Project C-7651

CONSTRUCTION AND APPLICATION OF A WATER QUALITY MODEL FOR THE UPPER BLACKFOOT RIVER BASIN IN THE CARIBOU NATIONAL FOREST, IDAHO

By

Harbhajan Singh
Civil Engineer

and

Dale Ralston
College of Mines and Earth Resources

Submitted to

Office of Water Research and Technology
United States Department of the Interior
Washington, D.C. 20242

IDAHO WATER RESOURCES RESEARCH INSTITUE
University of Idaho
Moscow, Idaho

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CONSTRUCTION AND APPLICATION OF A WATER QUALITY MODEL FOR THE UPPER BLACKFOOT RIVER BASIN IN THE CARIBOU NATIONAL FOREST, IDAHO

A Dissertation

Presented in Partial Fulfillment of the Requirement for the

DEGREE OF DOCTOR OF PHILOSOPHY

Major in Civil Engineering

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

HARBHAJAN SINGH

November 1979

AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

This dissertation of Harbhajan Singh for the Doctor of Philosophy degree with major in Civil Engineering and titled "Construction and Application of a Water Quality Model for the Upper Blackfoot River Basin in the Caribou National Forest, Idaho," was reviewed in rough draft form by each Committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

Major Professor [signature] Date 10/18/79

Committee Members [signature] Date 10/19/79

[signature] Date 10/19/79

[signature] Date 10/30/79

REVIEW OF FINAL DRAFT:

Department Head [signature] Date 11/29/79

FINAL EXAMINATION: By majority vote of the candidate's Committee at the final examination held on date of 11/5/79 Committee approval and acceptance was granted.

Major Professor [signature] Date 11/30/79

GRADUATE COUNCIL FINAL APPROVAL AND ACCEPTANCE:

Graduate School Dean ____________ Date ____________

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ABSTRACT

This study relates to the construction and application of a water quality model for the Upper Blackfoot River basin in southeastern Idaho to serve as a management tool for future phosphate mining and processing operations in the area. The model was developed by making suitable modifications to an existing model which had been used for the Boise River study. The Blackfoot River model is steady state, deterministic and one-dimensional. It has been calibrated and verified and has been found satisfactory under the limitations of the observed data and the complexity of the ecosystem. The technique of model application has been illustrated with the help of arbitrary waste discharges at selected points in the basin. Two hypothetical combinations of inputs have been assumed. The effects of these discharges on the water quality of the streams have been simulated by the model.

The model can be useful in deciding the management policies for phosphate mining and processing operations in order to mitigate or avoid their adverse impacts on water quality of the streams. The model can be adapted to the planning of these operations as well as to the planning and management of other human activities in the area with regard to their water quality impacts.

Proposals for improving the data collection system in the basin include: (i) coordination of data collection programs of the various agencies, (ii) hydrologic and water quality data gathering on ungauged major tributaries and on the main stems of the Diamond Creek and the Blackfoot River, and (iii) collection of essential weather data in the basin.

CHAPTER I

INTRODUCTION

Statement of the Problem

Phosphate is used in the manufacture of fertilizer and in the production of elemental phosphorous which is widely used in the chemical industry. Phosphate reserves of the United States are 55 percent in the eastern fields and 45 percent in the western fields. A significant part of the western fields lies in southeastern Idaho which contains about 80 percent of the reserves of the western fields and consequently about 35 percent of the United States reserves. The Idaho reserves are located on private and public lands which can be easily mined by surface methods. These reserves are estimated at slightly over one billion tons using current economics and mining technology (U.S. Department of Interior and U.S. Department of Agriculture, 1977). The U.S. Department of Interior and U.S. Department of Agriculture (1977) have given estimates of phosphate ore production from different fields and their future trend.

> "The western phosphate fields currently supply about 14 percent of the U. S. production of phosphate rock. Florida and North Carolina supply about 81 percent, and Tennessee supplies about 5 percent. Florida production will probably peak by 1985 and decline by 1990. Increased demands for phosphate, at about 2 percent per year over the next 20 years and the projected Florida production indicate a probable increase in production from the western phosphate fields."

Phosphate mining is an important economic activity in southeastern Idaho. Involved agencies of the federal government are considering a number of actions related to the development of phosphate resources in southeastern Idaho. Approval of these actions will lead to large increase in the activities related to phosphate exploration, mining and processing in the area. These activities would cause environmental changes. It is anticipated that water quality of the streams may deteriorate with increases in phosphate mining operations. This concern underlines the need for adopting suitable management practices for future mining operations so that adverse effects on water quality of streams may be minimized or avoided.

Purpose of the Study

Activities involving exploration, mining and processing of phosphate cause environmental impacts on natural and cultural environment. The natural environment involves land resources, water resources, air resources, vegetation, wildlife and fisheries. The cultural environment covers land use, socioeconomic development, transportation and utilities systems, recreation resources, archeologic, historic and aesthetic values. The environmental impacts may be short term or long term, reversible or irreversible, adverse or beneficial. Many of the impacts resulting from phosphate operations are adverse. With suitable management practices it is possible to completely avoid certain impacts while minimizing others. It is anticipated that water quality of the streams in southeastern Idaho may deteriorate with the increase in phosphate mining activities. The purpose of this study is to provide a technique which can assist in the management of future phosphate mining operations so that adverse effects on water quality of the streams may be minimized or avoided.

Objectives of the Study

The phosphate mining area in southeastern Idaho is drained by parts of four major drainages - the Portneuf, Blackfoot and Salt rivers, all tributary to the Snake River, and the Bear River which is tributary to the Great Salt Lake. These stream basins include about 90 percent of the potential mining area. The remaining 10 percent is drained mostly by Willow Creek and several other small tributaries to the Snake River. Quantitative evaluations of changes in the values of water quality parameters resulting from various levels of mining and ore processing would aid in adopting suitable management practices for such operations in these basins. A mathematical water quality model could be utilized as the basis for these evaluations.

Construction and verification of such a model require historic data on water quality constituents, hydrologic parameters and meteorological elements and information on system coefficients and system geometry. The U. S. Forest Service, Idaho Department of Health and Welfare, U. S. Geological Survey and Alumet have collected these data for Upper Blackfoot River basin which was, therefore, selected for development of a water quality model for its streams.

The general objective of the study is to construct and verify a water quality model for the Upper Blackfoot River basin to aid in predicting the impacts of different levels of phosphate mining and processing. This model would be a prototype for construction of similar models for other basins in the area.

The specific objectives are:

a) to construct, calibrate and verify a water quality model for the Upper Blackfoot River basin;

b) to apply the model to arbitrary point inputs of large dosages of pollutants and to predict the water quality changes at specific points on the river;

c) to suggest procedures for application of the model to evolve suitable management practices for phosphate mining and processing; and

d) to recommend improvement of data collection system for improvement and better application of the model.

CHAPTER II

BACKGROUND INFORMATION

Description of the Study Area

Physiography

The Upper Blackfoot River basin lies in southeastern Idaho between latitudes 42° 59'N. and 42° 37'N. and longitudes 111° 09'W. and 111° 27'W. (figure 1) and covers an area of 159 square miles. Its primary streams are Diamond Creek, Lanes Creek and Angus Creek. After the confluence of Diamond and Lanes creeks the main channel takes the name of the Blackfoot River.

The principal physical characteristics of the basin are two valleys - Upper and Rasmussen - which are surrounded by steep and high mountain ranges. The basin is bounded on the east by Webster Range and on the west by Dry Ridge and Wooley Range. These ridges and valleys which extend generally north and south, have resulted from horizontal thrust faulting and folding. Horizontal sedimentary beds were buckled and overthrusted by forces pushing from the west. These ridges and valleys are, therefore, curved in a distinct crescent pattern from northwest to south-by-southwest. The elevation ranges from 6350 feet at the weir to 8977 feet on the Webster Range. The average elevation of the Upper Valley is about 6450 feet with surrounding mountains rising to over 7700 feet.

The landforms of the basin have been designated by the U. S. Forest

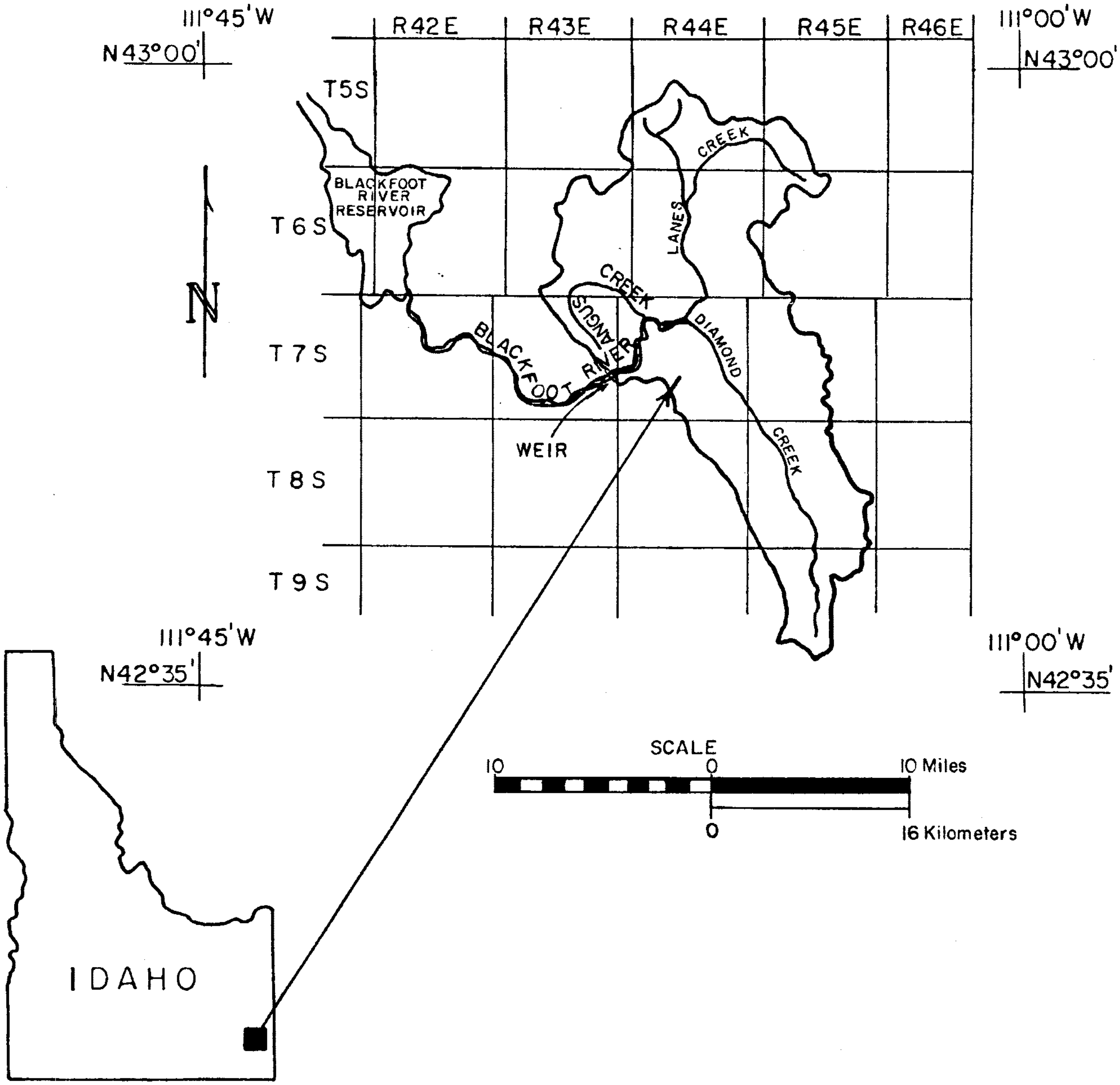

FIGURE 1 - LOCATION MAP FOR UPPER BLACKFOOT RIVER BASIN, IDAHO

Service (1976) by six land type associations - bottomlands, foothills, sideslopes, canyonlands, uplands, and ridgelands. These landtype associations represent broad areas of similar landforms.

U. S. Forest Service (1976) has classified the natural soil of the area into four major types: (1) residual, (2) colluvial, (3) alluvial-colluvial, and (4) alluvial. The residual soils occur on the ridges and uplands and extend one-half to two-thirds down the ridge sideslopes. The colluvial soils follow the residual soils to nearly the bottom of the drainage-ways of most of the tributaries. The alluvial-colluvial soils occupy the drainage bottoms, mainly along the permanent stream channels. Alluvial soils are confined to the stream valley bottoms.

Climate

Climate of the Upper Blackfoot River area is influenced by Pacific air currents and the major topographic features. The mountain ranges trend north and south and are nearly at right angles to the prevailing eastward airflow, affecting wind, precipitation, and temperature patterns. Pacific air currents drop much of their moisture on the coast and other ranges to the west before they enter the study area. The area is affected to a lesser extent by the air masses from the Gulf of Mexico and Caribbean region. This latter effect occurs in late summer and early fall to create severe thunderstorms.

Precipitation

Winter precipitation usually is in the form of snowfall, whereas summer precipitation is received from scattered showers and thundershowers. Average annual precipitation varies from 20 to 35 inches. An average of

54 percent of the annual precipitation falls from November to April which is mainly as snow. July is usually the driest month and June is the wettest. Precipitation varies with elevation; points at high elevations receive more precipitation. Study of the precipitation distribution in the nearby areas shows that in an average water year about 43 percent more precipitation falls on the ridges than in the valleys (Ralston and Trihey, 1975, p. 12). Prevailing winds are from the southwest which result in snow accumulation on the north and east sides of the ridges. Drifts may pile up to 30 feet or more in depth and be as long as six miles.

Temperature

Temperatures over the study area range from 90° to -40° F. Mean monthly temperature for the warmest month of July is about 60° F and for the coldest month of January, about 12° F (U. S. Department of Commerce, 1974). In general, temperature decreases as altitude increases. The rate of decrease vertically, called the lapse rate, averages about 3.6° F per 1000 feet of rise.

During the fall and winter months, thermal inversions, when temperatures increase with elevation, are common in the valleys. These inversions coupled with industrial pollution can be harmful to vegetation and animal life.

Evaporation

Evaporation is greatly influenced by temperature and varies, therefore, with the elevation and the season. About 80 percent of the total annual evaporation takes place between the months of April and October with a maximum in July which is the warmest month. The average annual evaporation over the study area is about 43 inches with about 9 inches for the month of July (U. S. Department of Commerce, 1974).

Solar Radiation

The mean daily sunshine ranges from a minimum of 9 hours in December to a maximum of 19 hours in July and August, with an annual daily mean of 14 hours (U. S. Department of Commerce, 1974).

Mean daily solar radiation ranges from 140 Langleys in December to 625 Langleys in June, with an annual daily mean of 400 Langleys (U. S. Department of Commerce, 1974).

Relative Humidity

Maximum relative humidity occurs in winter while it is low in summer; July and August are the lowest, during which a level of about 40 percent can be expected. Annual mean relative humidity is 62 percent (U. S. Department of Commerce, 1974).

Hydrology

Surface Water

The headwaters of the Upper Blackfoot River originate in Upper Valley which is drained by two principal tributaries - Diamond Creek and Lanes Creek. After the confluence of these two tributaries, the stream takes the name of Blackfoot River, which flows west through the Narrows.

Many of the small streams at higher elevations flow only during snowmelt or at the time of high intensity rainstorms. The large streams have perennial flow which is sustained by ground water discharge during the low flow period.

Snowmelt provides most of the water for streamflow. The high streamflows from snowmelt generally extend over a two to six weeks period, usually in May and June. In larger streams, the duration of high flows may be extended because of elevation differences within the watershed. The high north-facing and east-facing slopes are the predominant snowpack areas that produce late runoff.

Peak runoff usually is caused by snowmelt but heavy rainfall during summer thunderstorms can also cause flooding but the areas affected by such storms are small.

Ground Water

Ground water flows through alluvium or bedrock and commonly emerges at lower altitudes as springs or base flow of streams. Ground water flow systems in the bedrock strata are complicated due to fracturing of rock unit through past faulting and folding. Ground water flow is mainly through fractured limestone and is tortuous in both horizontal and vertical directions. The fractured limestone beds and some of the more permeable sandstone beds, probably are the main sources of water for numerous large springs in the area.

The most accessible source of ground water, other than springs, is in the alluvium in the larger valleys. Water enters the alluvium from direct precipitation, from tributary streamflow from the surrounding ridges and from bedrock formations underlying the valleys. The ground water in the alluviated valleys moves, in general, towards the streams that drain the valleys.

Activities Affecting Environment

The human and other activities which are being carried out in the study area and which might have environmental impacts are:

i) phosphate mining and associated operations,

ii) grazing,

iii) timber harvesting,

iv) irrigation,

v) recreation, and

vi) wildlife.

The above activities can have impacts on the following aspects of environment:

A. Natural environment

i) land resources,

ii) water resources,

iii) air resources,

iv) vegetation,

v) wildlife, and

vi) fisheries.

B. Cultural environment

i) land use,

ii) socioeconomic development,

iii) transportation and utilities,

iv) recreation,

v) archeologic and historic values, and

vi) aesthetic values.

Phosphate Mining

The present study concerns itself with the impacts of phosphate mining on the water quality of streams of Upper Blackfoot River basin.

As mentioned in Chapter I, there are plans to increase the phosphate mining activity in the study area. The phosphate beds, operating mines, phosphate leases and phosphate applications for fringe acreage, lease and prospecting permits for the Upper Blackfoot River basin are shown in figure 2.

The areas which could be subjected to mining under full development of the phosphate reserves in the Upper Blackfoot River basin up to the year 2000 are shown in figure 3. These will be covered by the following mines:

i) Wooley Valley,

ii) Rasmussen Ridge,

iii) Diamond Creek,

iv) Lanes Creek,

v) North Maybe Canyon and

vi) Husky No. 1.

The anticipated phosphate ore production from the above mines up to A.D. 2000 will be as below: (U. S. Department of Interior and U. S. Department of Agriculture, 1977, p. 1-3)

Wooley Valley	9.5 million short-tons
Rasmussen Ridge	16.0
Diamond Creek } Lanes Creek	57.5
North Maybe Canyon	not available
Husky No. 1	51.5

The above ore production figures were estimated by the U. S. Department of Interior and U. S. Department of Agriculture (1977) assuming that all

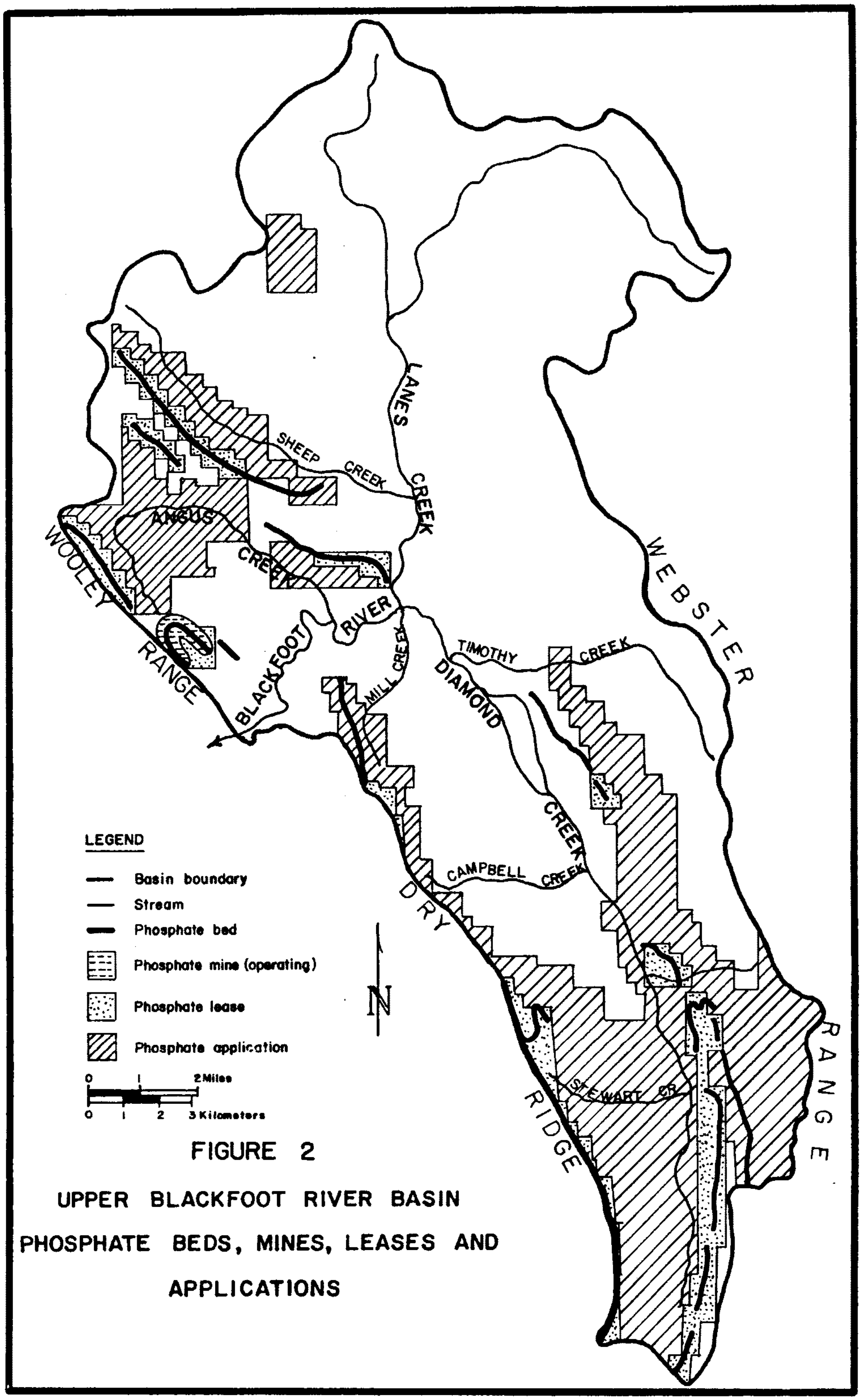

FIGURE 2

UPPER BLACKFOOT RIVER BASIN

PHOSPHATE BEDS, MINES, LEASES AND APPLICATIONS

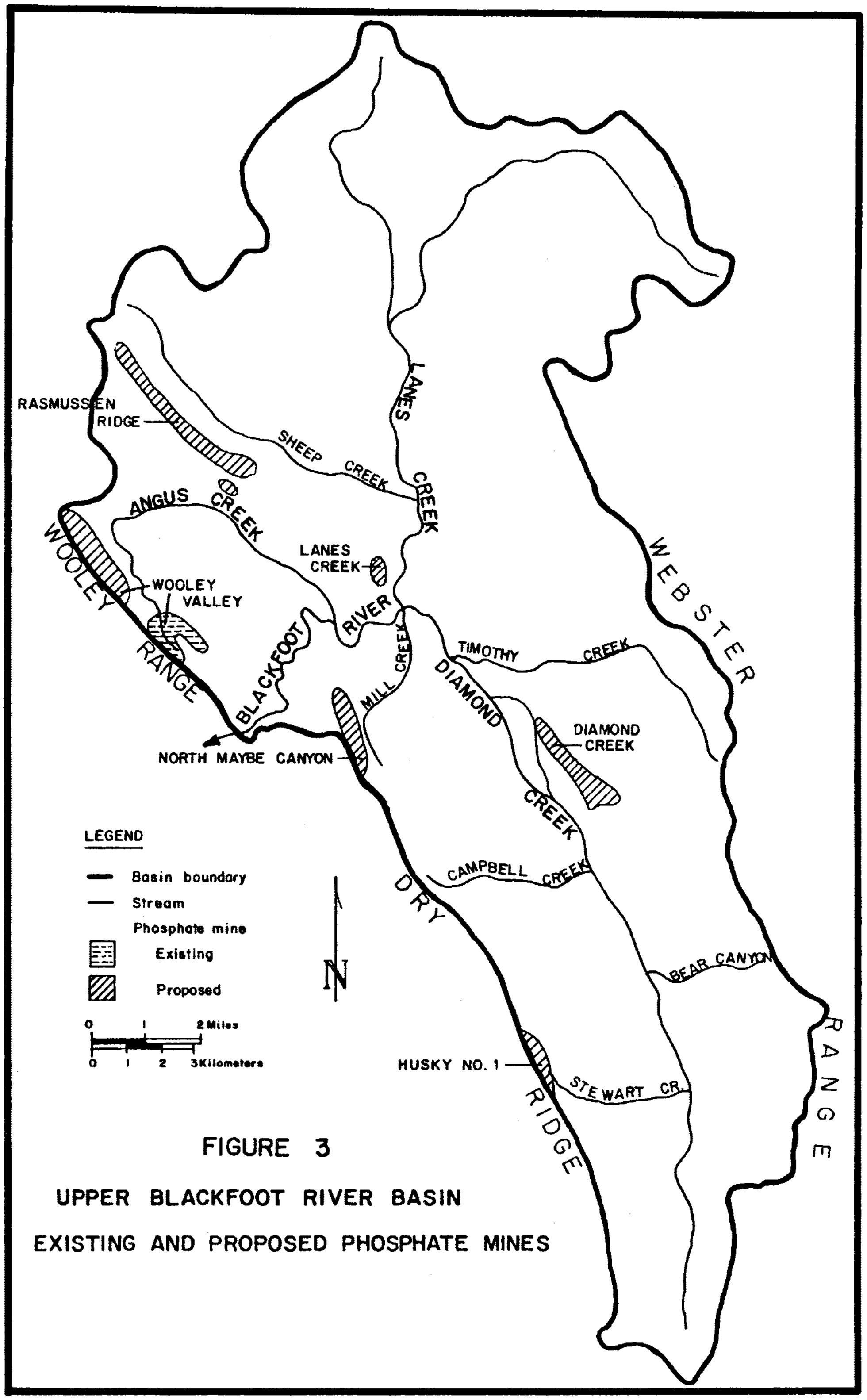

FIGURE 3

UPPER BLACKFOOT RIVER BASIN

EXISTING AND PROPOSED PHOSPHATE MINES

mining plans and pending applications for leases and fringe acreages would be approved and that all prospecting permits needed for projected mining would be issued. The present mining plan covers a period of 24 years from 1976 to 1999. On completion of this plan sufficient phosphate reserves would still be available in the area for the mining to continue beyond the year 2000.

Alumet, which will be operating the Diamond Creek and Lanes Creek mines, has plans to build a washing-sizing-calcining plant in the Upper Valley west of the proposed Diamond Creek Mine.

It is considered that the following facets of phosphate mining and processing are the primary factors controlling water quality degradation.

i) Forest clearing for exploration drilling, mining, mine waste and ore piling and rail and road construction.

ii) Rail and road construction.

iii) Ore mining.

iv) Mine waste piling.

v) Ore stockpiling.

vi) Oil, fuel and greases used for mining and transportation machinery.

vii) Ore processing - beneficiation, calcination.

viii) Possible failure of water and sediment control devices, as a result of inadequate design or unusual event.

ix) Leakage of ore slurry pipes if used.

x) Release of untreated slime, either by accident or by seepage from tailings ponds.

