
824.00	7.20
905.00	7.30
993.00	7.40
1087.00	7.50
1190.00	7.60
1300.00	7.70
1419.00	7.80
1547.00	7.90
1685.00	8.00
1833.00	8.10
1993.00	8.20

1
0 SUMMARY OF ITERATION DATA FOR ROUTING OPTION

CHANGES BETWEEN ITERATIONS
VOLUMES AT END OF ITERATION

```
 ITERATION          MAXIMUM CHANGE          ABSOLUTE CHANGE
  NET VOLUME          VOLUME OF FLOW
    NO.                  IN                      IN
      OF                    AT
            BANK STORAGE DISCHARGE   BANK STORAGE VOLUME
 BANK STORAGE       DOWNSTREAM STATION
                        (CFS)                (CFS - DAYS)
  (CFS - DAYS)          (CFS - DAYS)
0     1                 153.2                      696.
     -696.                   9145.
0     2                  15.4                       22.
     -682.                   9160.
0     3                   1.7                        3.
     -682.                   9159.
0     4                    .2                        0.
     -682.                   9159.
0 CLOSURE WAS OBTAINED AFTER  4 ITERATIONS
     CRITERIA FOR CLOSURE                        1.0 CFS
     GREATEST CHANGE IN LAST ITERATION            .2 CFS

 BANK STORAGE DISCHARGE AFFECTED DOWNSTREAM ROUTED DISCHARGE
1 TIME STEPS LATER.
1------------------------------------------------------------
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 REACH NO.  2:          BEGINS AT GAGING STATION 000002
ARNOLD DITCH

                          ENDS AT GAGING STATION 000003
FARMERS AND BENCH CANALS


 TOTAL STUDY PERIOD:    BEGINS  7/17/1992
                          ENDS  7/31/1992

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0

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 THIS SIMULATION PERIOD BEGINS  7/17/1992  AND ENDS
7/31/1992

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0
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SUMMARY OF STREAMFLOW DIVERSIONS AND DEPLETIONS

DISCHARGE CFS	STARTING DAY	DISTANCE FROM STREAM FEET	ENDING DAY
	NUMBER OF DAY FROM BEGINNING OF MODEL RUN		
-46.40	1	.00	1
-44.90	2	.00	2
-46.30	3	.00	3
-48.50	4	.00	4
-44.60	5	.00	5
-53.40	6	.00	6
-67.60	7	.00	7
-75.10	8	.00	8
-72.40	9	.00	9
-73.40	10	.00	10
-72.40	11	.00	11
-78.80	12	.00	12
-89.60	13	.00	13
-91.20	14	.00	14
-73.90	15	.00	15

0

SUMMARY OF DATA AND RESULTS

OBSERVED PREDICTED
DOWNST. Q W/O BANK DIVERSIONS
CHANGE
UPSTREAM DOWNSTREAM DOWNSTREAM
BANK STORAGE STORAGE AND UPSTREAM
DOWNSTREAM IN
DATE TIME DISCHARGE DISCHARGE DISCHARGE
AND LOSSES DISCHARGE DEPLETIONS STAGE STAGE
STAGE

7/17/1992	800	49.90	.00	3.60 *	50.00	-29.39	-46.40	8.32	5.59	.18
7/17/1992	1600	488.72	.00	78.37	154.16	-87.92	-46.40	9.18	5.76	.43
7/17/1992	2400	664.76	.00	391.03	525.35	-139.35	-46.40	9.52	6.45	.52
7/18/1992	800	636.38	.00	471.55	655.79	-112.20	-44.90	9.47	6.63	.12
7/18/1992	1600	657.71	.00	484.72	641.83	-90.14	-44.90	9.51	6.66	.02
7/18/1992	2400	661.27	.00	523.26	658.29	-81.33	-44.90	9.51	6.73	.03
7/19/1992	800	640.05	.00	528.52	656.15	-69.39	-46.30	9.47	6.74	-.01
7/19/1992	1600	651.94	.00	527.46	643.16	-63.46	-46.30	9.50	6.74	.00
7/19/1992	2400	658.71	.00	543.65	653.42	-62.90	-46.30	9.51	6.77	.03
7/20/1992	800	751.89	.00	569.50	680.90	-73.82	-48.50	9.66	6.82	.10
7/20/1992	1600	1012.11	.00	690.61	812.93	-100.82	-48.50	10.02	7.01	.23