Phosphate mining and processing activities if carried out at full scale are likely to affect the environment adversely in a number of sectors. Mining is expected to affect the water quality of the streams in the study area unless suitable management actions are taken to eliminate or at least mitigate these effects.

Range

The lands of the study area are very productive sheep and cattle range and are some of the good grazing lands in Idaho. There are 16 sheep allotments and 2 cattle allotments within the Caribou National Forest area of the Upper Blackfoot River basin. In addition there are cattle ranges on private lands. The sheep graze at higher altitudes while cattle use the valleys and foothills. Over 75 percent of the range area is used by sheep.

Controlled grazing of cattle and sheep is practiced in the study area. Grazing is normally allowed during the following periods:

Cattle	1 June to 15 October
Sheep	1 July to 15 September

Details of the numbers of cattle and sheep and grazing periods in different ranges of the Upper Blackfoot River basin have been given in table 1, which is based on the information collected from the Soda Springs Ranger District, Caribou National Forest, Forest Service, U. S. Department of Agriculture.

Timber Harvesting

Timber stands in the study area contain mainly lodgepole pine and/or Douglas fir. Minor volumes of Engelmann spruce and subalpine fir are found intermixed.

Table 1. Cattle and sheep grazing in Upper Blackfoot River basin.

No.	Range	Type of Animal	Number of Animals	Area in Acres	Grazing Period
1	Stewart Creek	Sheep	1,195	5,739	7/6 - 9/10
2	Diamond Creek				
	Sage Creek (part)	Sheep	1,000	2,959	7/1 - 8/30
	Diamond Creek (rest)	Cattle	280	3,572	6/11-10/10
3	Timber Creek (part)	Sheep	1,000	2,630	7/1 - 8/30
4	Bear Canyon	Sheep	975	2,730	7/1 - 8/30
5	Yellowjacket Canyon	Sheep	975	4,085	7/1 - 8/30
6	Lower Bacon Creek	Sheep	1,000	6,601	7/1 - 9/5
7	Upper Bacon Creek (part)	Sheep	900	4,568	7/1 - 9/10
8	Diamond Flat (part)	Sheep	950	5,800	7/1 - 8/30
9	Brown Canyon	Sheep	1,000	-	7/1 - 9/15
10	Lanes Creek	Sheep	1,000	-	7/1 - 8/31
11	Olson Creek	Sheep	750	4,432	7/1 - 8/31
12	Kendall Canyon (part)	Sheep	1,150	5,233	6/21- 9/15
13	Henry Peak	Sheep	800	3,137	7/1 - 8/31
14	Sheep Creek	Sheep	1,100	4,128	7/1 - 9/5
15	Little Long Valley	Sheep	1,000	4,035	7/1 - 8/30
16	Mill Canyon	Sheep	800	2,833	7/1 - 8/30
17	Lower Angus				
	Rasmussen Valley	Cattle	384	2,788	6/11- 9/30
18	Private Ranges	Cattle	1200-1500 (average 1300)	-	-

Recent bark beetle infestations have decimated lodgepole pine stands. This infestation generally moved from the northeast through the area over a period of about 9 years. Losses up to 50 percent of the lodgepole pine resulted from this infestation which was severe in the Diamond Creek drainage area. U. S. Forest Service had to contract out harvesting of recently dead and dying trees in this area before the infested trees were rendered useless.

Timber has been harvested on a planned basis from the Caribou National Forest in the study area. Information on the past and future timber cutting in the area as obtained from the Soda Springs Ranger District, Caribou National Forest has been given in table 2.

Timber harvesting has effect on the accumulation, melt and evaporation of the snow in the area. This activity also causes disturbance of the soil by the machinery and road building which in turn leads to increase in sediment in the streams draining the area.

Irrigation

There are diversions of water from a number of streams in the study area for livestock watering and for irrigating forage crops and grains (wheat, barley). The diversions for which water rights existed in 1976 have been listed in table 3.

The total drainage area of Upper Valley has been adjudicated to service existing water rights and reservoir storage. "Only flood flows would be available for new appropriations and then only when there is a spill at Milner Dam", (Idaho Water Resources Board, 1968).

Table 2. Past and future timber harvesting in the Upper Blackfoot River basin.

Sub-basin	Location	Tree Type*	Number of Trees	Volume (MBF)*	Area Disturbed (acres)	Period of Harvesting	Contractor
Little Long Valley	Sec 11, T.7S., R.43E.	DF, LP	744	39	3	1/ 6/75 to 12/31/75	Stauffer Chemical Co.
Mill Creek	Sec 28, 33, T.7S., R.44E.	DF, AF	3544	85.5	30	5/12/75 to 12/31/75	Agricultural Products Co., Conda
Angus Creek	Sec 33, T.6S., R.43E. Sec 2, 3, 10, 11, T.7S., R.43E.	All species	7497	542	210	6/25/71 to 9/30/73	Stauffer Chemical Co., Montpelier
Angus Creek	Sec 14, T.7S., R.43E.	DF, AF, LP	354	41	22.5	10/ 2/72 to 10/15/74	Stauffer Chemical Co., Montpelier
Kendell Creek Cabin Creek and Yellowjacket Canyon Campbell and Hornet Canyons Coyote Creek, Hornet Canyon Bear Canyon Timber Creek Stewart Creek Diamond Creek	Sec 34, 35, T.7.S., R.44E. Sec 27, 28, 31-34, T.7S., R.45E. Sec 1, 2, 11-14, 24, T.8.S., R.44E. Sec 2-11, 14-23, 26-29, 31-35, T.8S., R.45E.	LP, DF, AF	-	8021	888.8	6/25/75 to 3/31/77	Star Studs Co.
Daves and Olsen Creeks (Midnight Spring Sales No. 1)	Sec 12, 13, T.6S., R.43E. Sec 7, 18, T.6S., R.44E.	-	-	2650	192.5	7/11/73 to 3/31/76	Rexburg Lumber Co.
Midnight Springs No. 2 (Sheep Creek, Gravel Creek, Daves Creek, Olsen Creek)	T.6S., R.43E.	-	-	2000	-	1979	
Lanes Creek	T.5-6S., R.44-45E.	-	-	5000	-	1980-81	
Sage Creek	T.9S., R.45E.	-	-	1000	-	1981	
Diamond Flat No. 2	T.6-7S., R.45-46E.	-	-	5000		1982 and beyond	
Blackfoot River	T.6-7S., R.43E.	-	-	1500		1982	

*DF = Douglas Fir, AF = Alpine Fir, LP = Lodgepole Pine, MBF = Million Board Feet

Table 3. Water rights for flow diversions within Upper Blackfoot River basin as of 1976 (Greiner Environmental Sciences, Inc., 1976).

No.	Stream or Diversion Location	Location of Area to be Irrigated	Amount (cfs)	Period of Diversion
1	Canon View	Sec 13, 14 T.7S., R.44E.	11.2	to July 1
2	Diamond Creek	Sec 23, 24, 25 T.7S., R.44E.	11.2	to July 1
3	Diamond Creek	Sec 14, 15, 22, 23 T.7S., R.44E.	11.2	to July 1
4	Diamond Creek	Sec 26, T.7S., R.44E.	4.0	to July 1
5	Home Spring Creek	Sec 22, 29 T.7S., R.44E.	6.4	to July 1
6	West Spring Creek	Sec 4, 9 T.7S., R.44E.	11.36	to July 1
7	Lane Creek	Sec 2, 11 T.7S., R.44E.	8.0	to July 1
8	Lane Creek	Sec 3, T.7S., R.44E.	5.68	to July 1
9	Duck Spring Creek	Sec 10, 15 T.7S., R.44E.	12.8	to July 1
10	Highland Creek	Sec 32, 33 T.6S., R.44E.	12.8	to July 1
11	Butte Creek	Sec 11, 14 T.7S., R.44E.	8.0	to July 1
12	Sec 36, T.5S., R.44E.	Sec 35, T.5S., R.44E.	0.4	-
13	Lane Creek	Sec 33, 34 T.6S., R.44E.	11.2	to July 1
14	Sec 31, T.5S., R.44E.	Sec 32, T.5S., R.44E.	1.0	-
15	Sec 2, T.6S., R.44E.	Sec 34, T.5S., R.44E.	2.2	-
16	Sec 17, T.6S., R.44E.	Sec 17, 20 T.6S., R.44E.	2.4	-
17	Sec 31, T.5S., R.44E.	Sec 31, 32 T.5S., R.44E.	3.1	-
18	Sec 8, T.6S., R.44E.	Sec 5, T.6S., R.44E.	2.0	-

Recreation

At present there are very few recreational activities in the Upper Blackfoot River basin. There is a camping facility in the Mill Canyon above the Narrows. Other than this only transitory visitors pass through the area which results in dispersed recreation. The impacts of the existing recreational activities on the water quality are negligible.

Wildlife

The study area is part of the Idaho Fish and Game, Big Game Herd Unit 76. Important big game species are elk, deer, moose, bear and mountain lion. Upland game birds include sage grouse, blue grouse, ruffled grouse, Hungarian partridge and mourning doves. Waterfowl includes species such as mallard, pintail, green-winged teal, shoveller, gadwall, widgeon, Canada geese, sandhill and whooping crane. A good population of the birds is migratory and inhabit the area from April through October (U. S. Forest Service, 1976). A large population of beaver is present in the area.

CHAPTER III

PRESENT STATUS OF WATER QUALITY

Effects of Geologic Formations and Phosphate Mining on Water Quality

The water in the form of water vapor is pure but as it precipitates and goes through the hydrologic cycle, it undergoes changes in quality. It picks up impurities during its passage through air and over and inside the land. The natural water is and has never been pure, even when not impacted by man. The composition of a natural water as determined by an analysis is the result of its history since its precipitation as rain or snow. The concentrations of dissolved and suspended impurities in water depend on the time water stays in contact with soluble substances. The solubility of a substance is controlled by chemical reactions which proceed as long as water is in contact with the soluble substance or until equilibrium is reached. Subsequent contact of water with another soluble substance may change the equilibrium conditions for a previously dissolved substance and result in its precipitation from solution either in its original form or as another compound. The composition of water is, therefore, a changing condition which results from physical, chemical and biological processes taking place continuously in the aquatic ecosystem due to state and exogenous variables.

Cannon (1979, p. 39) has stated that, "the sedimentary sequence of the Dinwoody, Phosphoria and Wells formations forms the basic stratigraphic sequence at all mine sites within the study area. These sedimentary rock units, together with the unconsolidated deposits of colluvium and alluvium, form the most important geologic units of the study area, with respect to water resource systems at mine sites." Limited measurements of hydraulic conductivities of the three geologic formations have shown the following general pattern of hydraulic conductivity:

Dinwoody formation	moderate
Phosphoria formation	low
Wells formation	moderate to high

The Wells formation has a large percentage of limestone while the Dinwoody formation has limestone to some extent. The hydrologic and geologic studies conducted so far of the study area show that the Dinwoody and Wells formations act as aquifers and that the Phosphoria formation allows little or no flow through it. Further there is considerable interchange of surface and ground waters. This inference is supported by the existence of losing and gaining streams and a number of springs in the area.

From the above description of the rock units one would expect high concentration of calcium carbonate in the waters of the study area and pH values greater than 7.0. This is actually the case as will be seen later from the field data.

Main constituents of phosphate mineral apatite are phosphate, fluoride and calcium. Trace elements occur in higher concentrations in the Phosphoria formation than in most other rocks. Their average concentrations are listed below (U. S. Department of the Interior and U. S. Department of Agriculture, 1977).

Element	Concentration in Phosphate Rock (ppm)
Vanadium	800
Zinc	750
Arsenic	30
Selenium	30
Cadmium	90
Thallium	3
Uranium	90

These trace elements which are toxic are probably present in the erosion products of mine wastes and ore stockpiles.

The base nature (pH > 7.0) of the waters of the study area would keep the concentrations of trace elements low. This has been substantiated by Wai (1979) in his study "Leaching of Soils from Phosphate Mine Waste Dumps in Southeastern Idaho".

Although fluoride ions occur in the phosphate ore, the pH of the water (about 7.0 to 8.5) and relatively high concentration of calcium in the waters of the study area, appear to limit the concentration of fluoride and phosphate ions in solution owing to precipitation of fluorapatite.

The Phosphoria formation contains considerable organic matter and such sediments deposited in water bodies during mining could produce nitrogen food source (U. S. Department of the Interior and U. S. Department of Agriculture, 1977).

It is considered that the following water quality constituents would be affected by phosphate mining operations:

i) suspended solids,

ii) dissolved solids,

iii) turbidity,

iv) phosphorous - total and dissolved,

v) organic nitrogen and ammonia,

vi) nitrite - NO_2-N,

vii) nitrate - NO_3-N,

viii) specific conductance,

ix) alkalinity,

x) hardness,

xi) pH and

xii) trace elements.

Statistical Analysis of Water Quality Data

Prior to 1974, hydrologic and water quality data of Upper Blackfoot River and its tributaries were meager. Since then, discharge data, chemical and partial biological data have been obtained on a fairly intensive basis. The agencies involved in the collection of these data are U. S. Forest Service, Idaho Department of Health and Welfare and U. S. Geological Survey. In addition to these agencies Greiner Environmental Sciences, Inc. has, on behalf of Alumet, collected hydrologic and water quality data within the Diamond Creek and Lanes Creek basins. These observations covered the area of impact from Alumet's proposed phosphate mining operations in the Upper Blackfoot River basin. These data were collected for a period of about 12 months starting in August, 1975.

U. S. Forest Service conducted statistical analyses of their data for the two year period from September, 1974 to August, 1976. Values of three statistical parameters - mean, range, and standard deviation - for 13 water quality indices for 8 sites in the study area, taken from these analyses have been reproduced in table 4. The numbers of samples used in computation of statistical values were as below.

Stream	Number of Samples
Diamond Creek	43 to 46
Stewart Creek	49 to 62
Mill Creek	71 to 84
Kendell Creek	21 to 27
Sheep Creek	69 to 81
Upper Angus Creek	71 to 84
Lower Angus Creek	66 to 79
Blackfoot River	73 to 86

The numbers of samples available for pH and dissolved phosphorous (PO_4) were less than the figures given above. Lesser numbers of samples for Diamond and Stewart creeks are due to these streams either going dry or becoming frozen. The observations on Kendell Creek were stopped in December, 1975 which explains why much lesser numbers of samples were used for this stream. The numbers of samples taken monthly ranged from four to eight except during the five winter months of November to March when one or no sample was taken.

Statistical analyses were not carried out by the U. S. Forest Service for trace elements. Means and ranges were calculated for these water quality constituents for the same period of 2 years and have been presented in table 5. Three samples were available for these calculations: one each in May and September, 1975 and May, 1976.

The means and ranges of additional water quality parameters were evaluated using data collected by the Idaho Department of Health and Welfare and U. S. Geological Survey. These statistical values have been presented in table 6. Dashes in the table represent no data. The numbers of samples were small and varied from one to five.

Table 4. Statistical values of water quality constituents based on data from September, 1974 to August, 1976 for U. S. Forest Service stations in Upper Blackfoot River basin.

Stream	Water Temperature (°F)			Turbidity (F.T.U.)			Suspended Solids (mg/l)			Dissolved Solids (mg/l)			Total Phosphorous (mg/l)		
	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.
Diamond Creek	45.5	32-56	6.8	5.7	.2-45	9.3	53	1-197	56	192	140-238	20	.17	.04- .44	.08
Stewart Creek	41.6	32-51	4.6	3.0	.2-30	6.1	44	0-856	114	205	181-425	31	.12	.02- .35	.07
Mill Creek	44.4	37-59	4.5	1.1	.2-11	1.3	12	0- 62	10	213	175-285	20	.16	.05- .88	.12
Kendell Creek	39.3	32-45	3.2	3.2	.3-63	12.2	12	0- 59	13	201	190-225	7	.11	.03- .71	.13
Sheep Creek	47.6	32-62	8.1	2.3	.3-15	2.8	26	0-260	44	213	130-525	41	.12	.01- .79	.09
Upper Angus Creek	46.4	32-69	11.8	6.4	.4-41	9.3	22	0-512	58	213	10-303	50	.18	0 -1.06	.17
Lower Angus Creek	43.8	32-61	8.9	3.2	.4-32	4.9	16	0-206	27	205	120-266	21	.14	.05- .53	.09
Blackfoot River	45.8	33-63	8.4	4.0	.4-73	8.3	26	0-150	32	234	183-650	58	.13	0 - .29	.06

Stream	Dissolved Phosphorous PO_4 (mg/l)			Total Kjeldahl N (mg/l)			NO_3-N (mg/l)			Total Alkalinity $CaCO_3$ (mg/l)			Total Hardness $CaCO_3$ mg/l		
	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.
Diamond Creek	.11	.07-.17	.03	2.08	.09-21	2.89	.16	.06-.34	.07	145	102-181	22	155	112-184	21
Stewart Creek	.08	.02-.12	.03	1.69	.08-11.2	1.41	.16	.09-.56	.07	165	150-182	8	172	154-326	21
Mill Creek	.05	0 -.2	.11	1.62	.45- 3.8	.62	.15	.04-.25	.04	170	138-190	11	174	154-198	9
Kendell Creek	.06	.02-.09	.02	1.83	.80- 2.9	.54	.14	.05-.20	.04	161	134-176	10	166	154-192	9
Sheep Creek	.09	.06-.11	.01	1.70	.60- 4.7	.61	.15	.09-.21	.03	168	86-326	35	172	106-248	29
Upper Angus Creek	.16	.07-.68	.13	2.02	.1 - 5.1	.84	.23	.1 -.6	.11	157	6-258	49	165	8-240	41
Lower Angus Creek	.08	.05-.11	.02	1.64	.38- 3.8	.55	.16	.05-.38	.05	155	58-194	32	159	64-198	29
Blackfoot River	.11	.04-.76	.13	1.80	.9 -16.8	1.70	.13	.04-.27	.13	179	44-960	91	178	98-310	35

Stream	pH (field)			NO_2-N (mg/l)			Conductivity (µmhos)		
	Mean	Range	S.D.	Mean	Range	S.D.	Mean	Range	S.D.
Diamond Creek	7.3	6.6-8.0	.5	0	0-0	0	295	215-366	30
Stewart Creek	7.3	7.0-8.1	.4	0	0-0	0	311	270-616	44
Mill Creek	7.8	6.8-8.8	.7	0	0- .01	0	232	269-438	31
Kendell Creek	8.0	6.9-8.8	.7	0	0- .05	.01	293	0-346	61
Sheep Creek	7.7	6.5-8.8	.8	0	0- .01	0	323	200-761	58
Upper Angus Creek	7.1	6.4-7.6	.4	.02	0- .15	.04	327	14-439	65
Lower Angus Creek	7.8	6.5-8.7	.8	.02	0-1.01	.13	311	184-409	30
Blackfoot River	7.5	6.5-8.8	.9	0	0- .01	0	355	281-942	83

S.D. = Standard Deviation

Table 5. Means and ranges of concentrations of trace elements based on data from September, 1974 to August, 1976 for U. S. Forest Service stations in Upper Blackfoot River basin.

Stream	Arsenic (mg/l)		Cadmium (mg/l)		Chromium (mg/l)		Copper (mg/l)		Selenium (mg/l)		Vanadium (mg/l)		Zinc (mg/l)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Diamond Creek	0	0-.001	0	0-.001	.001	0 -.003	.003	.002-.004	.004	.001-.010	.013	.001-.031	.019	.008-.029
Stewart Creek	0	0-.001	0	0-.001	.001	0 -.002	.011	.003-.021	0	0 -.001	.210	.001-.027	.035	.011-.068
Mill Creek	0	0-.001	0	0-.001	.006	.001-.014	.008	.003-.017	0	0 -.001	.012	0 -.035	.014	.003-.024
Sheep Creek	0	0-.001	0	0-.001	.001	0 -.001	.006	.004-.008	0	0 -.001	.010	.001-.022	.017	.014-.023
Upper Angus Creek	0	0-.001	0	0-.001	.004	0 -.010	.008	.003-.016	0	0 -.001	.010	.001-.021	.022	.018-.025
Lower Angus Creek	0	0-.001	0	0-.001	.001	0 -.002	.004	.002-.005	0	0 -.001	.003	.001-.071	.020	.019-.021
Blackfoot River	0	0-.001	0	0-.001	.002	0 -.006	.002	0 -.004	0	0 -.001	.010	0 -.030	.013	.005-.021

Table 6. Means and ranges of additional water quality parameters based on data from other sources for Upper Blackfoot River basin.

Site	Period	Dissolved Oxygen (mg/l)		BOD (mg/l)		COD (mg/l)		Total Coliform /100 ml		Fecal Coliform /100 ml		Ammonia NH_3-N (mg/l)		Fluoride (mg/l)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Diamond Creek 2 miles below Campbell Canyon	2/1975 to 10/1976	11.1	9.2-13.9	1.6	0.1-2.4	3.8	0.3-11.8	22	4-34	3	2- 4	.05	.01-.12	.11	.01-.16
Lanes Creek at mouth	6/1977 to 10/1977	8.5	7.7- 9.4	-	-	11.0	0.4-20.1	5	2- 7	14	2-25	.06	.04-.06	.11	.07-.15
Blackfoot River after confluence of Diamond Creek and Lanes Creek	10/1975 to 10/1976	10.9	9.7-13.1	1.6	0.7-2.4	3.6	2.0- 4.7	-	-	-	-	.06	.01-.17	.15	.14-.15
Blackfoot River above Angus Creek	12/1974	-	-	-	-	-	-	-	-	-	-	-	-	.10	-
Blackfoot River below the Narrows	7/1977 to 11/1977	9.7	7.1-13.0	-	-	10.7	0.8-31.2	39	2-70	4	-	.08	.02-.23	.14	.07-.16

Water Quality Standards

The State of Idaho has designated the Blackfoot River waters as Class A (Idaho Department of Environmental and Community Services, 1973) in their system of water quality standards. Under this classification the waters should be suitable for domestic water supply, industrial water supply, irrigation, livestock watering, salmonid fish spawning, salmonid fish rearing, other fish and aquatic life, hunting and wildlife, water skiing and swimming, pleasure boating and aesthetics. The relevant standards of the State of Idaho have been extracted from the publication entitled "Water Quality Standards and Wastewater Treatment Requirements" (p. 8-12), Idaho Department of Environmental and Community Services, 1973 (now Idaho Department of Health and Welfare) and have been given below.

1. Coliform

   a. Total coliform concentrations where associated with a fecal source(s) not to exceed a geometric mean of 240/100 ml, nor shall more than 20 percent of total samples during any 30-day period exceed 1000/100 ml (as determined by multiple tube fermentation or membrane filter procedures and based on not less than 5 samples for any 30-day period).

   b. Fecal coliform concentrations not to exceed a geometric mean of 50/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 200/100 ml; or greater than 500/100 ml for any single sample.

2. Dissolved Oxygen

   The DO concentration shall not be less than 6 mg/l or

90 percent of saturation whichever is greater.

3. Hydrogen Ion Concentration (pH)

   The pH values shall be within the range of 6.5 to 9.0. The induced variations shall not be more than 0.5 pH units.

4. Temperature

   a. No wastewater discharge to cause measurable increase (more than 0.5^{o}F in temperature of the receiving water) when water temperatures are 66^{o}F or above, or more than 2^{o}F increase other than from natural causes when water temperatures are 64^{o}F or less (unless otherwise specified).

   b. No increase exceeding 0.5^{o}F due to any single source, or 2^{o}F due to all sources combined.

5. Turbidity

   The turbidity other than of natural origin shall not exceed 5 Jackson Turbidity Units (JTU). Whenever the receiving water is greater than 5 JTU, due to conditions other than those caused by man, then no discharge and/or activity either alone or in combination with other wastewater or activity shall cause an increase of more than 5 JTU.

6. Toxic chemicals

   Toxic chemicals of other than natural origin in concentrations found to be of public health significance or to adversely affect the use for which the waters have been classified.

7. Nutrients

Excess nutrients of other than natural origin that cause visible slime growths or other nuisance aquatic growths.

The Environmental Protection Agency (1972) has for various water uses prescribed limits of water quality parameters beyond which they are harmful. The water quality criteria which have been recommended by EPA are listed in table 7. No recommendations could be made by the agency for remaining cases due to the fact that (i) harmfulness of some water quality constituents depends on the concentration of some other constituents, (ii) sufficient information was not available about the levels of concentrations beyond which they have adverse effects, (iii) complexity of relationships did not permit a recommendation.

McGauhey (1968) gave tentative guides for evaluating the waters for various beneficial uses. These guides were based on the information obtained from different sources. Those guides which are pertinent to the present study have been extracted and given in table 8. It may be emphasized that the values given in table 8 are only as guides and are not for strict applications as there can be variations in specific circumstances due to the complexity of relationships between different water quality parameters in indicating their harmful levels to various beneficial uses.

Raw water is used directly for recreation, aquatic and wildlife, livestock and irrigation while it is treated before use for public water supplies and industry. The quality of the raw water should be such that it can be treated economically for domestic and industrial supplies and should be suitable for other uses without treatment.

Table 7. Environmental Protection Agency's Water Quality Criteria*, 1972.

Water Use	Water Temp. (°F)	Fecal Coliform (MPN/100 ml)	Turbidity (FTU)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Dissolved Oxygen (mg/l)	Total Phosphorous (mg/l)	Dissolved Phosphorous $-PO_4$ (mg/l)	NH_3-N (mg/l)
Recreation and Aesthetics	59-93	-	-	-	-	-	0.1	-	-
Public Water Supplies+	-	2000	-	-	-	-	-	-	0.5
Aquatic life	-	-	-	80	-	-	-	-	.05
Wildlife	-	-	-	-	-	-	-	-	-
Livestock	-	-	-	-	-	-	-	-	-
Irrigation	-	-	-	-	-	-	-	-	-
Industrial water supplies	Varies with the type of industry and for boiler feedwater and for cooling water.								

Water Use	NO_2-N (mg/l)	NO_3-N (mg/l)	Alkalinity as $CaCO_3$ (mg/l)	Hardness as $CaCO_3$ (mg/l)	pH	Conductivity (µmho)	Arsenic (mg/l)	Cadmium (mg/l)	Chromium (mg/l)
Recreation and Aesthetics	-	-	-	-	6.5-8.3	-	0.1	-	-
Public Water Supplies+	1.0	10.0	-	-	5.0-9.0	-	-	.01	.05
Aquatic life	-	-	-	-	6.0-9.0	-	-	.03	.05
Wildlife	-	-	30-130	-	7.0-9.2	-	-	-	-
Livestock	10	90	-	-	-	-	.2	.05	1.0
Irrigation	-	-	-	-	4.5-9.0	-	0.1	.01	0.1
Industrial water supplies	Varies with the type of industry and for boiler feedwater and for cooling water								

- continued -

Table 7. continued.

Water Use	Copper (mg/l)	Selenium (mg/l)	Vanadium (mg/l)	Zinc (mg/l)	Fluoride (mg/l)
Recreation and Aesthetics	-	-	-	-	-
Public Water Supplies	1.0	.01	-	5.0	2.0
Aquatic life	-	-	-	-	-
Wildlife	-	-	-	-	-
Livestock	.5	.05	0.1	25	2.0
Irrigation	.2	.02	0.1	2.0	1.0
Industrial water supplies	Varies with the type of industry and for boiler feedwater and for cooling water.				

* Source - Environmental Protection Agency (1972).
In cases where there are no value ranges, the upper permissible values are given.
\+ For raw water.
\- No recommendation

Table 8. Tentative guides for evaluating the quality of water (source - McGauhey, 1968).

Water use	Water Temp. (°F)	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Turbidity (FTU)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)	Dissolved Oxygen (mg/l)	NH_3-N (mg/l)	NO_2-N (mg/l)
Recreation	86	-	-	7	20	-	-	-	-
Public Water Supply+	-	-	-	5	-	-	-	-	-
Aquatic life	73-93	-	-	-	-	2000	5.0	0.5	-
Livestock	-	-	-	-	-	2500	-	-	0
Irrigation	-	1000	-	-	-	500	-	-	-
Industry++									
Boiler feed (250 psi)	-	-	-	5	-	100-1500	-	-	-
Cooling	-	-	-	50	-	-	-	-	-

Water use	NO_3-N (mg/l)	Alkalinity as $CaCO_3$ (mg/l)	Hardness as $CaCO_3$ (mg/l)	pH	Conductivity (μmho)	Arsenic (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)
Recreation	-	-	-	6.5-9.0	-	-	-	-	-
Public Water Supply+	-	-	-	-	-	.01	.01	.05	1.0
Aquatic life	-	-	-	6.5-8.5	3000	1.0	.01	.05	.02
Livestock	200	-	-	6.0-8.5	-	1.0	-	5	-
Irrigation	-	-	-	7.0-8.5	750	1.0	-	-	0.1
Industry++									
Boiler feed (250 psi)	-	-	8	9.0	-	-	-	-	-
Cooling	-	-	50	-	-	-	-	-	-

Water use	Selenium (mg/l)	Vanadium (mg/l)	Zinc (mg/l)	Fluoride (mg/l)	Sodium Absorption Ratio (SAR)
Recreation	-	-	-	-	-
Public Water Supply+	.01	-	5	1.7	-
Aquatic life	-	-	.1	1.5	-
Livestock	-	-	-	1.0	-
Irrigation	-	-	-	-	6.0
Industry++	-	-	-	-	-

+ For treated water.

++ Water quality criteria vary from industry to industry; values for basic industrial uses are given here.

Present Status of Water Quality

The status of water quality of the waters of Upper Blackfoot River basin has been examined as it existed during the two years period September, 1974 to August, 1976 for which statistical analysis of water quality data is available. This examination is based on a comparison of the observed water quality data with the standards prescribed by the Idaho Department of Environment and Community Services and EPA and with the tentative guides prepared by McGauhey. The observed water quality data is not for completely natural waters but for waters impacted by certain levels of phosphate mining, grazing, timber harvesting, recreation, wildlife and irrigation. The levels of these activities have not changed much since August, 1976.

The activities which are carried out in the different sub-basins of the study area are:

i) Diamond Creek (above confluence with Stewart Creek)

Grazing, road construction, recreation, wildlife, logging.

ii) Stewart Creek

Grazing, road construction, timber harvesting, dispersed recreation, wildlife.

iii) Mill Creek

Timber harvesting.

iv) Kendell Creek

Timber harvesting, grazing, wildlife, dispersed recreation.

v) Sheep Creek

Grazing, dispersed recreation, wildlife.

vi) Upper Angus Creek

Mining, logging, wildlife.

vii) Lower Angus Creek

Mining, wildlife, grazing.

viii) Blackfoot River

Subjected to all the six activities.

ix) Diamond Creek (below Stewart Creek)

Irrigation, logging, grazing, wildlife, dispersed recreation.

x) Lanes Creek

Irrigation, logging, grazing, wildlife.

The examination of the water quality of the streams of the Upper Blackfoot River basin has resulted in the following conclusions:

i) The water quality is good in respect to the following constituents:

total and fecal coliform, DO, pH, total dissolved solids, ammonia (NH_3-N), nitrite (NO_2-N), conductivity, fluoride, arsenic, cadmium, chromium, copper, selenium, vanadium, zinc.

The concentrations of the trace elements and fluoride are very low due to the basic nature of the waters.

ii) Waters are alkaline and hard and below standards for some uses.

iii) Water temperautres are low but good for cold water fish.

iv) Turbidity is low except during peak flows when high values have been recorded.

v) Concentrations of suspended solids are satisfactory except during peak flow periods when they are high and below standards for certain uses.

vi) The nutrients - nitrogen and phosphorous are important for the growth of algae. Phosphorous is a limiting factor more than nitrogen as some of the plants can fix nitrogen from the atmosphere. Various workers have concluded that nitrogen below 0.1 mg/l and phosphorous below 0.01 mg/l may prevent algae growth (McGauhey, 1968). Considering these factors, concentrations of the two nutrients in the waters of the Upper Blackfoot River basin can result in moderate algae growth but according to McSorley (1978) there is very little algae in the streams of the study area. This probably is due to the low temperatures of their waters which inhibit algal growth.

The above analysis shows that water quality of the waters of the study area is generally good. Similar conclusions have been reached by other workers.

Platts and Martin (1977, p. 27) have concluded as follows:

> "The hydrochemical analysis indicated that waters in the study area are in a near natural state with possible modifications from surrounding land uses. No single parameter proved to be a major limiting factor in degrading fish health, lowering fish density, or adversely affecting fish community structure. Fish tissue analysis showed that no single metal was affecting fish health. Water

> quality degradation from present mining activity appears insignificant at this time."

U. S. Department of the Interior and U. S. Department of Agriculture (1977, p. 1-98, 1-99, 1-101, 1-107; vol. I) have arrived at the following conclusions about the quality of waters of the study area:

> "Thus, on the basis of available data, concentrations of most trace metals are low in the water of the mining area. ... the sediment concentrations that have been measured indicate that turbidity is low, except during high floods. ... Such high flows occur less than 5 percent of the time. ... Thus at high flows, small tributary streams are likely to have higher values of suspended-sediment concentration than do larger streams. As discharge decreases, smaller streams clear more rapidly than do larger streams. At medium flows, most streams are likely to have about the same suspended-sediment concentration (roughly 50 ppm), and at low flows, the tributary streams may contain less suspended-sediment than main-stem streams.
>
> Streamflows of bankfull discharge occur less than 5 percent of the time. Other than the relatively few days associated with snowmelt peak streamflow, and the even fewer days associated with high flows due to heavy rainfall events, channels in the proposed mining area normally transport only little suspended sediment.
>
> . . . .
>
> Generally, however, fluoride concentrations in groundwater and surface-water sources throughout the study area are below recommended upper limits."

The Greiner Environmental Sciences, Inc. (1976, p. 75, 79, 80) have reported on the water quality of the study area as follows:

> "... The current surface water quality in the project area is suitable for any crop irrigation, livestock watering, propagation of any desirable species of aquatic biota indigenous to the area, and human consumption.
>
> The macronutrients, phosphorous, nitrogen, inorganic carbon and silicon, are at levels considered acceptable for the control of nuisance macrophytic and planktonic algae...
>
> Water flowing in Diamond Creek are of excellent quality even during the low-flow base-flow period,

September through January. All available historical data and analysis performed on surface water samples from the Diamond Creek area reveal low levels of all constituents measured. During the September 1975 to January 1976 sampling period, total dissolved solids concentrations never exceeded 258 mg/l at any station; bicarbonate alkalinity (as Ca CO_3) and the hardness components (calcium and magnesium) constituted the major fraction of dissolved solids. ... The micronutrients measured, including iron, manganese, molybdenum, potassium, sodium, and zinc, were reported at very low concentrations, many being below detection limits.

All dissolved oxygen concentrations were measured at high levels relative to saturation concentrations. Indicative of these well-oxygenated waters are the low levels of oxygen-demanding materials present as measured by the chemical oxygen demand (COD) and biochemical oxygen demand (BOD). COD was consistently at levels below 5 mg/l. Chromium, lead, and copper were also consistently below detection limits.

Turbidity ... was at very low levels at all stations sampled in the Diamond Creek area....

Ground water quality data, ..., show considerable similarity, parameter for parameter, to those obtained from the surface water sampling stations."

The Greiner Environmental Sciences, Inc. (1976) reported that water quality for Lanes Creek area was similar to that from Diamond Creek area.

All the above shows that the water quality of the streams of Upper Blackfoot River basin is very good at present.

CHAPTER IV

WATER QUALITY MODEL

Review of Literature

Water is needed for a number of beneficial uses which include domestic, industrial and agricultural supplies, recreation, wildlife, aquatic life, hydropower generation and navigation. Quality of the waters which are suitable varies from one use to another. A number of water quality indices must be considered jointly in order to designate a water supply safe for the use to which it is to be put. Water quality indices that would provide the information required by most of the users are:

> water temperature, BOD, DO, fecal coliform, total dissolved solids, total suspended solids, turbidity, pH, alkalinity, hardness, ammonia (NH_3-N), nitrate (NO_3-N), phosphate, conductivity, toxic elements.

Quality of water is in a dynamic state and is changed by a number of physical, geochemical, biological and man-influenced factors. The impacting activities of man are industrialization, urbanization and large scale uses of water for agricultural purposes. The effects of these activities in causing pollution depends greatly on the relative location of the various users.

The managers of water resources would be interested in understanding the behavior of the aquatic system in order to evolve a suitable plan for water uses. This would in turn require a knowledge of the dynamic behavior of the quality indices of a water body. This can be done by a frequent or continuous analysis of the water body to evaluate its fitness for a particular use. This task would be prohibitively expensive due to the requirements of collection of huge quantities of data at a number of sites. Mathematical modelling of water quality can assist in this case by complementing the data collection program. Water quality models attempt to simulate the spatial and temporal variations of water quality parameters through mathematical formulations of the physical, biological and chemical processes occurring in the aquatic system.

Originally water quality models were designed to simulate DO-BOD which were considered most important for aquatic life. Harper (1971) has presented an excellent review of DO-BOD models. Lombardo (1973) reviewed the remaining water quality models. Since then a large number of water quality models have been developed through sponsorship of the Environmental Protection Agency. Many of these models have very similar structures as they were meant to modify and expand the existing models to provide capabilities to predict additional water quality constituents and to allow flexibilities in component linkages, in data input and output, in computational time and so on. A summary of the models which are applicable to streams and which have been reviewed by Harper (1971) and Lambardo (1973) and those discussed in other literature have been prepared and given in table 9.

Mathematical Basis of the Model

The aquatic system is subjected to biological, chemical and physical changes. It reaches a state of equilibrium under a steady condition of state and exogenous variables. These variables are, however, in a dynamic state of change which results in continuous change

Table 9. Water quality models applicable to streams.

Model	Developer	Water Quality Parameters Simulated	Reference
DOSAG-1	Texas Water Development Board	DO, BOD	Texas Water Development Board, 1970
QUAL-I	Texas Water Development Board	DO, BOD, conservative minerals	Texas Water Development Board, 1970
QUAL-II	Environmental Dynamics, Inc.	DO, COD, temperature, ammonia, nitrite, nitrate, phosphorous, chlorophyll a, coliforms, three conservative constituents	Environmental Dynamics, Inc.
Harper	Harper	Temperature, DO, BOD, conservative constituents, nitrate, ortho-phosphate, phytoplankton, benthic algae.	Harper, 1972
Lambardo and Franz	Lambardo and Franz	Temperature, DO, BOD, coliform, conservative constituents, organic-N, ammonia-N, nitrite-N, nitrate-N, total phosphorous, ortho-phosphate, phytoplankton, benthic algae, zooplankton	Lambardo et al, 1972
DiToro et al	DiToro et al	DO, BOD, conservative constituents, ammonia-N, nitrite-N, nitrate-N, ortho-phosphate, phytoplankton, zooplankton	DiToro et al, 1970
Chen and Wells	Chen and Wells	Temperature, toxicity, total suspended solids, coliform, DO, BOD, CO_2, PO_4-P, NH_3-N, NO_2-N, NO_3-N, algae, benthic algae, zooplankton, detritus, pH, insects, fish, benthic animals	Chen and Wells, 1975

of the aquatic system. To understand the state of the system it is necessary to know the functional relationships between the variables involved - state as well as exogenous. These functional relationships form the basis of a mathematical model which attempts to simulate changes in the state of ecosystem under a given environmental regime in response to the exogenous variables. Solutions of the mathematical functional relationships comprising the model are carried out with the help of a computer. A schematic diagram of the Upper Blackfoot River ecosystem is given in figure 4. The Boise River water quality model developed by Chen and Wells (1975) was found to be suitable for adoption to the study area after necessary modifications. The reasons for which this model was considered suitable for the study area are: (i) the Boise River and the Blackfoot River basins are both in the same geographical area which facilitates selection of the reaction coefficients needed for the model, (ii) the Boise River model has the ability to handle simulations of all the required water quality parameters needed for the study basin, and (iii) the Continuously Stirred Tank Reactor principle used in the Boise River model is suitable for Blackfoot River basin under the conditions of available field data. Chen and Wells model has, therefore, been suitably changed and used for the study area.

The model is based on the fundemental Law of Conservation of Mass which can be described by the following equation for the mass of a constituent.

$$\text{Change} = \text{In} - \text{Out} + \text{Generation} - \text{Loss}$$

The first two terms - In and Out, represent the outcome of physical processes and the last two terms - Generation and Loss, give the mass changes due to biological and chemical processes taking place in the aquatic ecosystem.

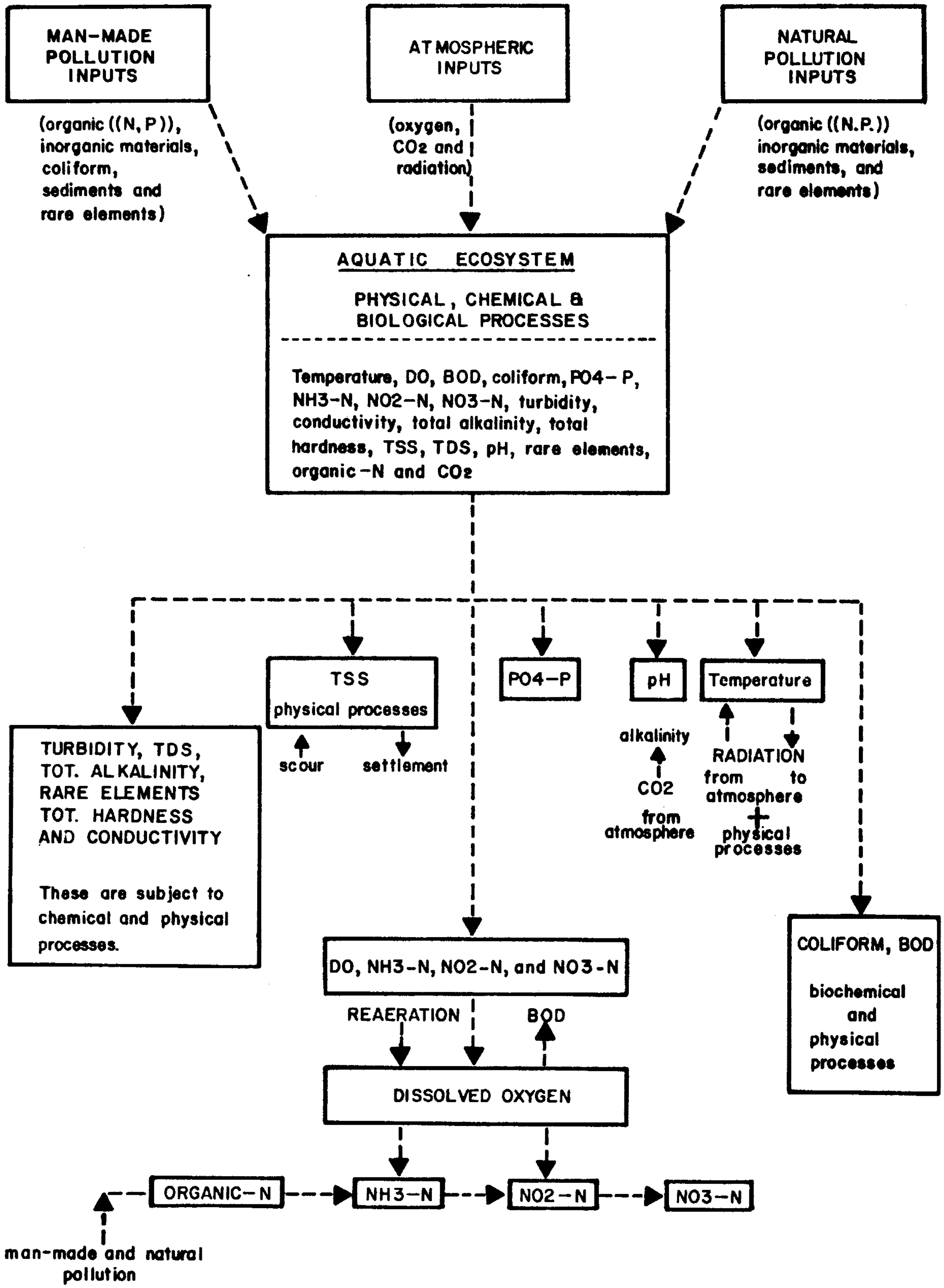

FIGURE 4 - SCHEMATIC DIAGRAM OF THE UPPER BLACKFOOT RIVER ECOSYSTEM AND ITS ENVIRONMENT

Certain simplifications and assumptions have to be made for mathematical representation of a complicated and dynamic ecosystem like the water quality of a stream. The simplifications and assumptions made for construction of the water quality model for the Upper Blackfoot River basin are:

i) The concept of Continuously Stirred Tank Reactor (CSTR) as applied in chemical engineering has been used. An input of known quality composition is fed into a reactor, the contents of which are mixed and maintained at a constant volume. The increase or decrease in concentration of a water quality constituent is analyzed and related to the conditions existing in the reactor. As the Law of Conservation of Mass holds and the volume is held constant, one can deal with the concentration of a constituent instead of its mass.

The application of the CSTR concept can be approximated in the water quality model by segmentation of the stream into small units and considering each unit as a CSTR.

ii) Steady state condition is assumed. This implies that if the input is a constant, then the output will be constant. This is approximated in the model by taking short time intervals.

iii) The ecosystem is a Single System which means that there is a functional relationship between input and output.

iv) The system is linear for most reactions. In such a system the functional relationships for the various processes undergoing in the system are of first order. This holds fairly well for the water quality parameters being considered for the study area. A second order non-linear behavior was assumed only in the case of PO_4-P deposition on sediment.

In a linear system if the input is composed of the sum of two sub-inputs as $x(t) = a \cdot x_1(t) + b \cdot x_2(t)$, then the output that is produced by x(t) is given by $y(t) = a \cdot y_1(t) + b \cdot y_2(t)$ where $y_1(t)$ is the output due to $x_1(t)$ acting alone and $y_2(t)$ is the output due to $x_2(t)$. This means that individual responses to individual inputs can be summed to provide the total response.

v) The parameters of the functional relationships describing the water quality changes remain constant over time and for a river reach.

vi) The system is one dimensional; the water quality constituents change only along the length of the stream (say X-direction) while they have no gradient along the other two directions - Y and Z. This simplifying assumption is reasonably valid for macro studies of streams.

vii) Eddy dispersion is insignificant and hence ignored in the model. This is a valid assumption for streams with little or no ponding and especially in the case of mountainous streams with high flow velocities. Such a model is called advective model.

viii) The hydraulic characteristics of mean velocity, mean depth and mean width can be expressed as a simple function of the flow.

The general equation based on mass conservation principle and given by Thomann (1972) for change in a water quality constituent across a very small river segment of length ΔX is after small modifications:

$$\frac{\Delta C}{\Delta t} = \frac{QC}{A\Delta X} - \frac{(Q + \Delta Q)(C + \frac{\partial C}{\partial X} \Delta X)}{A\Delta X} \pm \Sigma_i K_i C + \frac{C_D}{A} \frac{\Delta Q_D}{\Delta X} \pm C_B + \Sigma_j \frac{C_{pj}}{A} \frac{\Delta Q_j}{\Delta X} \tag{1}$$

where:

C = concentration of a water quality constituent (M/L^3)

ΔC = change in concentration of a water quality constituent across the small segment length ΔX of the river (M/L^3)

t = time (T)

Δt = small change in time (T)

Q = discharge entering through upstream face of segment (L^3/T)

A = cross-sectional area of the segment (L^2)

X = distance along the stream (L)

ΔX = length of the small river segment (L)

K_i = reaction coefficient for ith biochemical process resulting in generation or loss of the constituent (1/T)

C_D = concentration of non-point or distributed source (M/L^3)

ΔQ = change in stream discharge across segment due to distributed and point sources (L^3/T)

C_B = concentration added to or withdrawn from the stream per unit time by a distributed source or sink along the bottom ($M/L^3 \cdot T$)

C_{pj} = concentration of jth point source (M/L^3)

ΔQ_j = discharge of jth point source (L^3/T)

ΔQ_D = discharge of distributed or non-point source (L^3/T).

In the above equation

$$\Delta Q = \Delta Q_D + \Sigma_j \Delta Q_j \tag{2}$$

Under the simplification of CSTR, the general equation reduces to the following:

$$\frac{\Delta C}{\Delta t} = \frac{Q}{A} \cdot \frac{C}{\Delta X} - \frac{(Q + \Delta Q)\ (C + \Delta C)}{A \cdot \Delta X} \pm \Sigma_i K_i C + \frac{C_D}{A} \cdot \frac{\Delta Q_D}{\Delta X} \pm C_B$$

$$+ \Sigma_j \frac{C_{pj}}{A} \cdot \frac{\Delta Q_j}{\Delta X}$$

$$= \frac{Q \cdot C}{V} - \frac{(Q + \Delta Q)\ (C + \Delta C)}{V} \pm \Sigma_i K_i C + \frac{C_D \cdot \Delta Q_D}{V}$$

$$\pm C_B + \Sigma_j \frac{C_{pj} \cdot \Delta Q_j}{V} \tag{3}$$

where:

V = the volume of the segment (L^3).

The terms other than $\Sigma_i K_i C$ and C_B represent the advective processes. The term $\Sigma_i K_i C$ covers the biological and chemical reactions taking place in the ecosystem. For certain water quality parameters like temperature, dissolved oxygen, other inputs and outputs are involved and they require special treatment. Similarly changes in pH involve different calculations. Mathematical treatment of these reactions and processes for the various water quality constituents has been given in the following pages. The advective processes, however, affect all the constituents.

Temperature

The water temperature is a function of the net heat flux which is given by the following equation for heat budget:

$$\Theta_n = \Theta_s + \Theta_a - \Theta_b - \Theta_e + \Theta_h \qquad (4)$$

where:

Θ_n = total water surface heat flux

Θ_s = net short wave solar radiation

Θ_a = net atmospheric radiation

Θ_b = emitted or back radiation from the water surface

Θ_e = evaporative heat flux

Θ_h = convective heat flux.

The mathematical formulae for the evaluation of each of the terms entering the heat budget equation are given (Anderson, 1954; Brown, 1969; Tennessee Valley Authority, 1972).

i) Net short wave radiation (Θ_s)

Θ_s is given by the equation: (5)

$$\Theta_s = (1 - 0.65C^2)(1 - R_t)\ \Theta_o \frac{a'' + 0.5\ (1 - a' - d_a)}{1 - 0.5\ R_g\ (1 - a' + d_s)}$$

where:

C = cloud cover in tenths

R_t = Albedo or total reflectivity of the water surface (dimensionless)

Θ_o = extra-terrestrial solar radiation intensity ($K.cal/m^2.sec$)

a' = mean atmospheric transmission coefficient for cloudless, dustfree, moist air after scattering only (dimensionless)

a" = mean atmospheric transmission coefficient for cloudless, dustfree, moist air after scattering and absorption (dimensionless)

d_s = depletion coefficient of the direct solar beam by dust scattering (dimensionless)

d_a = depletion coefficient of the direct solar beam by dust absorption (dimensionless)

R_g = total reflectivity of the ground in the vicinity of the site (dimensionless).

Further

$$\Theta_o = \frac{I_o}{r^2} \sin \alpha \qquad (6)$$

where:

I_o = solar constant, 1.94 cal/cm^2.min or 0.323 Kcal/m^2.sec, equal to solar radiation intensity at normal incidence at the top of the atmosphere for mean distance earth - sun.

r = radius vector, i.e. the ratio of actual distance earth - sun to mean distance earth - sun (dimensionless)

α = solar altitude (radians)

$$\sin \alpha = \sin \phi \sin \delta + \cos \phi \cos \delta \cos h \tag{7}$$

where:

ϕ = latitude of the location (radians)

δ = declination of the sun (radians)

h = local hour angle of the sun (radians)

$$r = 1 + 0.017 \cos \left[\frac{2\pi}{365} (181 - D) \right] \tag{8}$$

$$\delta = 23.45 \left(\frac{\pi}{180}\right) \cos \left[\frac{2\pi}{365} (172 - D) \right] \tag{9}$$

where:

D = number of the day, from 1 to 365

$$h = \frac{\pi}{12} \cdot LHA \tag{10}$$

where:

LHA = local hour angle of mean sun (hours)

LHA is -12 for 0 hrs (midnight)

0 for 12 hrs (noon)

12 for 24 hrs.

Correction for LHA from standard to local solar time is given by:

$$TC = \frac{1}{15} (LLM - LSM)$$

where:

LLM = longitude of the local meridian in degrees

LSM = longitude of the standard meridian in degrees. (It is $105^{o}W$ for Upper Blackfoot River - Mountain Standard Time)

Equation for corrected h is:

$$h = \frac{\pi}{12} (LHA + TC)$$

Hour angles of the sun at sun-rise and sun-set are obtained by rearranging equation (7):

$$\text{sun-rise} - \cos h_{sr} = \frac{\sin \alpha_{sr} - \sin \phi \sin \delta}{\cos \phi \cos \delta}$$

$$\text{sun-set} - \cos h_{ss} = \frac{\sin \alpha_{ss} - \sin \phi \sin \delta}{\cos \phi \cos \delta}$$

where α_{sr} and α_{ss} for sun-rise and sun-set are equal to zero

$$R_t = A\alpha'^{B} \tag{11}$$

where:

α' = solar altitude in degrees

A and B are constants and for the Upper Blackfoot River basin different values are used depending on cloud cover.

$$R_g = C\alpha'^{D} \tag{12}$$

where:

α' = solar altitude in degrees

C and D are constants and for the Upper Blackfoot River basin different values are used depending on cloud cover.

$$a' = e^{-(0.465 + 0.134w)(0.129 + 0.171e^{-.880\, m_p})m_p} \quad (13)$$

$$a'' = e^{-(0.465 + 0.134w)(0.179 + 0.421e^{-0.721 m_p})m_p} \quad (14)$$

where:

w = water content of the atmosphere in centimeters

m_p = optical air mass corrected for the station (dimensionless).

$$w = 0.85e^{(0.110 + 0.0614\, \Theta_d)} \quad (15)$$

where:

Θ_d = mean dew point in ^oC.

$$m_p = (P/P_o)\, m \quad (16)$$

where:

P = local barometric pressure (mb)

P_o = barometric pressure at sea level (1013 mb for standard atmosphere)

m = optical air mass (dimensionless).

$$m = 1/ [\sin \alpha' + 0.15\, (\alpha' + 3.885)^{-1.253}] \quad (17)$$

where:

α' = solar altitude in degrees.

ii) Atmospheric radiation (θ_a)

θ_a can be determined by the equation:

$$\theta_a = \varepsilon_a \sigma T_a^{\ 4} \ (1 + 0.17C^2)(1 - R_t) \tag{18}$$

where:

ε_a = $0.937 \times 10^{-5} \times T_a^{\ 2}$ (dimensionless)

σ = Stefan-Boltzman constant, 1.36×10^{-11} Kcal/m^2 · sec · K^{-4}

T_a = air temperature (^{o}K)

C = cloud cover in tenths

R_t = Albedo or reflectivity of water surface. For Upper Blackfoot River basin it is taken as 0.03.

iii) Back radiation from water surface (θ_b)

This is obtained from the Stefan-Boltzman law:

$$\theta_b = \varepsilon \cdot \sigma \cdot T^4 \tag{19}$$

where:

ε = emissivity of the surface (dimensionless) It is 1 for black body and less than 1 for other bodies. For water it is approximately 0.96.