7/20/1992	2400	956.88	.00	846.36	995.68	-98.45	-48.50	9.95	7.23	.11
7/21/1992	800	944.59	.00	811.58	954.63	-78.56	-44.60	9.93	7.18	-.02
7/21/1992	1600	1062.76	.00	849.82	972.98	-83.16	-44.60	10.08	7.23	.07
7/21/1992	2400	1041.62	.00	928.48	1056.24	-80.38	-44.60	10.05	7.33	.04
7/22/1992	800	966.02	.00	890.03	1023.81	-63.25	-53.40	9.96	7.28	-.05
7/22/1992	1600	951.43	.00	846.83	963.47	-54.80	-53.40	9.94	7.23	-.04
7/22/1992	2400	915.52	.00	834.83						

943.03	-49.61	-53.40	9.90	7.21
-.04				
7/23/1992	800	871.32	.00	788.19
905.40	-42.64	-67.60	9.84	7.15
-.05				
7/23/1992	1600	899.29	.00	768.31
878.55	-44.11	-67.60	9.88	7.12
-.01				
7/23/1992	2400	891.88	.00	785.46
897.18	-45.23	-67.60	9.87	7.15
.00				
7/24/1992	800	849.72	.00	761.56
881.90	-38.78	-75.10	9.81	7.12
-.03				
7/24/1992	1600	848.40	.00	736.05
849.93	-36.15	-75.10	9.81	7.08
-.03				
7/24/1992	2400	828.50	.00	732.41
843.66	-34.90	-75.10	9.78	7.07
-.02				
7/25/1992	800	777.25	.00	709.20
816.50	-28.38	-72.40	9.70	7.04
-.05				
7/25/1992	1600	766.31	.00	674.49
775.27	-25.28	-72.40	9.68	6.99
-.04				
7/25/1992	2400	755.36	.00	666.14
763.83	-26.02	-72.40	9.67	6.98
-.02				
7/26/1992	800	746.37	.00	653.92
753.35	-25.75	-73.40	9.65	6.96
-.01				
7/26/1992	1600	751.99	.00	648.67
747.83	-26.88	-73.40	9.66	6.95
-.00				
7/26/1992	2400	736.38	.00	647.90
748.19	-25.70	-73.40	9.64	6.95
-.01				
7/27/1992	800	690.80	.00	627.58
725.68	-19.33	-72.40	9.56	6.92
-.05				
7/27/1992	1600	680.17	.00	597.10
688.82	-16.47	-72.40	9.54	6.87
-.04				
7/27/1992	2400	678.20	.00	590.96
679.83	-17.64	-72.40	9.54	6.86
-.02				
7/28/1992	800	642.03	.00	573.15
669.58	-14.15	-78.80	9.48	6.82
-.04				
7/28/1992	1600	635.00	.00	547.85
640.80	-12.32	-78.80	9.46	6.78

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 -.03
  7/28/1992  2400     635.10        .00        543.98
635.11        -13.57        -78.80      9.46         6.77
 -.01
  7/29/1992   800     606.04        .00        524.98
628.15        -10.74        -89.60      9.41         6.74
 -.03
  7/29/1992  1600     603.12        .00        505.36
605.70        -10.36        -89.60      9.41         6.70
 -.02
  7/29/1992  2400     626.97        .00        508.90
608.86        -15.62        -89.60      9.45         6.71
  .01
  7/30/1992   800     606.89        .00        515.05
621.87        -15.58        -91.20      9.41         6.72
 -.00
  7/30/1992  1600     611.21        .00        501.39
608.17        -14.44        -91.20      9.42         6.69
 -.01
  7/30/1992  2400     621.46        .00        507.97
613.61        -18.37        -91.20      9.44         6.70
  .02
  7/31/1992   800     594.16        .00        522.54
614.81        -16.11        -73.90      9.39         6.73
 -.01
  7/31/1992  1600     594.61        .00        504.59
594.60        -13.98        -73.90      9.39         6.70
 -.02
  7/31/1992  2400     623.30        .00        513.58
601.46        -18.35        -73.90      9.44         6.71
  .02
                          -------     -------      -------
-------       -------     -------
 COLUMN TOTALS:
+                       32884.10    32440.46     27477.49
32440.46      -2045.83    -2935.50
0FOOTNOTE: *  DOWNSTREAM DISCHARGE IS LESS THAN SPECIFIED
MINIMUM FLOW.