σ = Stefan-Boltzman constant, 1.36×10^{-11} Kcal/m^2 · sec · K^{-4}

T = water temperature (^{o}K)

Substituting the above values in equation (19) we get

$$\Theta_b = (0.96)(1.36 \times 10^{-11}) \cdot T^4$$

$$= 1.3056 \times 10^{-11} \cdot T^4 \text{ (Kcal/m}^2\text{.sec)} \qquad (20)$$

iv) Evaporative heat flux (Θ_e)

The equation for calculating Θ_e is:

$$\Theta_e = \rho\lambda_w E \text{ (Kcal/m}^2\text{.sec)} \qquad (21)$$

where:

ρ = density of water (kg/m^3)

λ_w = latent heat of vaporization in Kcal/kg

E = evaporation rate (m/sec)

ρ and λ_w are functions of temperature which from chemical engineering tables are:

$$\rho = 1000 - \frac{(t_w - 3.98)^2 \times (t_w + 283)}{503.57 \times (t_w + 67.26)} \qquad (22)$$

$$\lambda_w = 598.1 - .57t_w \qquad (23)$$

where:

t_w = water temperature in ^oC.

The formula used in the model to evaluate evaporation rate had been developed during Lake Hefner studies and is (Anderson, 1954):

$$E = (a + b \cdot U_w)(e_s - e_a) \qquad (24)$$

where:

a = empirically derived constant (m/sec.mb)

b = empirically derived constant (1/mb)

U_w = wind speed over water at a height of 2 meters (m/sec)

e_s = saturation vapor pressure of air at the temperature of water surface (mb)

e_a = vapor pressure of the air at 2 meters (mb).

Murray (1967) gave the following equation for calculation of saturation vapor pressure:

$$e_s = 6.1078 \text{ Exp } [17.2693882T_w/(T_w + 237.30)]$$

which can be rewritten as:

$$e_s = e^{2.3026 \, [(7.5 \, T_w/(T_w + 237.3)) + .7858]} \qquad (25)$$

where:

T_w = water temperature in ^oC.

e_a can be calculated by substituting water temperature by dew point temperature. The equation for e_a will thus be:

$$e_a = e^{2.3026 \, [(7.5 \, T_d/(T_d + 237.3)) + .7858]} \qquad (26)$$

where:

T_d = dew point temperature in ^oC.

Jobson (1978) evaluated the wind function $(a + b \cdot U_w)$ for flowing water by collecting data on wind speed and wind function for San Diego aqueduct, California. He arrived at the wind function with the following coefficient values. The units of the wind function are meters per second per millibar (m/sec.mb).

$$(a + bU_w) = 3.4953 \times 10^{-9} + 1.30786 \times 10^{-9} U_w$$

v) <u>Convective heat flux</u> (Θ_h)

According to Bowen's Ratio

$$\frac{\Theta_h}{\Theta_e} = R$$

which gives

$$\Theta_h = R \cdot \Theta_e \qquad (27)$$

equation for R is:

$$R = \frac{(6.1 \times 10^{-4}) \cdot P \cdot (T_w - T_a)}{e_s - e_a} \qquad (28)$$

Substituting the equations (21), (24) and (28) in equation (27) gives:

$$\Theta_h = (6.1 \times 10^{-4})\, \rho \cdot \lambda\, (a + bU_w) \cdot P \cdot (T_w - T_a)$$

Coliform

The change in coliform concentration (mean probability number per 100 milliliters - MPN/OO) in the aquatic system can be simulated by the equation:

$$\frac{dC}{dt} = -K_1C \pm \text{advective terms from equation (3)} \tag{30}$$

where:

K_1 = rate of die off of coliform bacteria (1/day)

C = concentration of coliform bacteria (MPN/OO)

Dissolved oxygen (DO)

The equation that describes the rate of change of oxygen is written in the form:

$$\frac{dDO}{dt} = K_2(DO_s - DO) + (A - B) - K_3 \cdot BOD - \alpha_1K_4N_1 - \alpha_2K_5N_2$$
$$- S \pm \text{advective terms from equation (3)} \tag{31}$$

where:

K_2 = reaeration constant (1/day)

DO_s = saturation value of dissolved oxygen (mg/l)

A = oxygen production due to photosynthesis (mg/l.day)

B = respiration of plankton, fish and benthos (mg/l.day)

K_3 = rate of decay of BOD or deoxygenation rate (1/day)

K_4 = rate at which ammonia is oxidized to nitrite (1/day)

K_5 = rate at which nitrite is oxidized to nitrate (1/day)

N_1 = nitrogen concentration as ammonia, NH_3-N (mg/l)

N_2 = nitrogen concentration as nitrite, NO_2-N (mg/l)

α_1 = rate of oxygen uptake per unit of ammonia oxidation

α_2 = rate of oxygen uptake per unit of nitrite oxidation

S = benthic oxygen demand (mg/l.day)

The temperatures of waters of Upper Blackfoot River basin are generally low which are not conducive to production of phytoplankton. It was learned from the Division of Environment, Idaho State Department of Health and Welfare that there was very little algae in the streams of the study area and there was hardly any data available on algae and zooplankton. Also no data were available on benthic oxygen demand. The terms A, B and S were, therefore, not included in the model.

The reaeration rate constant has been the subject of a number of studies and hence a number of formulae have been developed. The formula used in the model is from Langbein and Durum (1967) and is:

$$K_2 = \frac{3.33\,\overline{U}}{D^{1.33}} \tag{32}$$

where:

$\overline{U}$ = average stream velocity (ft/sec)

D = depth of water (ft).

The equation for calculation of saturation oxygen concentration is:

$$DO_s = Dl \times OSMLT \tag{33}$$

where:

$$Dl = 14.5532 - 0.38217\ t + .0054258\ t^2$$

where:

t = water temperature in ^{o}C

OSMLT = oxygen super saturation multiplier (pure number).

Biological Oxygen Demand (BOD)

The equation for the rate of change of BOD is:

$$\frac{dBOD}{dt} = -K_3 \cdot BOD \pm \text{advective terms from equation (3)} \qquad (34)$$

Nitrogen Cycle

i) Organic Nitrogen (N)

The rate of change of organic nitrogen is given by:

$$\frac{dN}{dt} = -K_6 N \pm \text{advective terms from equation (3)} \qquad (35)$$

where:

K_6 = rate constant for biological oxidation of organic nitrogen, N to NH_3 (1/day)

N = concentration of nitrogen as organic nitrogen (mg/l)

ii) Ammonia (NH_3-N)

The rate of change of NH_3-N is represented by the equation:

$$\frac{dN_1}{dt} = K_6 \cdot N - K_4 \cdot N_1 \pm \text{advective terms from equation (3)} \qquad (36)$$

iii) Nitrite (NO_2-N)

It's equation for rate of change is:

$$\frac{dN_2}{dt} = K_4N_1 - K_5N_2 \pm \text{advective terms from equation (3)} \quad (37)$$

iv) Nitrate (NO_3-N)

As above it has the equation:

$$\frac{dN_3}{dt} = K_5N_2 - \alpha_3\mu A \pm \text{advective terms from equation (3)} \quad (38)$$

where:

α_3 = fraction of algal biomass that is nitrogen

μ = local specific growth rate of algae - temperature dependent (1/day)

A = algal biomass concentration (mg/l)

N_3 = concentration of NO_3-N (mg/l)

Due to the algal biomass concentration being considered negligible in the study area, the second term in equation (38) is dropped in the model.

Dissolved phosphorous (PO_4-P)

Dissolved phosphorous is an important nutrient for phytoplankton. Phosphorous is also lost to the sediments and it has a benthic source. Considering these processes the equation for the rate of change in orthophosphate concentration is:

$$\frac{dP}{dt} = -\alpha_4 \mu A - K_7 P^2 + P_b \pm \text{advective terms from equation (3)} \quad (39)$$

where:

α_4 = the fraction of algal biomass that is phosphorous

K_7 = the rate constant for deposition of phosphorous on sediment (1/day)

P = the concentration of ortho-phosphate as phosphorous (mg/l)

P_b = the benthos source rate for phosphorous (mg/l.day)

The second term of equation (39) is from the model used by Jaworski et al (1971).

Due to the algal biomass concentration being considered negligible in the study area and the lack of data on benthic source, the first and third terms in equation (39) were not considered in the model constructed for the Upper Blackfoot River basin.

Total inorganic carbon (TIC), carbon dioxide (CO_2) and pH

Thomas and Trussell (1970) presented a methodology for calculation of pH from total alkalinity data. They stated (page 185), "it is well established that the alkalinity in most potable waters is virtually all bicarbonate." They also mentioned that pH changes with the transfer of CO_2 in and out of the aqueous phase and it is possible to determine the final pH of a water when an equilibrium of aqueous CO_2 is reached with the CO_2 in the atmosphere.

CO_2 and TIC can be calculated from the equations for bicarbonate reactions.

i) Total inorganic carbon (TIC)

$$TIC = (ALK/50000)/\ [(1 + 2K_2/H)/(H/K_1 + 1 + K_2/H)] \times 12000 \qquad (40)$$

where:

TIC = total inorganic carbon (mg/l)

ALK = total alkalinity (mg/l)

H = hydrogen ion concentration = 10^{-pH}

K_1 and K_2 are thermodynamic constants and are evaluated by equations:

$$K_1 = 10^{(-3404.71/T + 14.8435 - 0.032786T)}$$

$$K_2 = 10^{(-2902.39/T + 6.498 - 0.02379T)}$$

where:

T = water temperature in ^{o}K

= (t + 273.15) where t is water temperature in ^{o}C.

ii) Carbon dioxide (CO_2)

$$CO_2 = TIC/(1 + K_1/H + K_1K_2/H^2) \qquad (41)$$

where:

CO_2 = carbon dioxide (mg/l)

TIC = total inorganic carbon (mg/l)

H = hydrogen ion concentration = 10^{-pH}

K_1 and K_2 are thermodynamic constants and are evaluated by equations:

$$K_1 = 10^{(-3404.71/T + 14.8435 - 0.032786T)}$$

$$K_2 = 10^{(-2902.39/T + 6.498 - 0.02379T)}$$

where:

T = water temperature in ^{o}K

= (t + 273.15) where t is water temperature in ^{o}C.

iii) pH

As mentioned earlier pH is evaluated by changing its values till a balance equilibrium condition is reached for CO_2 under the given total alkalinity of water. This is achieved when the following equation is satisfied:

$$[(BICARB) \times (H + 2K_{2a})/H] + Kwa/H - ALK - H = 0$$

where:

$$BICARB = [(TIC/12000) \cdot H \cdot K_{1a}]/ (H \cdot K_{1a} + K_{1a}K_{2a} + H^2)$$

ALK and H are as defined earlier.

K_{1a}; K_{2a} and K_{wa}, the thermodynamic constants used in the above equation are the modified constants using Debye Huckel term and temperature adjustment. The equations for modifications are:

Unextended Debye Huckel Term

$$DH1 = -(0.5085 \times .0025^{\frac{1}{2}})/(1 + 1.3124 \times .0025^{\frac{1}{2}})$$

$$DH2 = -(2.0304 \times .0025^{\frac{1}{2}})/(1 + 1.4765 \times .0025^{\frac{1}{2}})$$

Extended Debye Huckel Term

$$EDHCO_3 = 4.7456945 \times 10^{-3} + 4.1607623 \times 10^{-2} \times .0025 - 9.2848432 \times 10^{-3} \times .0025^2$$

$$EDCO_3 = 1.2056653 \times 10^{-2} + 9.715745 \times 10^{-2} \times .0025 - 2.0677462 \times 10^{-2} \times .0025^2$$

Log of Activity Coefficients

$$LGHCO_3 = DH1 + EDHCO_3$$

$$LGCO_3 = DH2 + EDCO_3$$

$$LGH_2CO_3 = 0.0755 \times .0025$$

Activity Coefficients

$$GHCO_3 = 10^{LGHCO_3}$$

$$GCO_3 = 10^{LGCO_3}$$

$$GH_2CO_3 = 10^{LGH_2CO_3}$$

Temperature adjustment for Thermodynamic Constants

K_1 and K_2 are as given earlier.

$$K_w = 10^{(-5242.39/T + 35.3944 - 0.00835T - 11.8261 \log_{10}T)}$$

Modified Thermodynamic Constants

$$K_{1a} = K_1 \times GH_2CO_3/GHCO_3$$

$$K_{2a} = K_2 \times GHCO_3/GCO_3$$

$$K_{wa} = K_w/GHCO_3$$

Conservative constituents

i) Total suspended solids (TSS)

It involves two processes - settlement and scouring in addition to advective processes, which together determine the concentration of total suspended solids. The settlement is evaluated with the help of average settling velocity which is taken as 2×10^{-5} ft/sec for the whole channel. For scouring, an average maximum scouring rate of .35 $g/m^2.sec$ has been used for the study area for a streamflow velocity of 8 ft/sec. It is reduced proportionately for lower velocities. The settling velocity and scouring rate values have been taken from the Boise River study by Chen and Wells (1975) as no field data were available for the study area.

ii) Total alkalinity, total hardness, TDS, turbidity

These water quality constituents are subject to physical and chemical processes. Turbidity is dependent on the total suspended solids and the grain size distribution and their shapes. The change in concentration of TSS can be determined as explained earlier but it is not possible to predict the changes in grain size distribution and shapes.

Rare elements

Concentrations of these elements in water depend on the amounts of their salts which are available and the time water is in contact with them. If only one salt is present and is available in large quantities and the time of contact with water is long enough, an equilibrium condition is reached when the concentration is at a saturation level. If at this stage another salt is added to the solution or temperature of water is changed the previous equilibrium condition is changed and the concentrations of the elements change. It is possible to determine the concentrations of the elements under laboratory conditions but under natural conditions, concentrations of rare elements are subject to continuous changes. It is, therefore, not possible to simulate accurately their changes through a mathematical model where representation of the continuously changing chemical processes is not feasible. The model can, however, simulate their changes due to physical processes of mixing. In the case of the Upper Blackfoot River concentrations of rare elements are kept very low due to the basic nature of its waters and are chemically nearly in a steady state condition. Chemical reactions would become significant if inputs of waste discharges lower the pH below 7.0. In such a situation the model will not produce accurate results.

Rate coefficients

The decay processes for coliform, BOD, organic nitrogen, ammonia nitrogen and nitrite nitrogen have been taken to be goverened by Streeter-Phelps equation which is:

$$L_t = L_o e^{-Kt}$$

where:

L_o = weight of a constituent at t = o (mg)

L_t = weight of the constituent after time t (mg)

K = decay parameter (1/day).

The above equation can be written in terms of concentrations as:

$$C_t = C_o e^{-Kt}$$

The change in C over a time period Δt can be obtained from the above equation.

$$\Delta C = C_t - C_o = C_o e^{-K \cdot \Delta t} - C_o$$

$$= (e^{-K \cdot \Delta t} - 1)\ C_o$$

or
$$\frac{\Delta C}{\Delta t} = \frac{(e^{-K \cdot \Delta t} - 1)}{\Delta t}\ C_o$$

$$= K' \cdot C_o$$

K' is represented by K_1, K_3, K_4, K_5 and K_6 in the earlier equations. These can be evaluated from the values of K, the decay coefficient for each process.

Temperature adjustment of rate coefficient

The rate constants are subject to change with change in water temperature. This change is based on Vant Hoff's principle which can be stated by the equation:

$$K_T = K_{T_s}\,\Theta^{T - T_s}$$

where:

K_T = rate coefficient at temperature T (1/day)

K_{T_s} = rate or reaeration coefficient at a standard temperature T_s (1/day)

Θ = temperature coefficient (dimensionless)

T_s = standard temperature (^oC).

T_s has been taken as 20^{o}C for the model. The above equation then changes to:

$$K_T = K_{20}\Theta^{T-20}$$

where:

K_{20} = rate or reaeration coefficient at 20^{o}C.

Construction of the Model

The water quality model constructed for the Upper Blackfoot River basin has been based on Chen and Wells' model (1975) which was used for Boise River in southern Idaho. Chen and Wells' model has been modified for application to the study area and to meet the objectives. Following are the major changes which were made in Chen and Wells' model.

i) The wind function entering the equation for evaporation rate which in turn was used to evaluate evaporation heat flux, was taken from Jobson's (1978) study which evaluated it for streams. The wind function used in Chen and Wells' model was derived for lake surfaces.

ii) Equations for calculation of latent heat of vaporization and vapor pressures were changed.

iii) Organic nitrogen term was introduced in the nitrogen cycle as its decay results in the production of NH_3-N.

iv) Due to negligible quantities of phytoplankton present in the study area and low water temperatures, the terms for algae and zooplankton were omitted from the nitrogen and phosphorous cycles.

v) The term for deposition rate of phosphorous on sediments as used in the model by Jaworski et al (1971) was introduced in the model for study area.

vi) Method of solution of the partial differential equations was changed to multiple X-step and single time step.

vii) Simulation of rare elements was included in the model.

viii) Modifications were made in the hydraulic calculations and calculations of water quality changes in each segment to conform accurately to the CSTR concept.

ix) A sub-program was included to plot the output by a plotter.

The mathematical water quality model is a set of partial differential equations, one for each water quality parameter to be simulated. These equations have been given under "mathematical basis of the model." The water quality parameters which the model for the study area can simulate are:

> Temperature, total suspended solids, coliform, BOD, DO, DO in percent, pH, CO_2, PO_4-P, NH_3-N, NO_2-N, NO_3-N, total inorganic carbon (TIC), total alkalinity, total dissolved solids, turbidity, total hardness, organic nitrogen and rare elements.

The above list includes more water quality parameters than those involved in phosphate mining and processing operations. This additional capability of the model would be useful later on in the management of other activities as well in the area.

The model is a steady-state model which means that over the time of simulation, the inputs - atmospheric, hydrologic and water quality - remain constant. This simplifies calculations and takes less computational time.

As has been mentioned earlier, the model is based on CSTR principle. This requires segmentation of the river such that each segment is treated as a CSTR. The segmentation of the river has to be done in such a manner that the number of segments is neither too large nor too small. In one case too large computational time will be needed while in the other case the accuracy will be sacrificed. These influence the acceptance of the model which depends on its economics as well as its accuracy of simulation. Also there are practical considerations of inputs and desired simulation points which enter into decision making for segmentation. Further the segment lengths have to be chosen such that the retention time is about equal to the time interval of simulation. A number of trials were made with different time intervals - 0.1, 0.5 and 1.0 hour - and different segmentations. The segmentation of the Upper Blackfoot River basin which was finally adopted for the model is shown in figure 5.

The basin was segmented such as to cover model simulation of the impacts of all the present and future mining operations in the study area. The segmentation resulted in 23 nodal points on the main river stem - Diamond Creek and Blackfoot River - and Angus Creek. The model is equipped to simulate each water quality constituent at these 23 nodal points. The segment lengths and river miles for the nodal points have been given in table 10. The time interval finally selected for model simulations was 1.0 hour which was close to the retention times of the river segments.

Each river segment is assumed completely mixed and for each time interval, a multiple step explicit solution is used to solve the partial differential equations describing the water quality processes.

The computer program for the model was designed to go through the following sequence of water quality processes.

1. Advective process,
2. Other physical processes; atmosphere-water interface, settling, scouring and

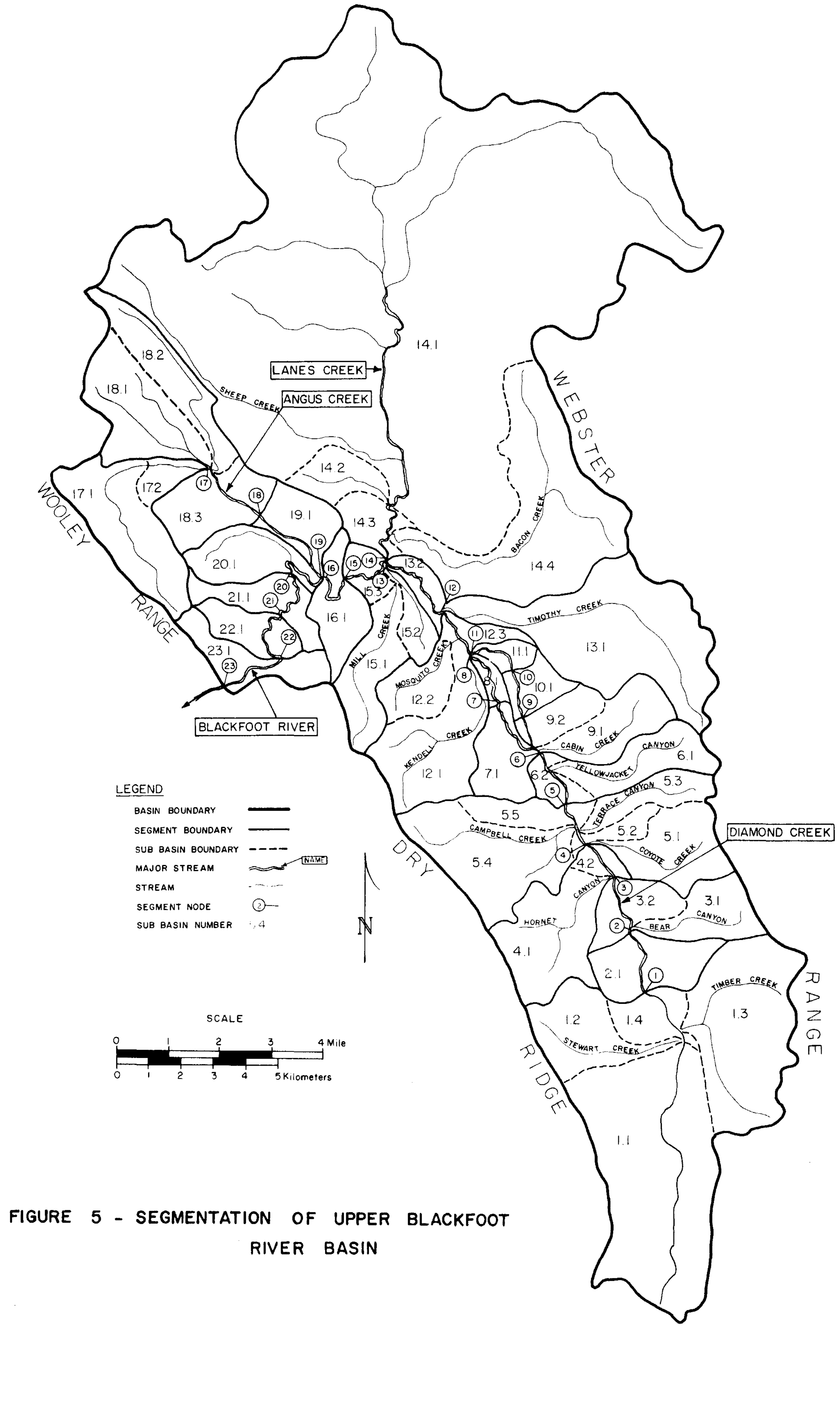

FIGURE 5 - SEGMENTATION OF UPPER BLACKFOOT RIVER BASIN

Table 10. Segment lengths and river miles for nodal points, Upper Blackfoot River basin.

Number of Segment and Nodal Point	Segment length (miles)	River Miles of Nodal Point (miles)
1	1.310	20.31
2	1.391	18.92
3	1.179	17.74
4	0.886	16.85
5	0.982	15.87
6	1.341	14.53
7	1.419	13.11
8	1.424	11.69
9	0.819	13.85
10	1.040	12.81
11	1.123	11.69
12	1.074	10.62
13	2.492	8.13
14	1.600	8.13
15	1.353	6.78
16	1.229	5.55
17	1.150	8.87
18	1.400	7.47
19	1.920	5.55
20	1.409	4.14
21	1.590	2.55
22	1.249	1.30
23	1.296	0.00

3. Biological and chemical processes.

The computer program comprised of a main program and 7 sub-programs as below:

a) MAIN - coordinates various sub-programs, controls the frequency and period of computations and outputs the simulated data.

b) DATA - reads information on system geometry, connectivity and reaction coefficients and converts them to suitable form for use in other sub-programs. Reads also the initial water quality conditions in each river segment.

c) WEATHR- reads and processes the weather data.

d) HEAT - calculates the energy components of heat budget equation.

e) FLOW - reads data on inflows and their water qualities and outflows; carries out hydraulic computations and calculates water quality changes due to advective process.

f) ECOSYS- computes water quality changes due to biological, chemical and other physical processes and evaluates the water qualities at the end of each time interval and for each segment.

g) PH - computes pH, CO_2 and TIC at the end of each time interval and for each segment.

h) PLOTER- plots the simulated water qualities as time plots at selected nodes and longitudinal plots for selected hours of the day.

A layout of the main program and the subroutines forming the complete computer program is presented in figure 6. The flow diagram showing the computational steps involved in the program is shown in figure 7. A listing of the computer program has been attached as Appendix A.

Collection of Data

Following types of data are required to be inputted into the water quality model:

i) general data,

ii) weather data,

iii) hydrologic and hydraulic data,

iv) water quality data, and

v) reaction and other coefficients.

A description of the sources and method of procurement and the necessary processing and computations involved in each type of data follows.

General Data

Some general data are required by the computer program to be used for control of operations and for certain calculations. These data are to provide the following information:

i) Starting day of computation, counting from 1 January as 1,

ii) Ending day of computation,

iii) Computations per day. This is determined from the time interval selected for solution of the partial differential equations,

iv) Days of simulation before tabular print out of the simulated

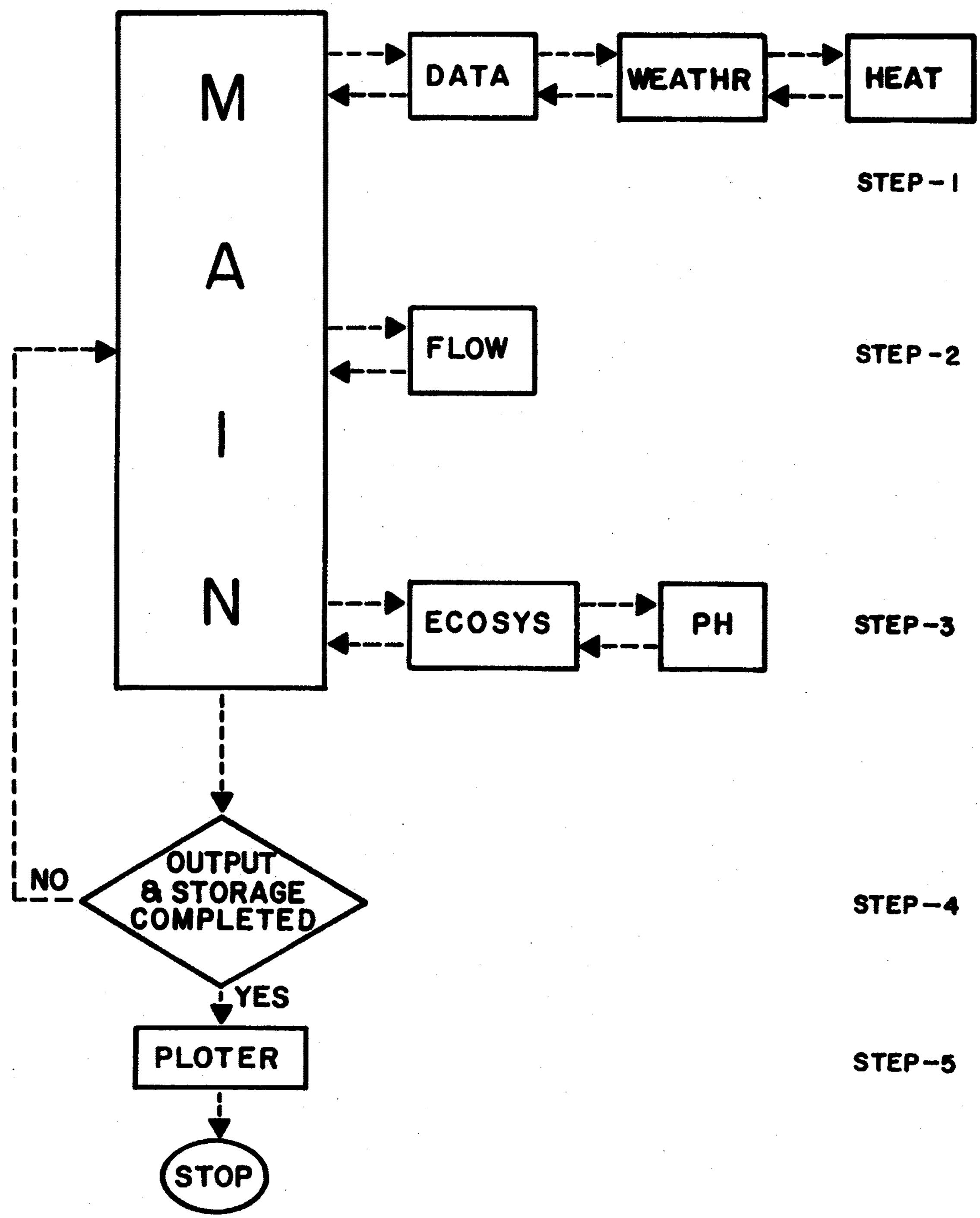

FIGURE 6 - LAYOUT OF COMPUTER PROGRAM - MAIN AND SUBROUTINES

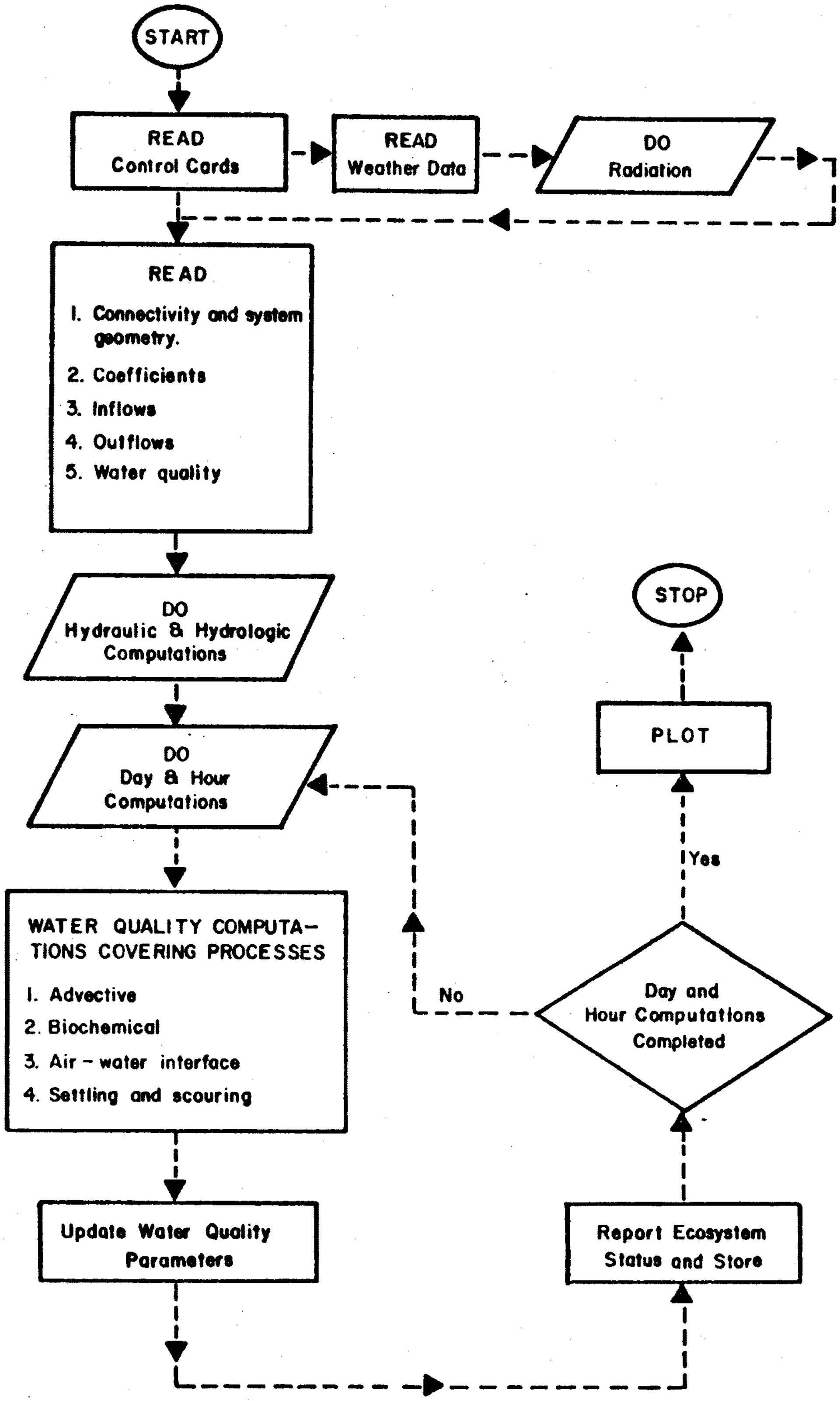

FIGURE 7 - FLOW DIAGRAM, UPPER BLACKFOOT RIVER MODEL

water qualities begins,

v) Print frequency,

vi) Mean latitude and longitude of the study area,

vii) Number of days in the hydrologic cycle,

viii) Number of weather zones covering the study area,

ix) Number of segments,

x) Tape number if used,

xi) Printing options, and

xii) Plot details.

a) Time plots - parameters, time period and the nodes to be covered.

b) Profile plots - parameters, nodes and the hours to be covered.

The above information must be supplied by the person using the model and is based on the type of output needed and on the type of weather and hydrologic data which are available.

Weather Data

The following weather data are required for use in the model:

i) Air temperature - dry bulb and wet bulb or dry bulb and dew point.

ii) Cloud cover,

iii) Wind speed and

iv) Atmospheric pressure.

The above weather data enter into the evaluation of heat flux.

U. S. Forest Service was observing cloud cover data during their discharge and water quality measurements in the study area. These cloud cover data were used for the two periods - May, 1976 and September, 1976 - selected for calibration and verification of the model.

Greiner Environmental Sciences, Inc. (1976) collected meteorological data at two sites in the study area for about a year starting from August, 1975. One of the stations was located at an elevation of 6550 feet in the Upper Valley near the proposed Diamond Creek mine. The second station was located at an elevation of 8200 feet on Dry Ridge. The Dry Ridge station was too high to be considered for application to the Upper Blackfoot River system. The data from the Diamond Creek station only were, therefore, utilized. These gave observations of dry bulb and dew point temperatures and wind speed. These data, however, were not available for the two periods selected for model testing.

The nearest weather station outside the study area was at Conda but its data were restricted to precipitation and temperature. The only station with comprehensive weather data was at Pocatello which was 75 miles from the study area. Greiner Environmental Sciences, Inc. (1976) conducted correlation studies between data from Pocatello and Diamond Creek and found them satisfactory. Polynomial curve fitting was, therefore, carried out between Pocatello and Diamond Creek station data with the help of a computer. This was done for daily values of dry bulb and dew point temperatures and wind speed for each three hour period (1-3, 4-6, 7-9, 10-12, 13-15, 16-18, 19-21, 22-24) for September, 1975. Curve fitting was tried for first, second and third order polynomials and it was found that the sum of squares of errors were the least for the second order polynomials. F-test for six selected sets of data, two sets for each element resulted in significant to highly significant correlation for four sets and not significant correlation for two sets, one of which was near the border line. The second order polynomial equations were, therefore, used to estimate the three weather data for the study area from Pocatello data for May and September, 1976. The polynomial equations used for these determinations have been included as Appendix B.

Atmospheric pressure data for the study area were evaluated from Pocatello data with the help of Laplace or hystrostatic equation for reduction of pressure with height. This equation is:

$$p_o = pe^{Z/KT}$$

where:

p_o = pressure (mb) at the lower station

p = pressure (mb) at the upper station

Z = difference in elevation (meters) between two stations

K = constant = 29.3

T = mean temperature (^{o}A) of air column between elevations of two stations.

T was calculated by determining the temperature of study area from the temperature at Pocatello using a temperature lapse rate of 1^{o}A per 200 meters and then averaging the two.

The elevation of Pocatello is 4478 feet and the mean elevation for the study area is approximately 6500 feet. The value of Z thus worked out to be 616.3 meters.

Pressure data were computed for each three hour period of the day for the months of May and September, 1976 for the study area.

The distribution of the weather stations from which data could be evaluated for the study area allowed the whole area to be considered only under one weather zone. Further, the weather observations were available at 3 hourly intervals but their hourly values were required for model computations using a time interval of 1.0 hour. The 3-hourly values were, therefore, assumed to be the same for each hour of the 3-hour period. This assumption was valid as changes in the weather data during the 3-hour periods would be negligible for the purpose of water quality model.

Pocatello weather data were obtained from the climatological records of U. S. Department of Commerce (1975) and National Weather Service Office (1976).

Hydrologic and Hydraulic Data

A survey of all the sources of hydrologic data for the study area was made. It was found that the following agencies had collected or were collecting these data.

i) U. S. Forest Service. They started collecting data at eight sites in the area in August, 1974. The station on Kendell Creek was closed in November, 1975. The observations are still being continued at the remaining seven stations. During the first two years four to eight observations were made each month except during the winter months of November to March when one or no observation was made during a month. From the third year the frequency was reduced to two per month with no change for winter period. Stage as well as discharge measurements are made at all these stations. The discharge measurements are made from wooden bridges at most of the sites. In some cases they are made by wading. On Blackfoot River just outside the forest boundary, measurements are made with a weir.

Observations of air temperature, cloud cover and water temperature are also made at the time of discharge measurements. Water samples are collected for laboratory analyses.

Information about the hydrologic stations has been provided in table 11 whereas their locations are shown in figure 8. Photographs of four stations were taken in June, 1977 when hydrologic and water quality observations were being carried out. These photographs have been reproduced as figures 9 through 12.

ii) Greiner Engineering Sciences, Inc. Greiner Engineering Sciences, Inc. (1976) collected and analyzed hydrologic data in the Diamond Creek and Lanes Creek basins as part of their study on environmental impact assessment of the proposed mining operations in the area by Alumet. They collected this data along with other data like meteorological, water quality, ground water etc. at a number of sites in the Diamond Creek and Lanes Creek basins. They installed Parshall flumes at all the sites except the two on Diamond Creek, one upstream and one downstream of the proposed mine and plant site area, where stilling wells with continuous stage recorders were built. Stage and

Table 11. Hydrologic stations in Upper Blackfoot River basin.

No.	Stream	Location of Station	Agency	Period and Frequency of data
1	Blackfoot River	42^{o} 47' 37" N, 111^{o} 22' 30" W (at diversion weir just below national forest boundary)	U. S. Forest Service (USFS)	8/1974 to-date (twice a month)
2	Upper Angus Creek	42^{o} 49' 50" N, 111^{o} 23' 50" W (near headwaters)	USFS	8/1974 to-date (twice a month)
3	Lower Angus Creek	42^{o} 51' 14" N, 111^{o} 24' 45" W (½ mile above national forest boundary)	USFS	8/1974 to-date (twice a month)
4	Sheep Creek	42^{o} 51' 47" N, 111^{o} 19' 45" W (on foot bridge 1½ miles above national forest boundary)	USFS	8/1974 to-date (twice a month)
5	Mill Creek	42^{o} 48' 35" N, 111^{o} 18' 20" W (100 yds above national forest boundary)	USFS	8/1974 to-date (twice a month)
6	Mosquito Creek	D2	Greiner Engineering Sciences, Inc. (GES)	10-12/1975
7	Timothy Creek	D4	GES	10-12/1975
8	Kendell Creek	42^{o} 46' 50" N, 111^{o} 16' 30" W (at national forest boundary)	USFS	10/1974 to 11/1975 (twice a month)
9	Kendell Creek	D3	GES	10/1975-10/1976
10	Diamond Creek	Below D1	University of Idaho (UI)	7-8/1976
11	Diamond Creek	D1 (below proposed Diamond Creek mine)	GES	12/1975 to 10/1976
12	Diamond Creek	Above station D1	UI	7-8/1976
13	Diamond Creek	Below fence and below station D8	UI	7-8/1976
14	Diamond Creek	D8 (above proposed Diamond Creek mine)	GES	12/1975 to 10/1976
15	Cabin Creek	D6	GES	9/1975 to 10/1976
16	Yellowjacket Canyon	D7	GES	9/1975 to 7/1976
17	Diamond Creek	Above Yellowjacket Canyon confluence	UI	7-8/1976
18	Diamond Creek	Lower Stewart Flat	UI	7-8/1976
19	Diamond Creek	Upper Stewart Flat	UI	7-8/1976

- continued -

Table 11. Continued.

No.	Stream	Location of Station	Agency	Period and Frequency of data
20	Stewart Creek	42^{o} 41' 45" N, 111^{o} 11' 57" W (above confluence with Diamond Creek)	USFS	8/1974 to-date (twice a month)
21	Diamond Creek	42^{o} 41' 30" N, 111^{o} 11' 50" W (above confluence with Stewart Creek)	USFS	8/1974 to-date (twice a month)
22	East Spring Creek	42^{o} 48' 25" N, 111^{o} 17' 30" W	GES	4 discharge observations during 9/1975 to 1/1976
23	West Spring Creek	42^{o} 48' 25" N, 111^{o} 17' 50" W	GES	4 discharge observations during 9/1975 to 1/1976

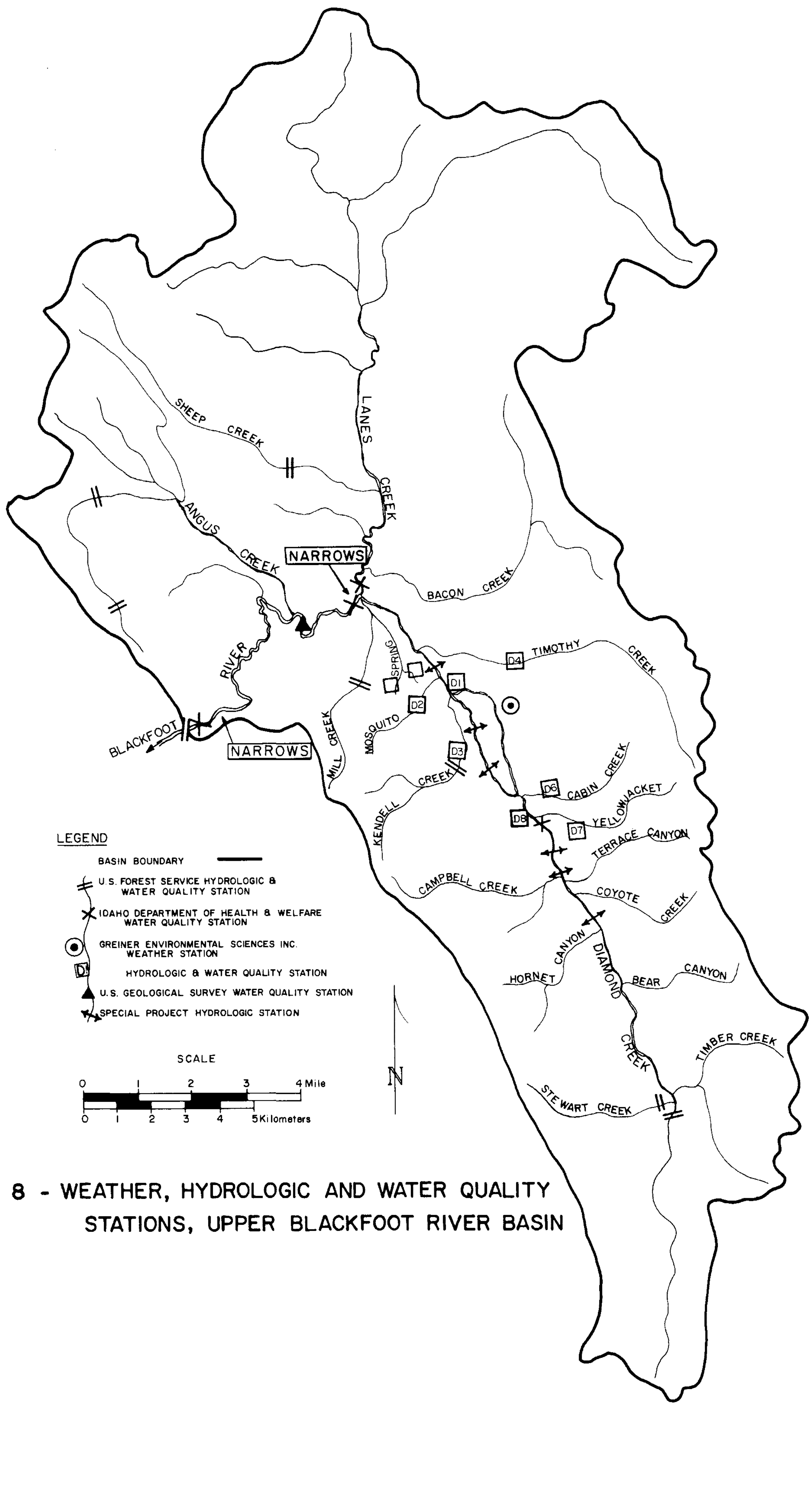

FIGURE 8 - WEATHER, HYDROLOGIC AND WATER QUALITY STATIONS, UPPER BLACKFOOT RIVER BASIN

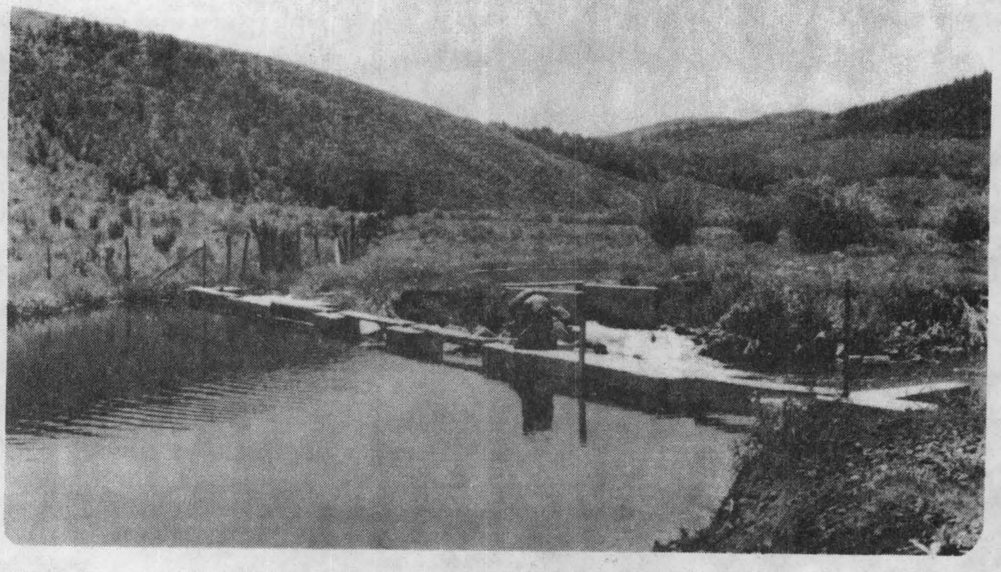

FIGURE 9 - HYDROLOGIC AND WATER QUALITY OBSERVATIONS IN PROGRESS AT THE WEIR ON BLACKFOOT RIVER (U.S.F.S), JUNE,1977

FIGURE 10 - HYDROLOGIC AND WATER QUALITY OBSERVATIONS IN PROGRESS AT UPPER ANGUS CREEK STATION (U.S.F.S), JUNE,1977

FIGURE 11 - HYDROLOGIC AND WATER QUALITY OBSERVATIONS IN PROGRESS AT SHEEP CREEK STATION (U.S.F.S), JUNE,1977

FIGURE 12 - HYDROLOGIC AND WATER QUALITY OBSERVATIONS IN PROGRESS AT MILL CREEK STATION (U.S.F.S), JUNE,1977

discharge observations were made at all these stations for a period of about one year starting in September, 1975.

Details of 9 sites whose data were relevant to this study and hence could be utilized have been included in table 11. The locations of these stations have also been shown in figure 8.

Greiner Engineering Sciences, Inc. carried out four discharge measurements for East Spring and West Spring creeks during the period September, 1975 to January, 1976 yielding nearly uniform flows of 0.9 cfs and 1.0 cfs respectively.

iii) University of Idaho. Edwards (1977) carried out investigations on the hydrogeology of the proposed phosphate mining area in the Diamond Creek drainage. During these investigations which were spread over two years period of 1975 and 1976, he established certain hydrologic stations in the Diamond Creek valley. He conducted stage and discharge observations at his stations and made supplementary observations at selected stations of the Greiner Engineering Sciences, Inc. The stations whose data were relevant to this study have been listed in table 11 and located on figure 8.

Preparation of Hydrologic Data. The hydrologic data required for the model are the inflows into and the outflows from each river segment as surface or ground water. These data are used to do flow calculations for each river segment. These calculations are started from the first segment and are carried down the river taking one segment at a time. These computations yield information for each segment on (i) inflows from upper segments, (ii) total inflows from sub-basins and ground water (point and distributed inputs), (iii) total outflows and (iv) flow through the segment.

The discharge data were not available for all the streams of the sub-basins of the study area. The flow data of ungauged streams were, therefore, estimated from the data of gauged streams using standard hydrologic techniques. The techniques employed were: (i) same discharge per square mile method for adjacent and similar sub-basins, (ii) use of observed stream loss and gain data and data of springs to evaluate the inflow from ground water or loss to ground water and (iii) allowances made for diversions for irrigation and stock watering.

The areas of the sub-basins of the study area have been given in table 12 while the inflow and outflow data appear later in the computer output.

Edwards (1977) reported stream losses to ground water from Diamond Creek between the two gauging stations D8 and D1 of Greiner Environmental Sciences, Inc. He observed these losses from miscellaneous as well as continuous data taken along the Diamond Creek. The miscellaneous data showed the following:

Loss between Upper Gage D8 and Below Fence Station	4.7 cfs (5.8 cfs/mile)
Loss between Below Fence and Above Lower Gage	6.7 cfs (5.7 cfs/mile)
Loss between Above Lower Gage and Lower Gage D1	3.3 cfs (3.3 cfs/mile)

Hydrographs for Upper and Lower Gages prepared by Edwards (1977)

Table 12. Areas of sub-basins of Upper Blackfoot River basin.

No.	Name of Sub-basin	Area (sq. miles)	Type of Discharge	No.	Name of Sub-basin	Area (sq. miles)	Type of Discharge*
1.1	Diamond Creek	10.03	P	12.2	Mosquito Creek	1.40	P
1.2	Stewart Creek	2.48	P	12.3	Unnamed	0.50	D
1.3	Timber Creek	5.92	P	13.1	Timothy Creek	7.53	P
1.4	Unnamed	1.23	D	13.2	Unnamed	0.70	D
2.1	Unnamed	2.25	D	14.1	Lanes Creek	59.88	P
3.1	Bear Canyon	1.70	P	14.2	Unnamed-1	1.29	P
3.2	Unnamed	1.47	D	14.3	Unnamed-2	1.10	D
4.1	Hornet Canyon Creek	3.44	P	14.4	Bacon Creek	8.35	P
4.2	Unnamed	0.50	D	15.1	Mill Creek	2.20	P
5.1	Coyote Creek	2.52	P	15.2	Spring Creek	0.80	P
5.2	Unnamed	0.59	D	15.3	Unnamed	0.73	D
5.3	Terrace Canyon Creek	1.31	P	16.1	Unnamed	1.83	D
5.4	Campbell Canyon Creek	4.24	P	17.1	Angus Creek	3.64	P
5.5	Unnamed	1.16	D	17.2	Unnamed	0.66	D
6.1	Yellowjacket Creek	2.01	P	18.1	Unnamed-1	3.32	P
6.2	Unnamed	0.70	D	18.2	Unnamed-2	2.39	P
7.1	Unnamed	1.60	D	18.3	Unnamed-3	2.41	D
8.1	Unnamed	0.34	D	19.1	Unnamed	1.52	D
9.1	Cabin Creek	2.07	P	20.1	Unnamed	1.89	D
9.2	Unnamed	0.94	D	21.1	Unnamed	1.60	D
10.1	Unnamed	1.06	D	22.1	Unnamed	1.28	D
11.1	Unnamed	1.06	D	23.1	Unnamed	1.73	D
12.1	Kendell Creek	3.82	P				

Total Area for Upper Blackfoot River Basin 159.19 sq. miles

*P - Point
D - Distributed

have been reproduced in figure 13. These hydrographs indicate losses along the Diamond Creek between the two points throughout the year. The maximum loss during high flows is of the order of 170 cfs and during the recession period it is about 20 cfs.

The Diamond Creek gains from Timothy Creek downstream due to the ground water entering the stream. This ground water appears chiefly from the alluvial aquifer which is recharged upstream. The existence of good size springs in the area supports this hypothesis.