                  THIS MAY BE CAUSED BY THE MODEL WHEN A
SHARP RISE IN STAGE OCCURS.
                  OR
                  THIS MAY ALSO BE CAUSED BY A HIGH
DIVERSION OR DEPLETION.

           ** DIVERSIONS AND DEPLETIONS WERE REDUCED TO
PREVENT NEGATIVE FLOW AT ONSET.
                  DOWNSTREAM DISCHARGES SHOWN RESULT FROM
BANK STORAGE.
1                                                VOLUME  OF
FLOW (CFS-DAYS)

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UPSTREAM STATION REACH
DOWNSTREAM STATION

0TOTAL 10961.37
TOTAL (W/O BANK STORAGE + LOSSES)
10813.49

TOTAL (W/ BANK STORAGE + LOSSES)
9159.16
BASE FLOW 750.00
BASE FLOW
750.00
RELEASE OR FLOOD 10211.37 STREAMFLOW LOSS OR GAIN
-1660.44 RELEASE OR FLOOD
8409.16

BANK STORAGE:
FLOW FROM STREAM
681.94
STORED IN AQUIFER
681.94
LOST TO SOIL
.00
RETURNED TO STREAM
.00
NET BANK STORAGE
DISCHARGE -681.94

DIVERSIONS AND WELL
LOSSES -978.50
FIRST REACH RELEASE OR FLOOD VOLUME
= 10679.3 CFS-DAYS
0 WELL LOSS, CUMULATIVE FROM FIRST REACH
= .00 CFS-DAYS
CUMULATIVE TOTAL
LOSS = -2041.96 CFS-DAYS
CUMULATIVE LOSS EXCLUDING WELL LOSS = -2041.96
CFS-DAYS = -19.12 PERCENT OF FIRST-REACH RELEASE OR
FLOOD VOLUME
0 NOTE: UNLESS STATED OTHERWISE
(-) INDICATES FLOW FROM STREAM
(+) INDICATES FLOW INTO STREAM

APPENDIX B

GREYBULL RIVER DATA FORMAT

Quattro Pro version 3.01 was used to store and manipulate stream stage and flow data for the Greybull River. Data for the months of July, August and September 1992 are stored on the attached floppy disk. The data is presented in a format that gives 12 values for each date, that is, there are twelve two-hour average stage values and twelve corresponding flow values for an individual date. The stage values are given in feet and the flow values are given in cfs. The disk contains five files, these files are: JUL2.WQ1, AUG1.WQ1, AUG2.WQ1, SEP1.WQ1 and SEP2.WQ1. JUL2.WQ1 is flow data for all stations from July 17, 1992 to July 31, 1992. AUG1.WQ1 and SEP1.WQ1 are flow values for the first half of the months of August and September, respectively. AUG2.WQ1 and SEP2.WQ1 are flow values for the second half of the months of August and September, respectively.