Edwards (1977, p. 58) has stated, "The author, however, feels that the Diamond Creek drainage is primarily a discharge area and that any regional ground water flow system in the Wells formation probably is recharged in the Webster Range and discharges into the alluvial aquifer system in Upper Valley." He has also stated that gains were observed upstream and downstream of his study area which covered Diamond Creek basin from about the point at which broad valley floor begins in the south to about Timothy Creek canyon in the north.

It was found by the author that the discharges of Blackfoot River observed at the weir below the national forest boundary much exceeded the values calculated for the whole basin assuming even the highest observed discharge per square mile for the streams in the basin. The discharge per square mile for the basin as a whole ought to be less than that for the streams with steep topography and with heavier precipitation. Higher discharges of Blackfoot River can be accounted for only if there is ground water discharge into the Blackfoot River both above and below the confluence of Lanes Creek and Diamond Creek. This ground water discharge would most probably be from intermediate and regional flow systems.

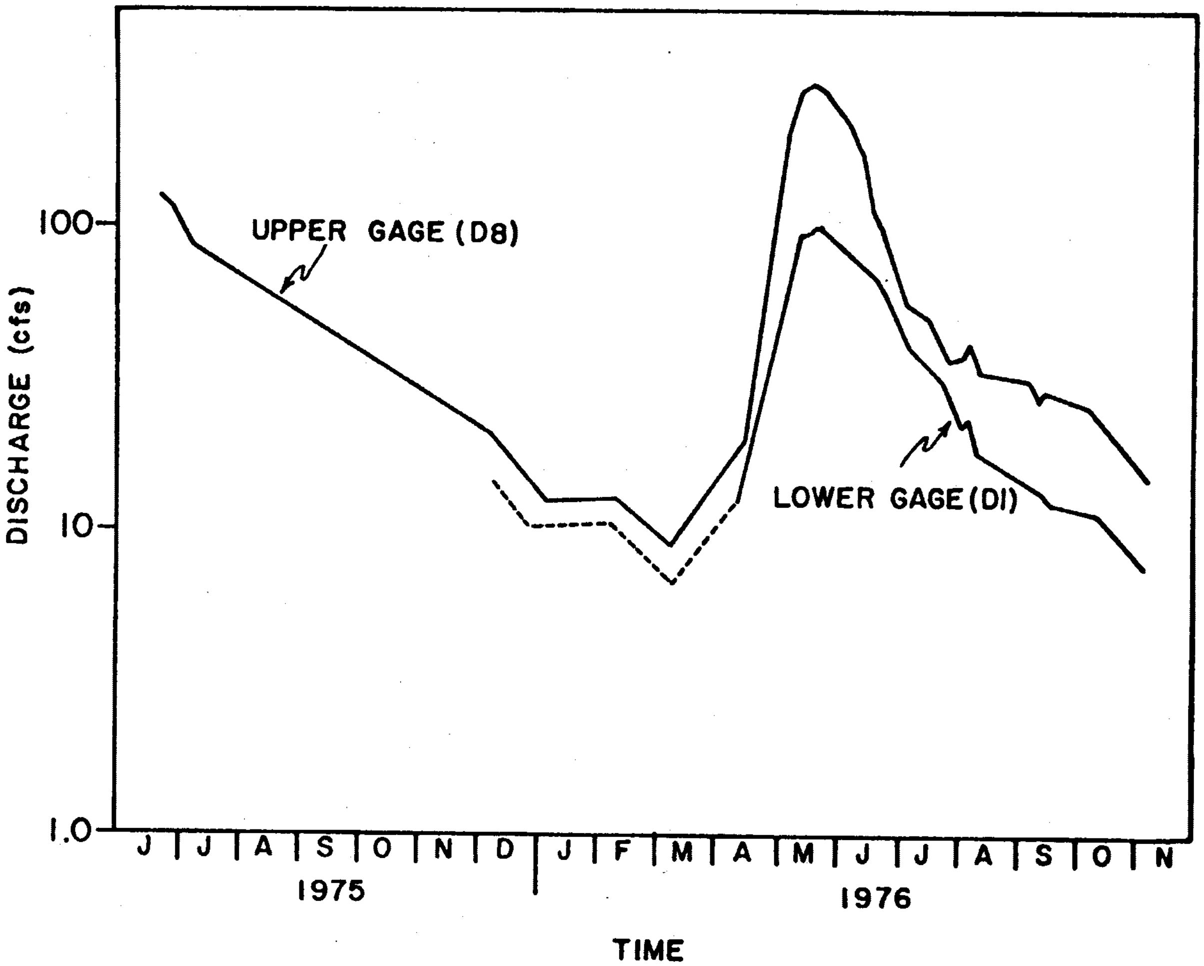

FIGURE 13 — STREAM FLOW HYDROGRAPHS FOR DIAMOND CREEK (SOURCE – EDWARDS, 1977)

The alluvial ground water discharge would most probably be limited to the point where the upper Narrow begins which is below the junction of Diamond and Lanes creeks. It has not been possible to verify the forgoing hypotheses as there were no observed flow data for the Blackfoot River above the weir station.

The hydrologic data required for inputting into the model were built up from the observed data and the hydrologic techniques described earlier assisted by the various conclusions regarding the surface and ground water flow systems in the study area.

Preparation of Hydraulic Data. The system geometry covering the width, depth and length of the stream and flow velocity are needed for each river segment for computing their water qualities. The lengths of the segments were determined from U. S. Geological Survey maps (scale 1:62,500) and have been given earlier. The widths, depths and flow velocities of the segments were determined with the help of the relationships developed by Leopold and Maddock (1953) between discharge, width, mean depth and mean velocity. These relationships are:

$$w = aQ^b$$

$$d = cQ^f$$

$$v = kQ^m$$

where:

w = width (ft)

d = mean depth (ft)

v = mean velocity (ft/sec)

Q = discharge (cfs)

a, b, c, f, k and m are numerical coefficients.

The product of width and mean depth is the cross-sectional area of flowing water. Discharge is the product of mean velocity and cross-sectional area of flow. Thus:

$$w \times d = A$$

$$w \times d \times v = Q.$$

It follows that:

$$aQ^b \times cQ^f \times kQ^m = Q \quad \text{or} \quad (a \times c \times k)Q^{(b + f + m)} = Q$$

which is possible only if:

$$b + f + m = 1 \quad \text{and} \quad a \times c \times k = 1.$$

The main stem of the Blackfoot River and Diamond Creek was divided into reaches such that the hydraulic geometry of the main stream was similar within a reach. This reach similarity would mean applicability of same coefficients involved in the above equations to all segments within the same reach. The stream of the study area was divided into 3 reaches bounded by the nodes, (i) 1-6, (ii) 7-12, and (iii) 13-23.

Observed data were needed for evaluating the numerical coefficients entering into the hydraulic geometry relationships. These data were available for the first two reaches only. The values of the coefficients for the third reach were estimated from their values for the first two reaches and considering the general physical characteristics of the stream in the third reach. This estimation was of course subjective to a certain extent.

The three plots, (i) w vs Q, (ii) d vs Q, and (iii) v vs Q, each for Reach 1 and Reach 2 are given in figures 14 through 19. These figures are based on the data from the U. S. Forest Service, the Greiner Engineering Sciences, Inc. and the University of Idaho. The values of numerical coefficients for the three reaches which were evaluated from these plots and by estimation are:

Reach	a	b	c	f	k	m
1	4.634	.250	.210	.553	1.021	.219
2	4.141	.459	.476	.127	.505	.414
3	3.968	.390	.350	.310	.720	.300

Connectivity data which gives information about the linkages of the river segments are needed by the model. This information which provides proper routing of flow and water quality computations through the various nodes was developed from segment locations and flow directions.

Water Quality Data

Water quality data were and are being collected by various agencies in the study area. These agencies are U. S. Forest Service, Greiner Environmental Engineering, Inc., Idaho Department of Health and Welfare, U. S. Geological Survey, University of Idaho and Monsanto mining company. A brief description of their stations and water quality data is given.

i) U. S. Forest Service. The U. S. Forest Service has been observing water quality data also at their hydrologic stations detailed earlier. This is done at the same time as the discharge observations. Water temperature and pH are taken in the field. Water samples are taken by integrating water sampler and then transferred to plastic

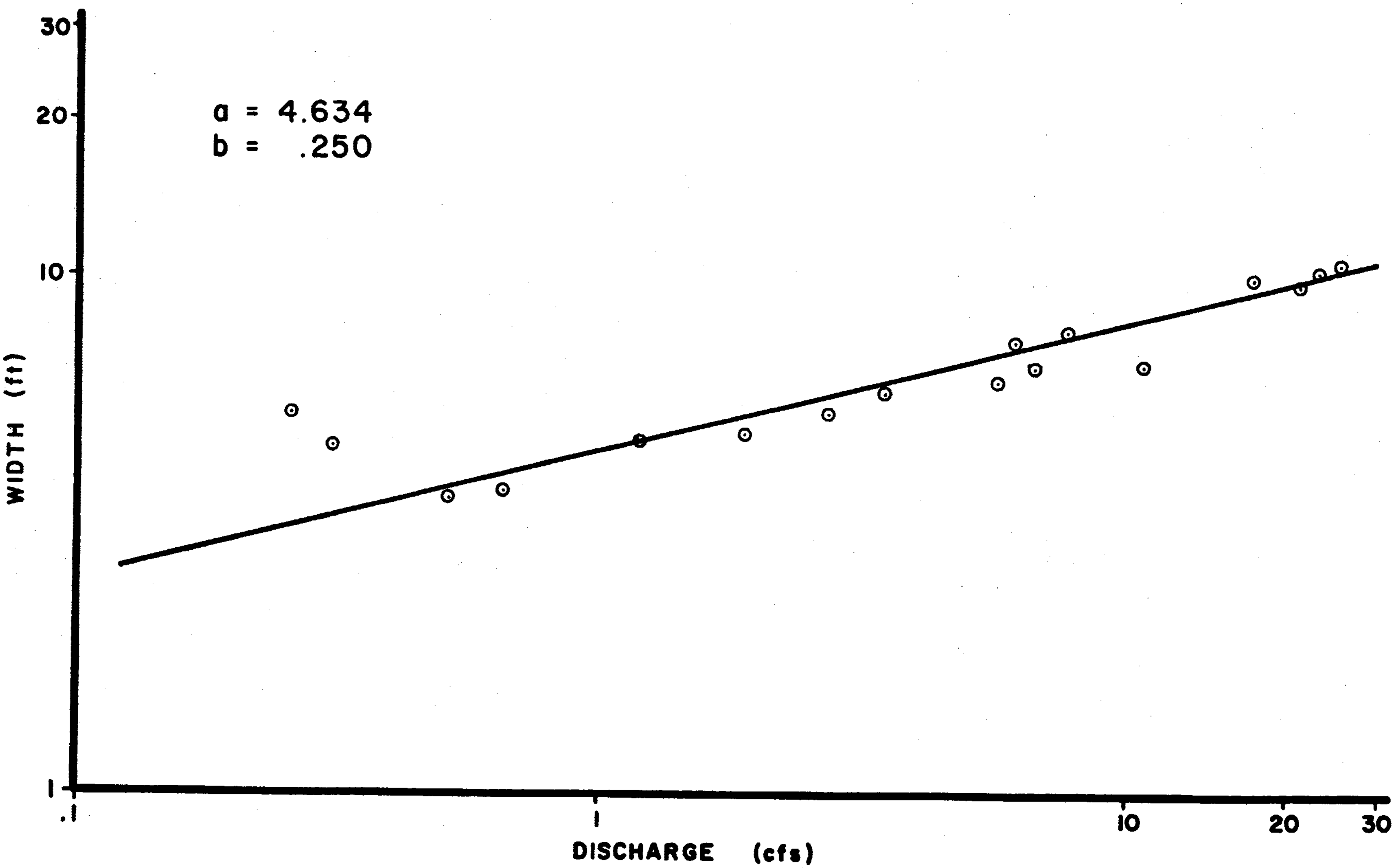

FIGURE 14 - WIDTH-DISCHARGE RELATIONSHIP FOR REACH I

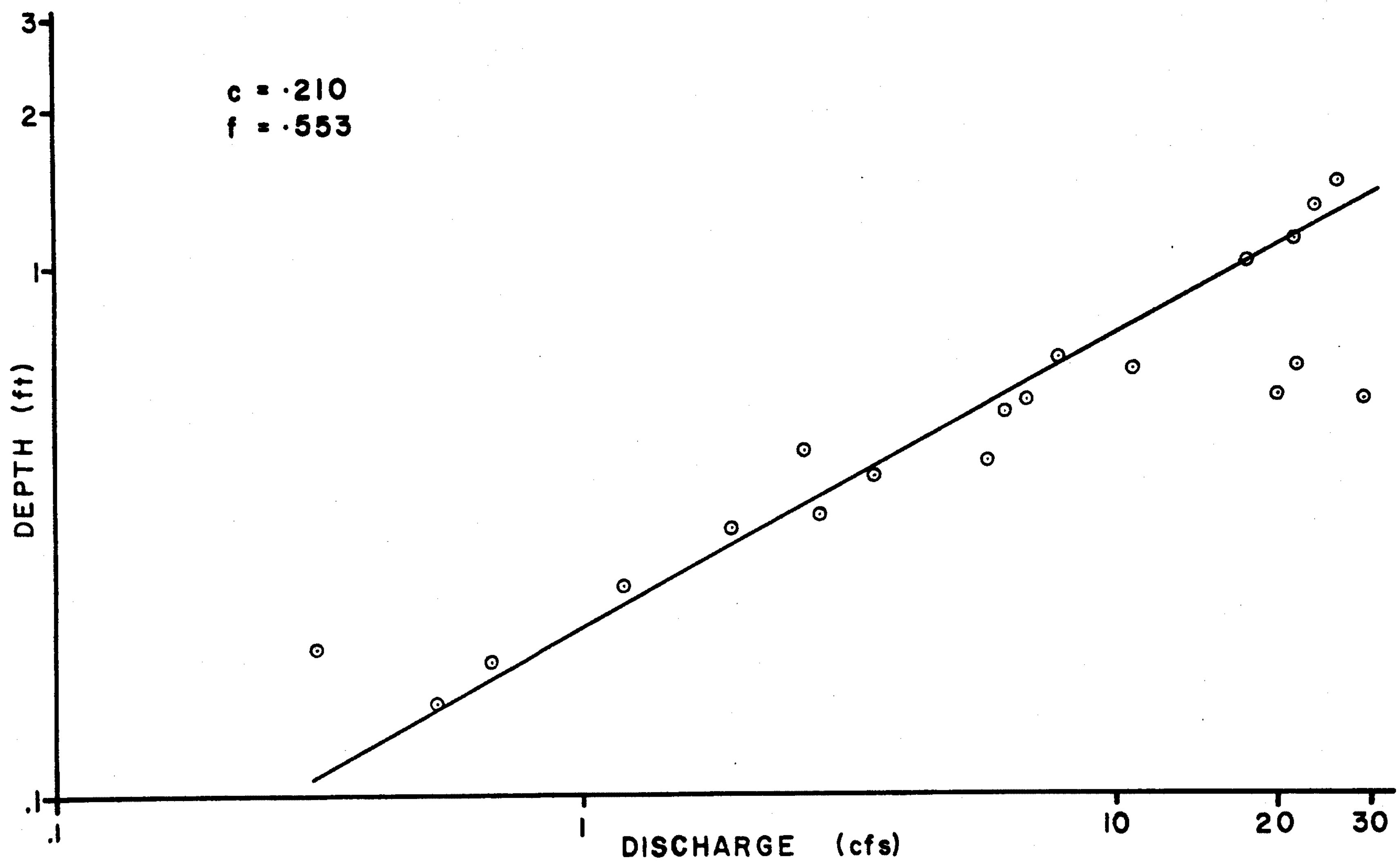

FIGURE 15 - DEPTH-DISCHARGE RELATIONSHIP FOR REACH I

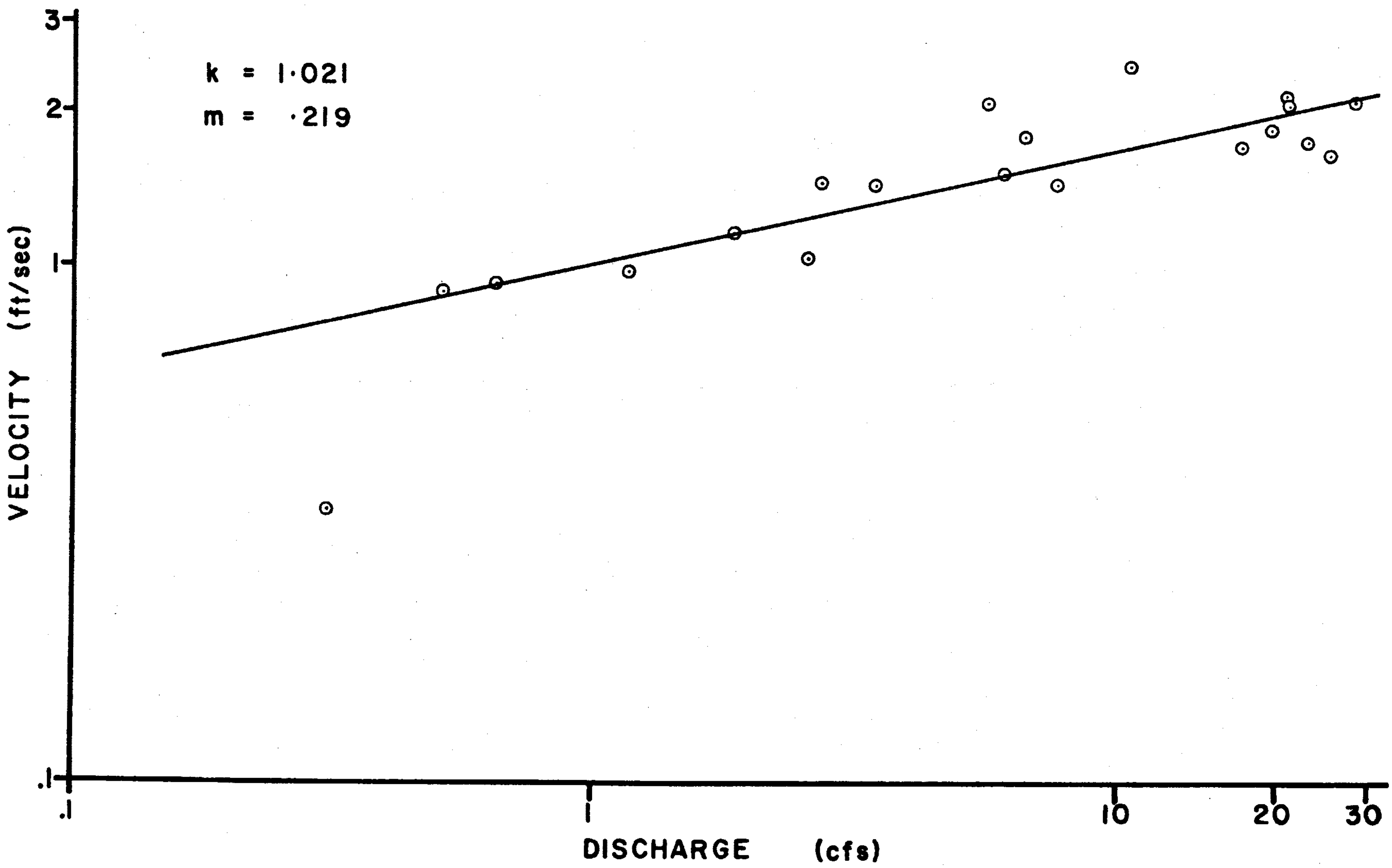

FIGURE 16 - VELOCITY-DISCHARGE RELATIONSHIP FOR REACH 1

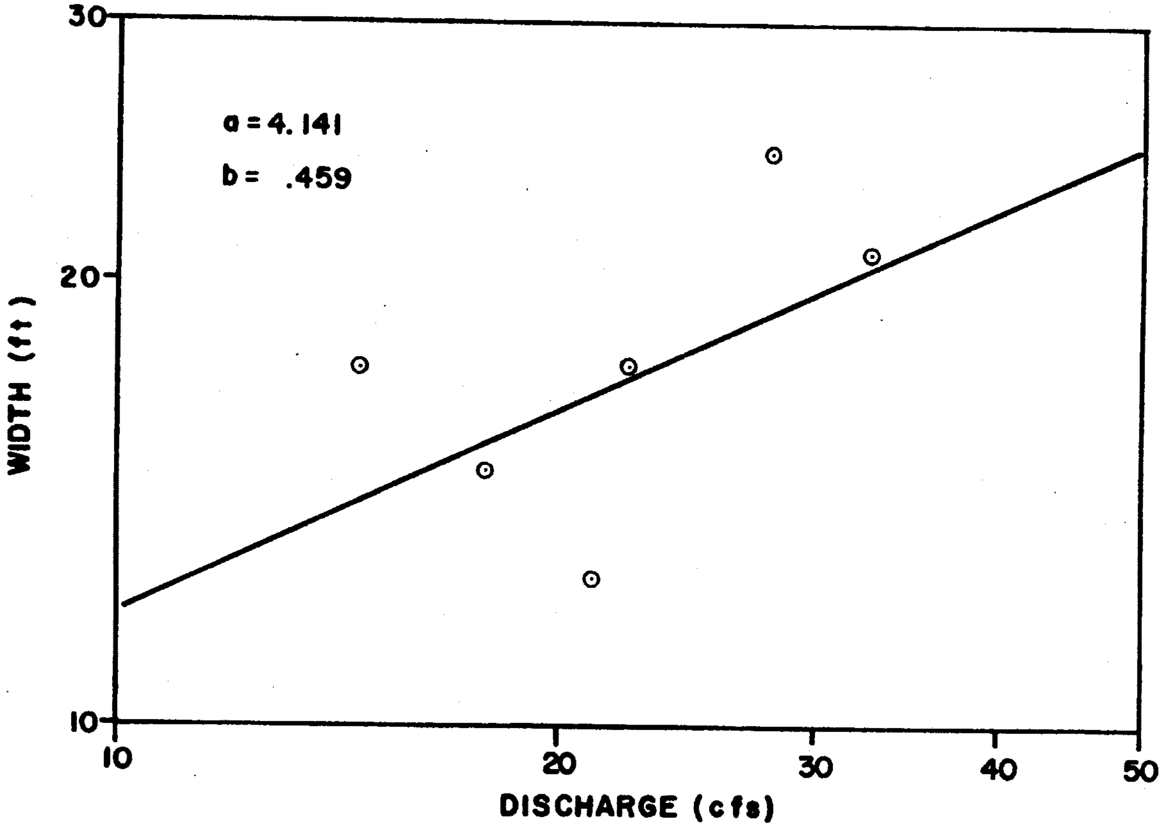

FIGURE 17_WIDTH–DISCHARGE RELATIONSHIP FOR REACH 2.

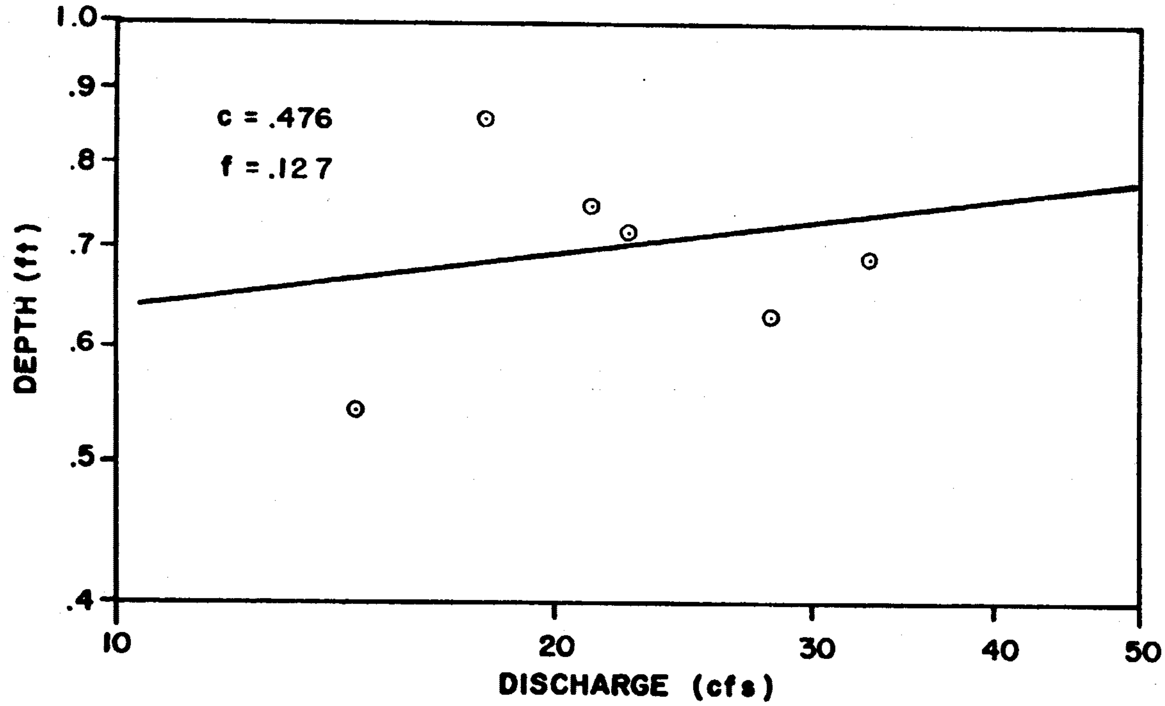

FIGURE 18_DEPTH–DISCHARGE RELATIONSHIP FOR REACH 2.

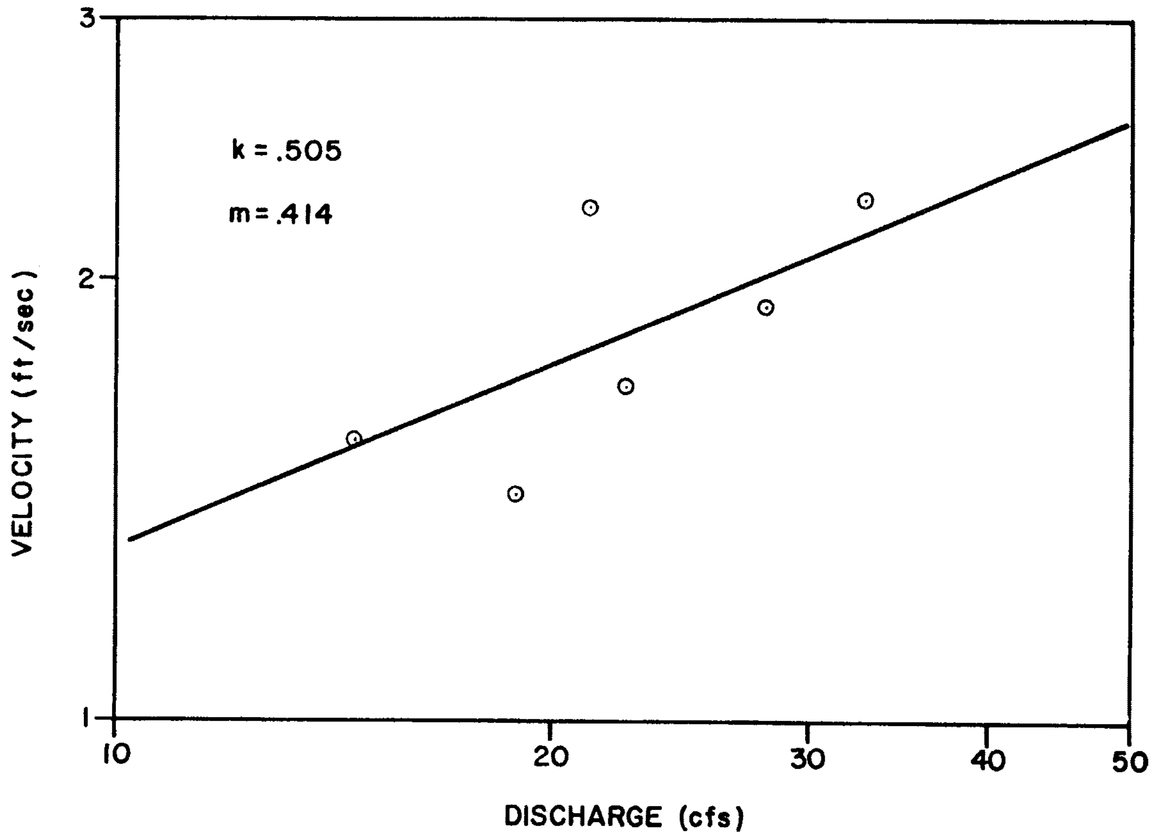

FIGURE 19—VELOCITY—DISCHARGE RELATIONSHIP FOR REACH 2

bottles and kept in an ice chest. These bottles are shipped within 5 days to Ford Testing Laboratory, Salt Lake City where the water samples are analyzed within a week. This analysis covers:

> turbidity, suspended solids, dissolved solids, specific conductance, total phosphorous, dissolved phosphorous, total Kjeldahl nitrogen, nitrite, nitrate, alkalinity, hardness, arsenic, cadmium, chromium, copper, selenium, vanadium and zinc.

The details of water sampling stations are given in table 13 and their locations are indicated in figure 8.

ii) Greiner Environmental Engineering, Inc. Greiner Environmental Engineering, Inc. has observed water quality data along with the hydrologic data at their nine stations. Details of their seven water quality stations whose data were used are listed in table 13 and their locations have been shown in figure 8.

The water quality data observed by this agency related to:

> alkalinity, coliform (fecal and total), conductivity, BOD, COD, DO, pH, radiation, total dissolved solids, total suspended solids, temperature, turbidity, dissolved phosphorous, total Kjeldahl nitrogen, nitrite, nitrate and a large number of rare and toxic elements.

iii) Idaho Department of Health and Welfare. The Idaho Department of Health and Welfare has been observing water quality data at 4 stations in the study area. They have been observing discharges at these sites only occasionally. Information about these stations has been detailed in table 13

Table 13. Water quality stations in Upper Blackfoot River basin.

No.	Stream	Location of Station	Agency	Period and Frequency of data
1	Blackfoot River	42° 47' 37" N 111° 22' 30" W (at diversion weir just below national forest boundary)	U. S. Forest Service (USFS)	8/1974 to-date (twice a month)
2	Blackfoot River	42° 47' 00" N 111° 22' 30" W (at the Narrows)	Idaho Department of Health and Welfare	10/1975 to 1976 (twice a month) 7/1977 to-date (monthly except during winter)
3	Upper Angus Creek	42° 49' 50" N 111° 23' 50" W (near headwaters)	USFS	8/1974 to-date (twice a month)
4	Lower Angus Creek	42° 51' 14" N 111° 24' 45" W (½ mile above national forest boundary)	USFS	8/1974 to-date (twice a month)
5	Blackfoot River	42° 49' 20" N 111° 19' 50" W (above Angus Creek at the narrows)	U. S. Geological Survey	12/1974
6	Blackfoot River	42° 49' 30" N 111° 18' 40" W (on road and just below confluence of Diamond Creek and Lanes Creek)	Idaho Department of Health and Welfare	10-11/1975, 6-8/1976, 10/1976, 6/1977 to-date (twice a month in 1975 and 1976 and monthly thereafter except winter)
7	Sheep Creek	42° 51' 47" N 111° 19' 45" W (on foot bridge 1½ miles above national forest boundary)	USFS	8/1974 to-date (twice a month)
8	Lanes Creek	42° 49' 50" N 111° 18' 20" W (at mouth)	Idaho Department of Health and Welfare	6/1977 to-date (monthly, none in winter)
9	Mill Creek	42° 48' 35" N 111° 18' 30" W (100 yds above national forest boundary)	USFS	8/1974 to-date (twice a month)
10	Mosquito Creek	D2	Greiner Engineering Sciences, Inc. (GES)	10/1975 - 9/1976
11	Timothy Creek	D4	GES	10/1975 - 9/1976

- continued -

Table 13. Continued.

No.	Stream	Location of Station	Agency	Period and Frequency of data
12	Kendell Creek	42^o 46' 50" N 111^o 16' 30" W (at national forest boundary)	USFS	10/1974 - 11/1975 (twice a month)
13	Kendell Creek	D3	GES	10/1975 - 9/1976
14	Diamond Creek	D1 (below proposed Diamond Creek Mine)	GES	11/1975 - 9/1976
15	Diamond Creek	D8 (above proposed Diamond Creek Mine)	GES	10/1975 - 9/1976
16	Cabin Creek	D6	GES	10/1975 - 9/1976
17	Diamond Creek	42^o 47' 00" N 111^o 15' 00" W (above station No.15 and 2 miles below Campbell Canyon)	Idaho Department of Health and Welfare	2/1975, 10-11/1975, 2/1976, 6/1977 to-date (1975 and 1976 twice a month, monthly thereafter; none in winter)
18	Yellowjacket Canyon	D7	GES	9/1975 - 9/1976
19	Stewart Creek	42^o 41' 45" N 111^o 11' 57" W (above confluence with Diamond Creek)	USFS	8/1974 to-date (twice a month)
20	Diamond Creek	42^o 41' 30" N 111^o 11' 50" W (above confluence with Stewart Creek)	USFS	8/1974 to-date (twice a month)

and their locations indicated in figure 8.

The water quality indices covered by this program are:

COD, nitrate-N, nitrite-N, ammonia-N, total Kjeldahl nitrogen, total phosphorous, ortho-phosphate-P, total solids, suspended solids, volatile suspended solids, turbidity, total hardness, magnesium, total alkalinity, iron, sodium, potassium, chloride, sulphate, silica, fluoride, DO, temperature, pH, specific conductance.

iv) U. S. Geological Survey. U. S. Geological Survey observed water quality data in the study area only once. Details of their station are given in table 13 while its location is marked on figure 8.

v) University of Idaho. Edwards (1977) took water quality observations at sites selected from the network of Greiner Environmental Engineering, Inc. during his investigations in the Diamond Creek basin. These observations were taken during 1975 and 1976 and covered the following indices:

temperature, specific conductance, pH, DO turbidity, sodium, calcium, magnesium, iron, copper, zinc, lead.

vi) Monsanto. Monsanto had been monitoring turbidity and total PO_4 on some of the streams impacted by their mining operations. These data were for a large portion on turbidity. The data observed by Monsanto were too little and hence could not be used for the present study especially when similar data were available from the U. S. Forest Service stations.

Information on the technique of collection and sample handling was not available for agencies other than the U. S. Forest Service and hence could not be reported. It is presumed that standard practices prescribed by EPA for collection, handling and testing of the water samples were followed by all agencies.

The water quality information which is required by the model is:

i) initial water qualities of each segment.

ii) water qualities of the inflows into each segment.

All of the required data were not available and could not be practically obtained. The qualities of the inflows where data were not available were estimated from the adjacent inflows. The field data showed that there was a high degree of similarity in the water qualities of the adjacent streams in the study area due to their being mostly in natural state. This technique for evaluation of water qualities for unrecorded streams was, therefore, justified.

The initial water qualities of the segments were also obtained from the recorded data along the main stem wherever these data were available. In the event of complete absence of suitable data, approximate values for initial water qualities were used. This is justified as the water quality values for a segment at the end of a simulation time period become the initial water quality values for the next segment and the next time period. The errors, if any, in the starting initial values are, therefore, eliminated after a few simulations.

Reaction and Other Coefficients

The model needs information on the various reaction and other coefficients appearing in the different equations for the physical, chemical and biological processes taking place in the river ecosystem as described earlier under the mathematical description of the model.

Many of the coefficients are fundemental in nature and can be estimated from the aggregate of information contained in many literature sources. However, some coefficients must be estimated from little theoretical basis or by empirical methods. These coefficients can either be derived from actual measurements or can be taken from other studies in the region. A survey was made of coefficients used in models for Chattahoochee-Flint-Apalachicola basin (Hammer, Silver, George Associates et al, 1975), Doe River (Yearsley, 1975) and Boise River (Chen and Wells, 1975). The coefficients to be used in the water quality model fall under three broad categories, (i) fundemental coefficients, (ii) empirical coefficients which are of general application and (iii) empirical coefficients which are applicable to specific cases. The coefficients which have been used in the Upper Blackfoot River model are:

a) Fundemental coefficients.

i) Stoichiometric equivalence of chemical transformation

oxygen/NH_3 3.500

oxygen/NO_2 1.200

CO_2/BOD 0.200

ii) Oxygen saturation coefficient 0.909

b) Empirical coefficients of general application

i) Temperature coefficient (K_{20}) 1.047

ii) Reaeration constant (K_2)

VC1 3.330

VC2 1.330

VC3 1.000

iii) Maximum scouring rate 0.35 (g/m^2.sec)

iv) Sediment settling rate 2×10^{-5} (ft/sec)

The above coefficients were determined empirically by different workers.

c) Empirical coefficients applicable to the Upper Blackfoot River.

The following coefficients need to be determined empirically for the river under study or can be taken from other rivers studied in the region and modified where necessary during calibration of the model.

K_1 for coliform

K_3 for BOD

K_4 for NH_3-N

K_5 for NO_2-N

K_6 for organic nitrogen

K_7 for PO_4 deposition.

The initial values of the above coefficients except K_6 and K_7 were taken from the Boise River model (Chen and Wells, 1975). The Boise River model does not use terms involving K_6 and K_7. The initial value of K_6 came from Doe River study (Yearsley, 1975) and that for K_7 from the study of Potomac (Jaworski, et al, 1971). The initial values of the coefficients were:

K_1 (coliform)	.500
K_3 (BOD)	.250
K_4 (NH_3-N)	.100
K_5 (NO_2-N)	.300

K_6 (organic nitrogen) .200

K_7 (PO_4 deposition) .023

The above coefficients were modified during the calibration of the model for the study area as will be described in the next chapter.

CHAPTER V

MODEL CALIBRATION, VERIFICATION AND APPLICATION

Calibration of Model

In order to be able to depend on the model predictions of future events, the model should be calibrated and verified using past events. Calibration of the model is required for adjustment of those coefficients which are obtained from other studies. Verification of the model gives an independent check on the coefficient values obtained after calibration. The two steps yield also a test of the mathematical representations of the water quality processes.

Calibration and verification of the model needed two different periods with sufficient amounts of meteorological, hydrologic and water quality data to serve as model inputs. After careful examination of the available field data, it was seen that selection of the two periods had to be restricted to the year 1976. During this year all the agencies had recorded data which could be assembled together to form suitable inputs. The data of other years were not sufficient for the model. Two periods, (i) 27-31 May, 1976 and (ii) 23-30 September, 1976 were finally chosen. May and September represent high and low flow periods respectively. The latter period was used for calibration of the model whereas the former was used for its verification. These periods were used to test the correctness of the mathematical representations of the processes affecting water quality changes and the coefficients involved. Once the model has been proved successful, it should hold good under any other hydrologic and meteorological conditions and under most water quality situations. These input parameters should be constant during the simulation period to satisfy the steady state assumption of the model. As mentioned in Chapter IV water quality simulations for some parameters will not be accurate if pH of the waters is lowered below 7.0 through man-made pollution.

During calibration of the model, simulated values of the water quality constituents were compared with their observed values. In case of poor simulations of any constituents, the concerned coefficients were adjusted and the model was rerun. This process was continued until satisfactory simulations were obtained.

The output from the model is obtained in tabular as well as graphical form. The tabular output includes information on most of the water quality constituents which the model is equipped to handle whereas the plots are made for selected indices.

The model was run to simulate water quality changes for 8 days with initial ecological conditions on 23 September, 1976 and steady state inputs thereafter until 30 September, 1976. Complete information outputted by the computer program for this period has been given in Appendix C. The observed values of water quality parameters as far as available have also been indicated on the plots of simulated values.

The final values of the coefficients for which initial values were taken from other studies and were tested and modified where necessary are as follows:

BOD (K_3)	0.200 (1/day)
Coliform (K_1)	0.500 (1/day)
Organic nitrogen (K_6)	0.150 (1/day)
NH_3-N (K_4)	0.250 (1/day)
NO_2-N (K_5)	0.900 (1/day)
PO_4 - Deposition (K_7)	0.020 (1/day)

Verification of Model

The model was verified by comparing the observed data with that simulated by it for 31 May, 1976. The data for the period 27-31 May, 1976 were fed into the model. The initial state of the river ecosystem at 0 hour of 27 May, 1976 was taken and steady state inputs into it were considered over the 5-day period extending to 31 May, 1976. The simulated state of the ecosystem on 31 May, 1976 was compared with the observed values of the water quality indices.

The tabular and graphical computer output from the model simulation for this period has been attached in Appendix D. The observed values of water quality parameters as far as available have also been shown on the plots of simulated values for comparison. One of these plots is as figure 20. The observed and simulated water quality indices for four points on the main stem of the Upper Blackfoot River system have been tabulated in table 14. An analysis of the data of this table is given below:

i) The average errors of simulated values of DO, total alkalinity, total hardness, pH, total dissolved solids, vanadium and cadmium were about 10 percent. These simulations can be considered as good.

ii) The average errors for temperature, BOD, total suspended solids and zinc were between 10 and 25 percent. These simulations can be considered satisfactory.

iii) The average errors for coliform, PO_4-P, NH_3-N, NO_3-N, chromium, copper, arsenic and turbidity were greater than 25 percent. These simulations cannot be considered

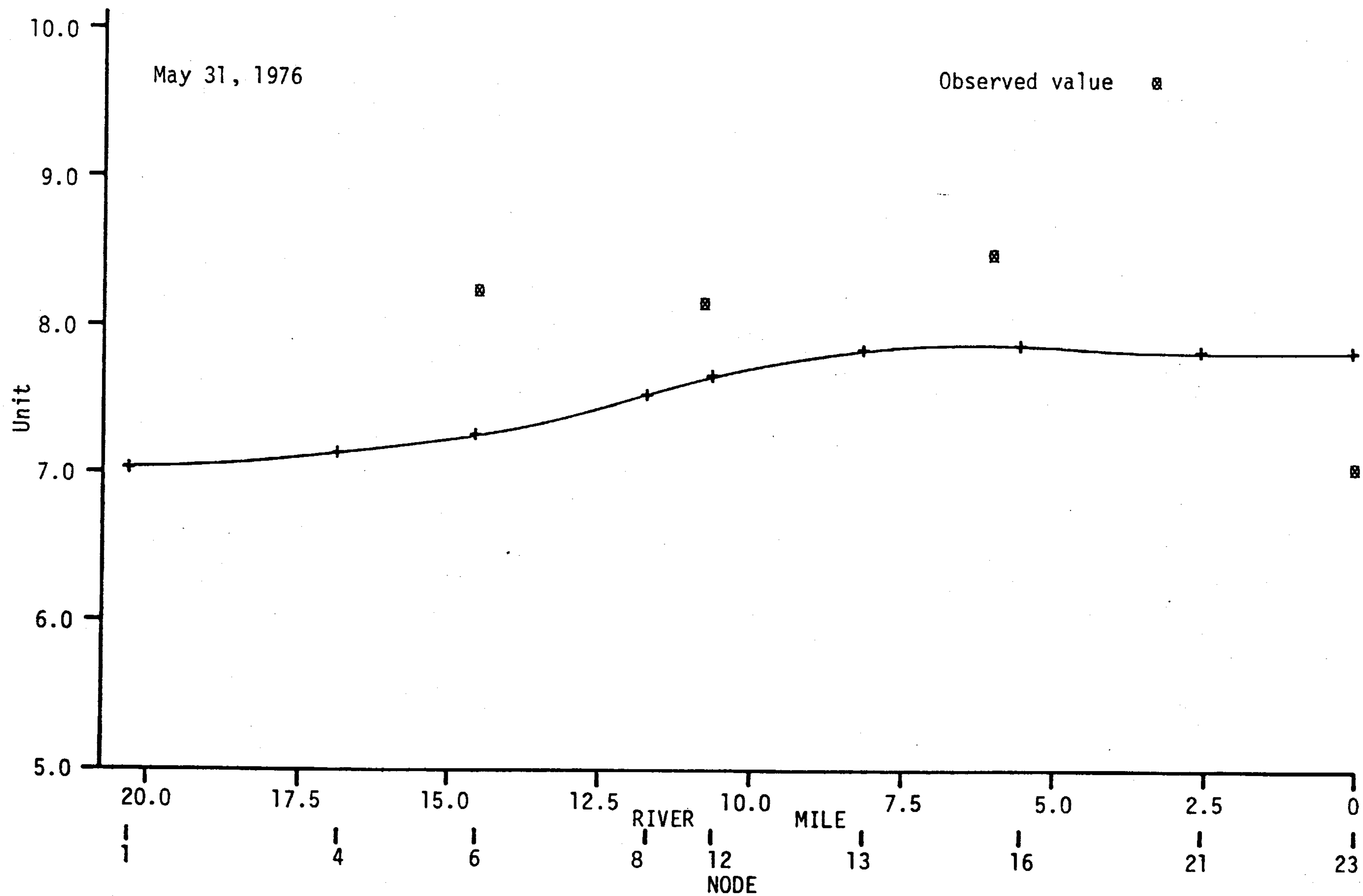

FIGURE 20 - LONGITUDINAL PLOT OF PH, UPPER BLACKFOOT RIVER BASIN

Table 14. Comparison of observed and simulated water quality data - 31 May 1976 - Upper Blackfoot River Basin.

Node	Kind of Data	Temp °C	TSS mg/l	Coliform MPN/100 ml	BOD mg/l	DO mg/l	PO_4-P mg/l	Alkalinity mg/l	pH	NH_3-N mg/l	NO_3-N mg/l
6	observed	-	143	4	0.8	-	.03	161	8.3	-	.08
	simulated	8.1	70	2	0.6	10.0	.06	149	7.4	.08	.15
below 8 & 11	observed	8.0	56	4	0.8	9.0	.03	162	8.2	.04	.06
	simulated	9.8	68	2	0.6	10.5	.05	149	7.9	.08	.14
below 13 & 14	observed	9.0	5	-	1.6	9.0	.06	172	8.5	.07	.10
	simulated	11.6	44	2	1.2	9.6	.05	156	8.0	.08	.14
23	observed	10.0	26	4	3.0	9.5	.06	162	7.0	.06	.09
	simulated	10.0	35	10	1.1	10.2	.06	150	7.9	.08	.14

Node	Kind of Data	TDS mg/l	Turbidity FTU	Total Hardness mg/l	Chromium mg/l	Zinc mg/l	Copper mg/l	Vanadium mg/l	Cadmium mg/l	Arsenic mg/l
6	observed	-	-	-	.001	-	-	.001	-	.002
	simulated	206	13.8	149	.001	.013	.004	.001	.001	.001
below 8 & 11	observed	-	1.5	160	.010	-	-	-	.001	.010
	simulated	206	13.3	149	.001	.013	.004	.001	.001	.001
below 13 & 14	observed	-	3.0	176	.010	-	-	-	.001	.010
	simulated	202	8.8	157	.001	.010	.007	.001	.001	.001
23	observed	212	5.0	170	.001	.013	.001	.001	.001	.001
	simulated	194	8.5	148	.004	.015	.007	.001	.001	.001

satisfactory.

Large variations in turbidity values are due to the fact that it is dependent not only on the concentration of suspended solids but also on their grain sizes and shapes. The first factor can be taken care of by the model through advective process but the last two factors cannot be handled by the model. Accurate simulations of turbidity are, therefore, not possible by the model. The concentrations of some of the elements like coliform, PO_4-P and rare elements are very low in the waters of the study area and errors in their estimated values for unmeasured streams can result in large errors percentage-wise, in their simulated values. Spatially representative data for these elements would be needed for their satisfactory simulation.

Model simulations were tried by changing the coefficient values for biochemical terms. This resulted in small changes in the final water qualities. This shows that the advective process is predominant in affecting water quality changes in the streams of the Upper Blackfoot River basin. This appears to be due to small residence time available for biochemical processes to reach a significant level in the mountainous streams.

The concentrations of rare elements are kept very low in the study area due to pH values being greater than 7.0. These elements are, therefore, in a near steady state situation. Chemical processes would become important in these cases only when pH is lowered below 7.0 due to man-made pollution.

The concentrations of total alkalinity, total hardness and total dissolved solids are mainly due to carbonates and bicarbonates which are dissolved from limestone present in the geologic formations of the area. Concentrations of these elements are near saturation levels at the pH of the waters. Under this condition, the model would yield satisfactory results for these parameters.

Considering the limitations of field data and the complexity of the ecosystem and the above explanations, the model simulations are considered satisfactory.

Application of Model

In order to manage the phosphate mining operations in the Upper Blackfoot River basin to achieve little or no adverse effects, a large number of water quality measurements at many sites would normally be required. This would be a very expensive proposition. The mathematical model which has been developed can help in simulating the effects of waste inputs along the main stream downstream of the points of waste discharges. If the information about the magnitudes of waste inputs is available, the model can yield data on the concentrations of the water quality constituents at selected points downstream resulting from the waste as well as natural discharges. This can assist in assessing the suitability of the water for the intended uses along the stream. If the water quality reaches a level where it can be harmful, then either the mining operations causing the waste inputs would need to be modified or certain other actions would be required so that the waste inputs are reduced to acceptable levels. For application of the model some water quality and hydrologic measurements would, however, be necessary.

The technique of model application has been illustrated by comparing water quality simulations under actual conditions with those which would result if selected levels of wastes were discharged into certain streams of the basin. The period of 27 to 31 May, 1976 for which model simulations under actual conditions had already been made, was taken for this illustration. Four water quality parameters were selected for the exercise: (i) total suspended solids (TSS), (ii) total dissolved solids (TDS), (iii) BOD, and (iv) zinc. Their concentrations in the inflows at selected points in the Upper Blackfoot River basin were increased to arbitrary high values as detailed in table 15. These arbitrary values were chosen to be much higher than their upper limits prescribed under water quality standards. It was assumed that man-made wastes were dumped into the streams at the selected points and that they raised their concentrations from their actual levels to the higher arbitrary levels. The magnitudes of the discharges of the streams were assumed to remain the same as before. It was also assumed that the inflow and outflow conditions remained the same as before at all other places of the basin during the simulation period. The points selected for arbitrary waste inputs were at places where mining operations would be expanded or started in the future. Different combinations of waste input areas were tried to determine the effects from different sets of hypothetical mining operations which might take place in the basin. There were two such cases:

i) Case 1 - arbitrary discharges in segments 1, 7, 9, 10, 11 and 17.

ii) Case 2 - arbitrary discharges in segments 7, 9, 10 and 11.

The results of the model simulations for 31 May, 1976 with (i) actual inputs throughout the basin and (ii) with arbitrary waste inputs at selected

Table 15. Actual and arbitrary concentrations of selected water quality parameters, Upper Blackfoot River basin.

Segment No.	Stream	Actual/Arbitrary	Concentrations (mg/l) TSS	TDS	BOD	Zinc
1	Diamond Creek	Actual	109	207		
		Arbitrary	500	500		
1	Stewart Creek	Actual	72	205		
		Arbitrary	500	500		
7	Unnamed Creek	Actual	35	205	1.0	.005
		Arbitrary	500	500	10.0	.200
9	Cabin Creek	Actual	12	205	.50	.005
		Arbitrary	500	500	10.0	.200
9	Unnamed Creek	Actual	50	205	.80	.005
		Arbitrary	500	500	10.0	.200
10	Unnamed Creek	Actual	50	205	.80	.005
		Arbitrary	500	500	10.0	.200
11	Unnamed Creek	Actual	71	210	1.0	.005
		Arbitrary	500	500	10.0	.200
17	Angus Creek	Actual	19	190		
		Arbitrary	200	500		

points and actual inputs elsewhere in the basin, have been shown in figures 21 through 26. Tables 16 through 19 give information on the water qualities of the inflows and the water qualities of each segment on 31 May, 1976 for the two cases.

It will be observed from the figures 21 through 26 that there are major increases in concentrations near the points of arbitrary waste inputs and that the gap between the two levels of concentrations narrows as we proceed downstream. Tables and plots of water qualities resulting from waste discharges in real cases would be similar to the ones in tables 16 through 19 and in figures 21 through 26. The authorities responsible for monitoring the water quality of the basin can know from these tables and graphs whether the concentration level of any water quality parameter has exceeded the prescribed level at any point of the stream. If such a case is noticed, remedial action can immediately be taken in the form of reducing the waste discharge at the source or treating it before discharging into the stream. In the case of phosphate mining, this would mean controlling levels of various operations, singly and collectively, such that water qualities downstream stay within the prescribed levels.

The above examples show that the model can be used in programming the levels of various mining activities on a short term basis by monitoring their waste inputs and simulating their effects downstream. The model can thus help in keeping the levels of operations to safe limits. The model in short can assist in the management of phosphate mining operations in the Upper Blackfoot River basin as far as water quality of the basin is concerned.

To manage a watershed from water quality aspect, it is necessary

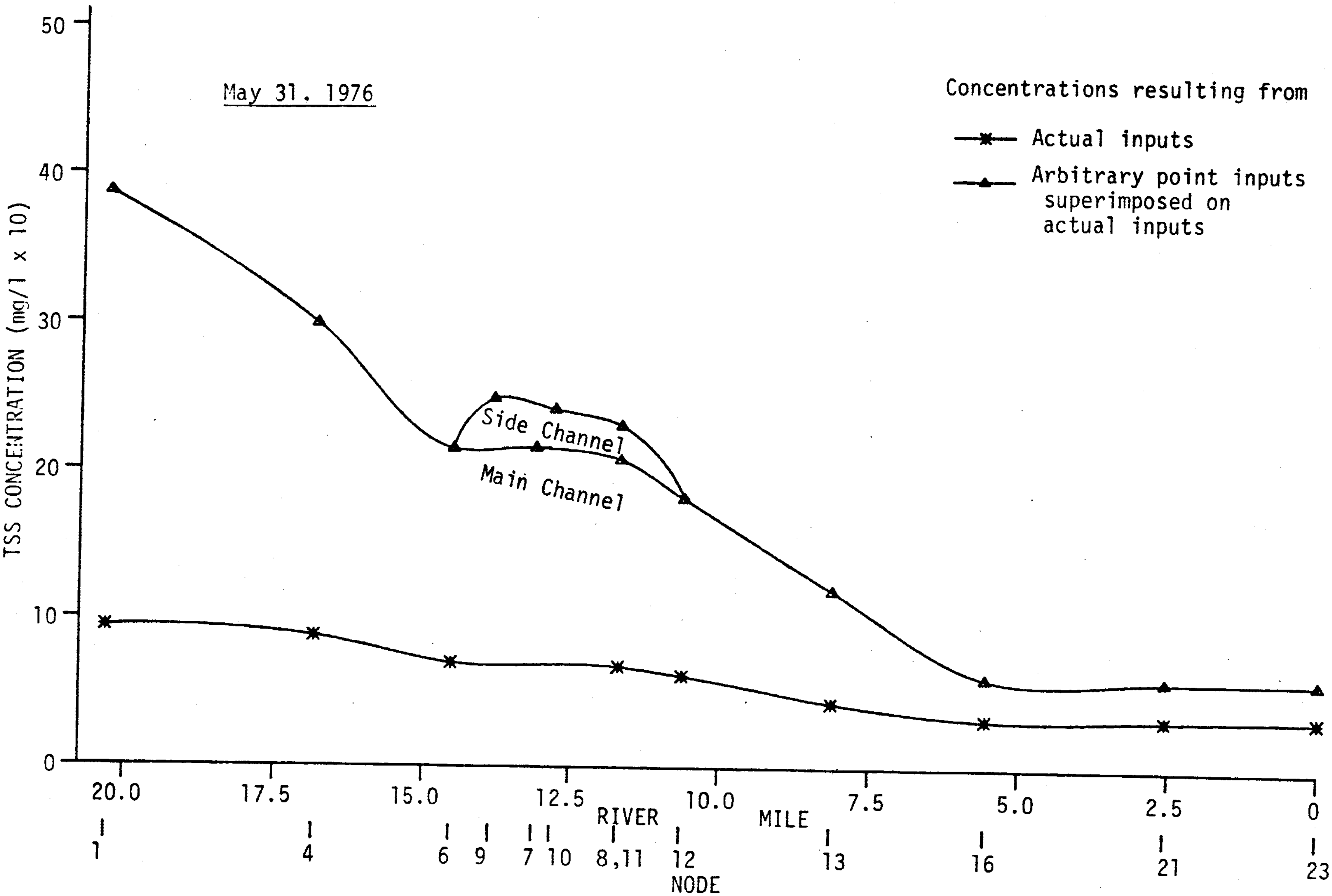

FIGURE 21 - LONGITUDINAL PLOT OF TSS, UPPER BLACKFOOT RIVER BASIN - CASE 1

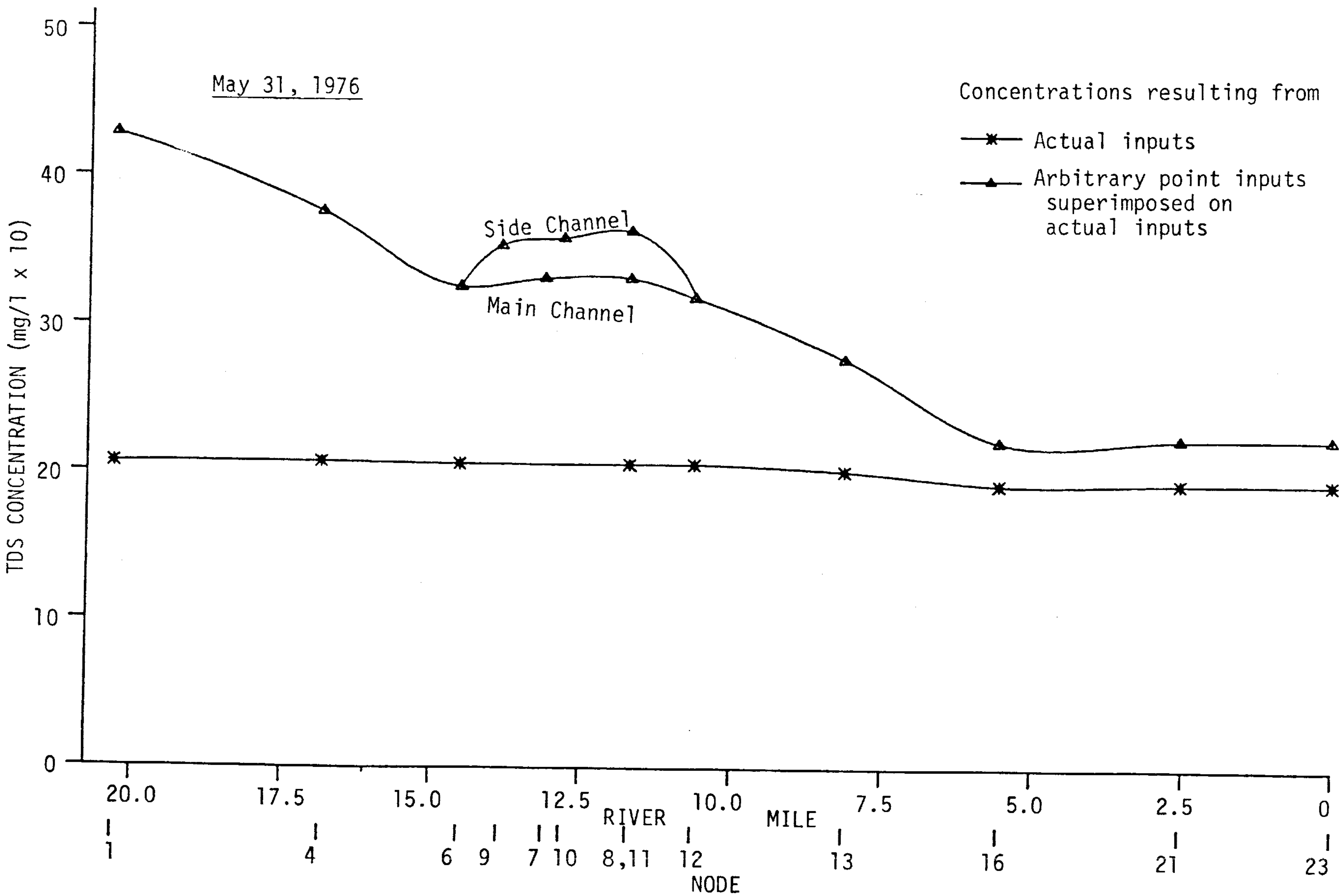

FIGURE 22 - LONGITUDINAL PLOT OF TDS, UPPER BLACKFOOT RIVER BASIN - CASE 1

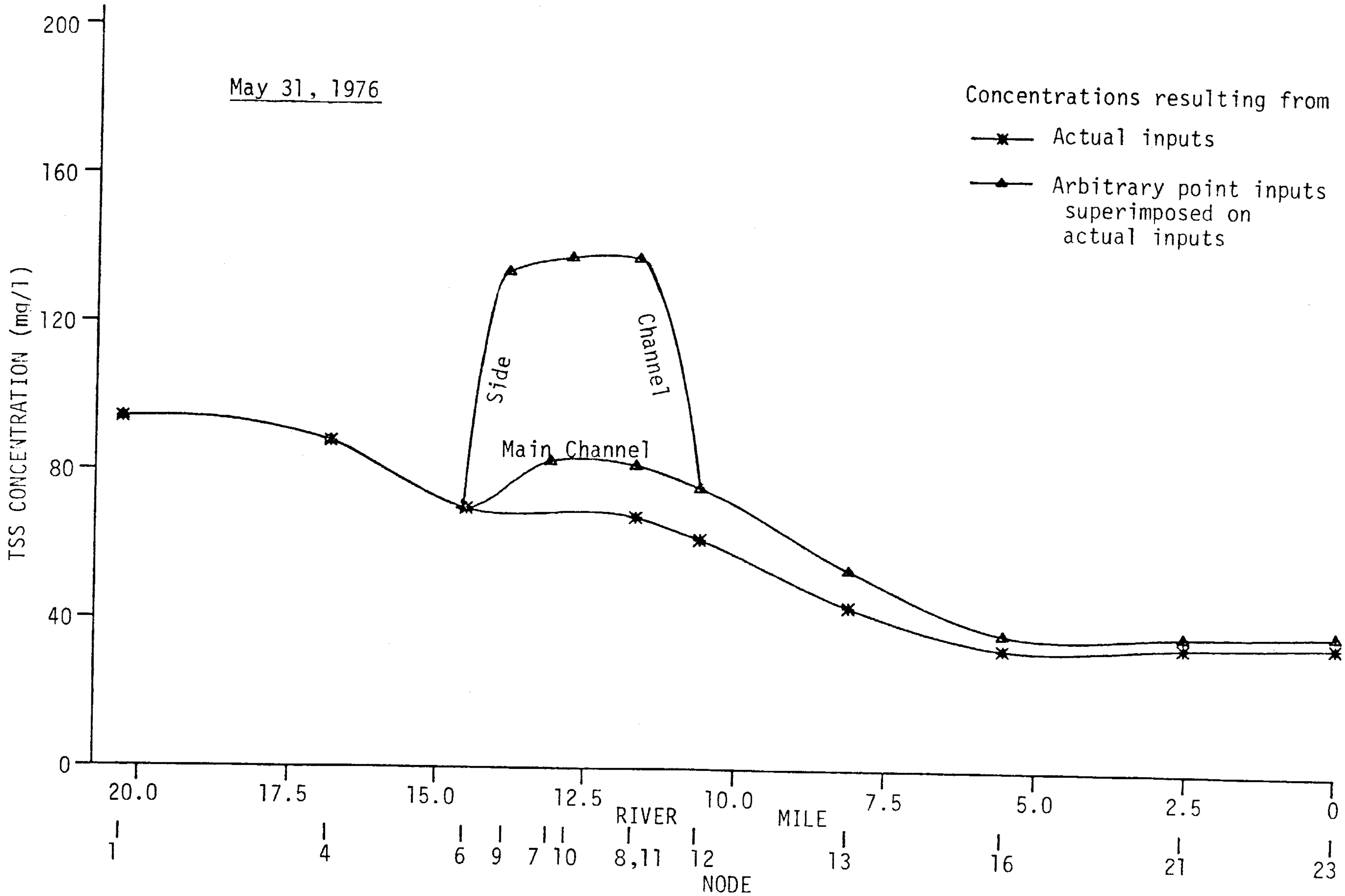

FIGURE 23 - LONGITUDINAL PLOT OF TSS, UPPER BLACKFOOT RIVER BASIN - CASE 2

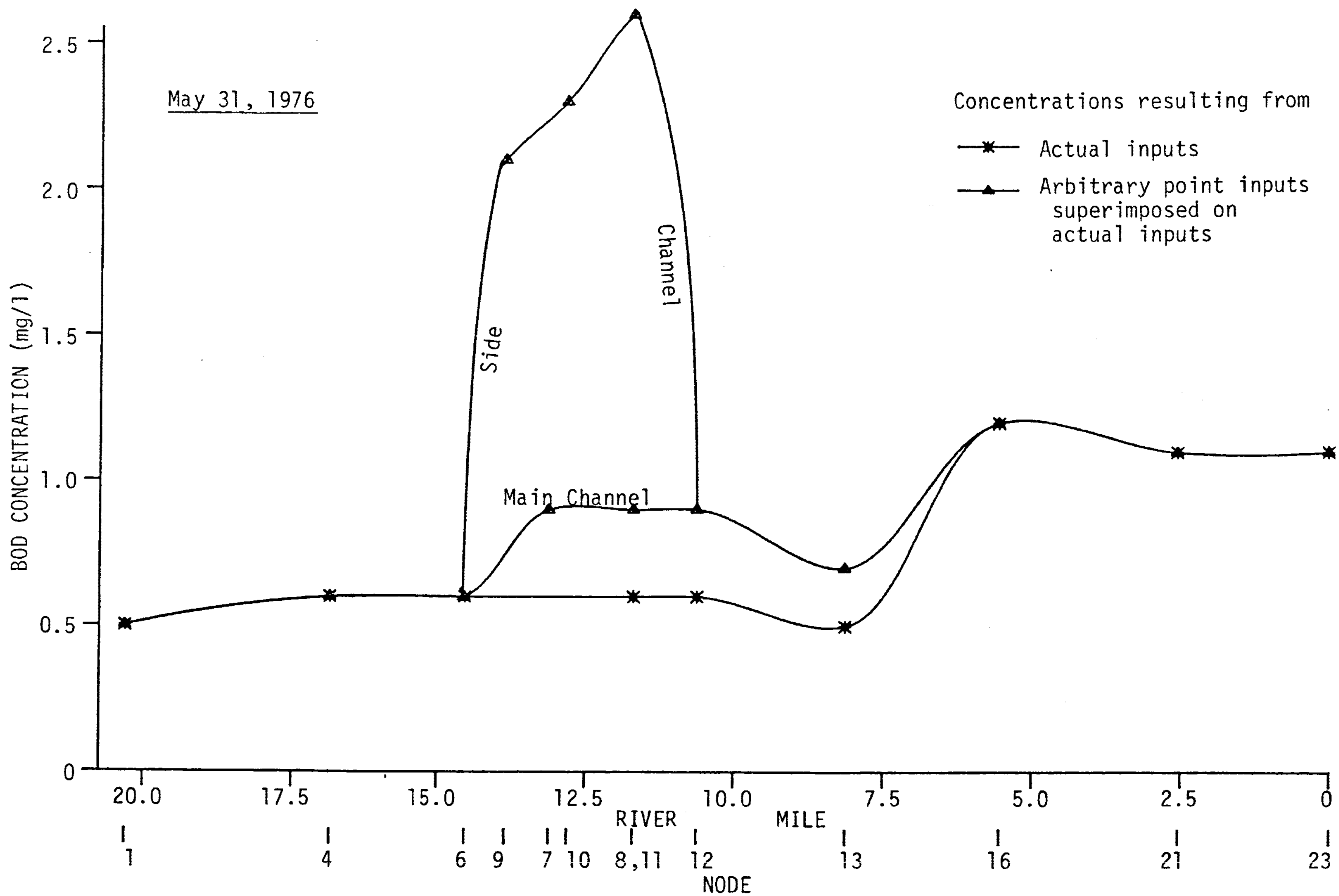

FIGURE 24 - LONGITUDINAL PLOT OF BOD, UPPER BLACKFOOT RIVER BASIN - CASE 2

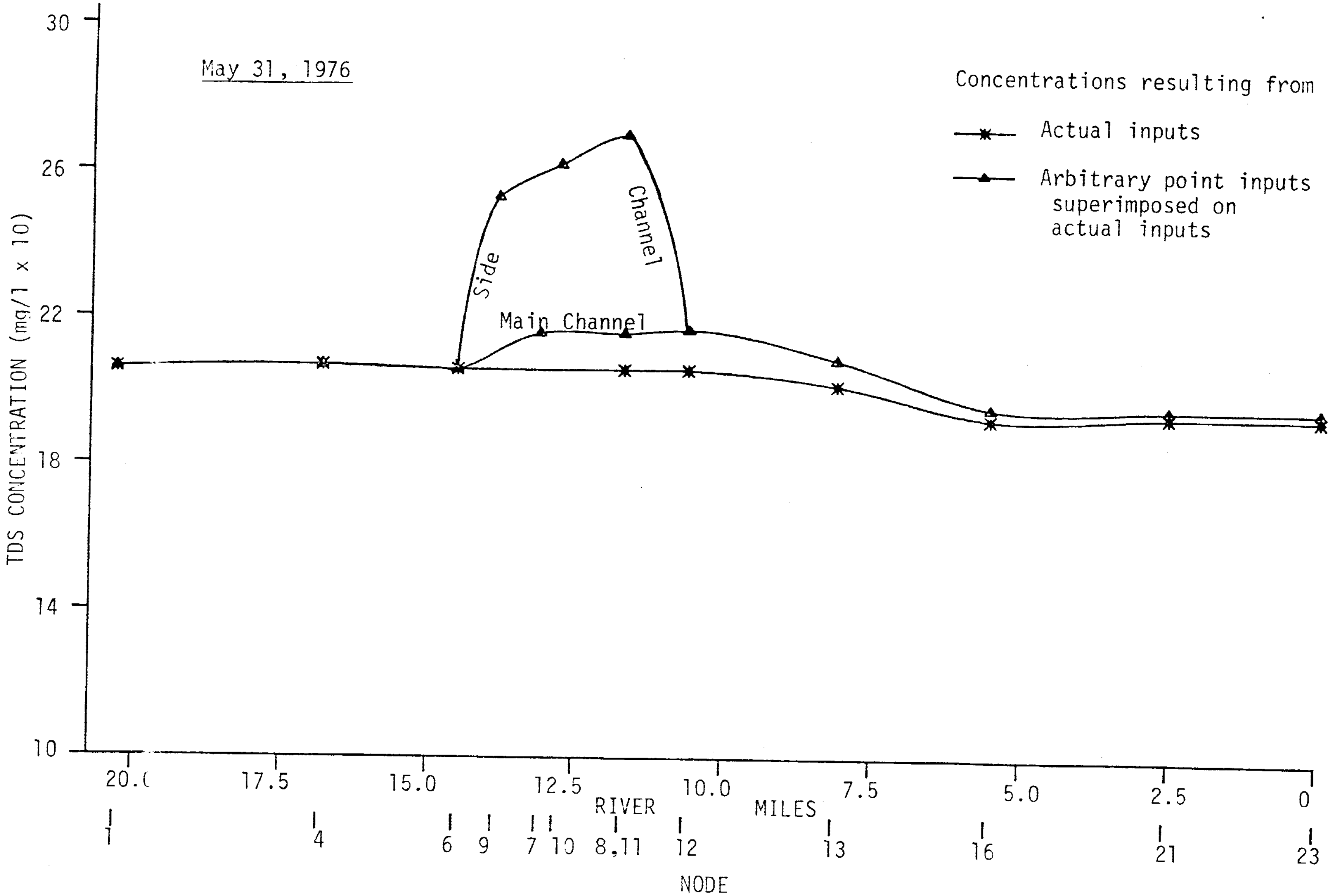

FIGURE 25 - LONGITUDINAL PLOT OF TDS, UPPER BLACKFOOT RIVER BASIN - CASE 2

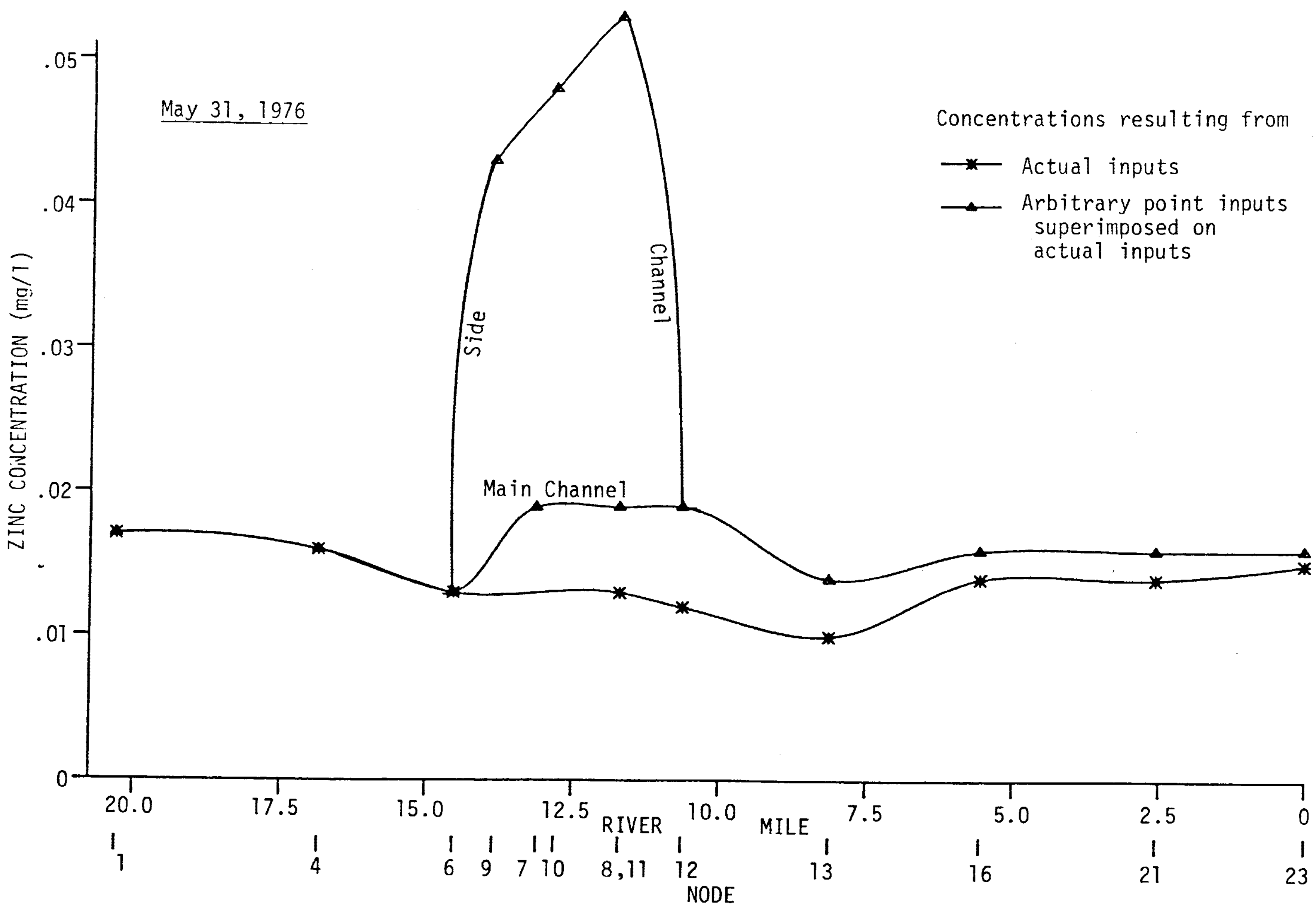

FIGURE 26 - LONGITUDINAL PLOT OF ZINC, UPPER BLACKFOOT RIVER BASIN - CASE 2

TABLE 16 - INFLOW QUALITY DATA OF UPPER BLACKFOOT RIVER BASIN - 27-31 MAY,1976 - Case 1

SEG	NAME	INFLOW CFS	TEMP C	TSS MG/L	COLIF MPN/00	BOD MG/L	DO MG/L	ALKA MG/L	PH	TIC MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	TDS MG/L	TBTY FTU	HARD MG/L	CHRM MG/L	ZINC MG/L	CUPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	DIAMOND CR	49.6	8.1	500.	2.	0.5	9.0	129.	7.0	40.4	0.50	0.10	0.20	500.	20.5	130.	.001	.021	.200	.001	.001	.001	1.42
1	STEWART CR	9.8	6.9	500.	2.	0.5	9.0	163.	7.0	51.4	0.50	0.10	0.15	500.	13.5	157.	.001	.011	.200	.001	.001	.001	1.13
1	TIMBER CR	18.4	6.9	72.	2.	0.5	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
1	UNNAMED	1.0	7.8	100.	3.	0.5	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
2	UNNAMED	3.0	7.8	100.	3.	0.8	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
3	BEAR CANYON	5.0	7.2	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
3	UNNAMED	2.0	7.8	100.	3.	0.8	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
4	HORNET CR	11.0	6.9	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
4	UNNAMED	0.2	8.1	100.	3.	0.8	9.5	163.	7.0	51.0	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
5	COYOTE CR	7.0	6.9	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
5	UNNAMED 1	0.2	7.5	35.	3.	0.8	9.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
5	TERRACE CR	1.5	6.9	25.	3.	0.8	9.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
5	CAMPBELL CR	20.0	6.1	15.	3.	0.8	9.5	159.	7.7	40.5	0.03	0.05	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.75
5	UNNAMED 2	1.5	6.9	20.	3.	0.8	9.5	136.	7.7	34.6	0.04	0.05	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.75
6	YELLOWJACKET	3.0	6.9	25.	2.	0.8	10.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
6	UNNAMED	0.2	7.9	30.	4.	1.0	10.5	136.	8.0	33.6	0.04	0.07	0.10	220.	15.0	165.	.001	.005	.010	.001	.001	.001	1.16
7	UNNAMED	3.0	7.2	500.	100.	10.0	9.0	159.	7.7	40.5	1.00	0.04	0.08	500.	1.9	160.	.002	.200	.010	.0	.0	.0	1.76
9	CABIN CR	1.5	6.9	500.	100.	10.0	9.5	191.	8.3	46.3	1.00	0.20	0.32	500.	13.5	157.	.001	.200	.010	.001	.001	.001	1.03
9	UNNAMED	0.4	7.5	500.	100.	10.0	9.5	191.	8.3	46.3	1.00	0.20	0.32	500.	13.5	157.	.001	.200	.010	.001	.001	.001	1.03
10	UNNAMED	0.3	7.5	500.	100.	10.0	9.5	191.	8.3	46.3	1.00	0.20	0.32	500.	13.5	157.	.001	.200	.010	.001	.001	.001	1.03
11	UNNAMED	0.2	7.6	500.	100.	10.0	9.7	179.	8.3	43.4	1.00	0.03	0.06	500.	14.5	170.	.001	.200	.010	.001	.001	.001	1.20
12	KENDELL CR	10.0	6.1	13.	2.	0.5	10.5	159.	7.7	40.5	0.03	0.04	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.76
12	MOSQUITO CR	0.5	7.5	15.	2.	0.5	10.5	171.	8.0	42.2	0.02	0.07	0.12	190.	1.7	163.	.002	.005	.010	.0	.0	.0	1.13
12	UNNAMED	0.1	9.4	30.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.03	0.06	210.	14.5	170.	.001	.005	.010	.001	.001	.001	1.20
13	TIMOTHY CR	6.2	8.3	33.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.10	0.16	170.	10.0	120.	.001	.005	.010	.001	.001	.001	0.55
13	GW GAIN	35.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
14	LANES CR	160.6	12.8	25.	26.	2.0	8.0	136.	8.0	33.4	0.04	0.10	0.16	188.	11.0	133.	.008	.020	.008	.001	.001	.001	0.62
14	UNNAMED 1	1.6	6.3	30.	2.	0.5	9.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
14	UNNAMED 2	1.4	8.3	30.	2.	0.5	9.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
14	BACON CR	9.2	8.9	35.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.10	0.16	170.	10.0	120.	.001	.005	.010	.001	.001	.001	0.55
15	MILL CR	5.1	7.5	17.	2.	0.5	10.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	UNNAMED 1	11.4	9.4	15.	1.	0.2	10.0	164.	7.2	46.7	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	UNNAMED 2	0.7	9.4	30.	2.	0.5	9.5	164.	7.2	46.7	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	GW GAIN	13.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
16	UNNAMED	3.2	10.0	17.	3.	0.5	10.0	164.	7.2	46.6	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
16	GW GAIN	13.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
17	ANGUS CR	6.6	11.9	200.	5.	1.0	9.0	139.	6.8	48.1	0.50	0.08	0.13	500.	6.0	138.	.001	.019	.002	.001	.001	.001	1.04
17	UNNAMED 1	0.9	11.9	19.	5.	1.0	9.0	139.	6.8	48.1	0.10	0.08	0.13	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.04
18	UNNAMED 1	5.5	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
18	UNNAMED 2	4.0	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
18	UNNAMED 3	3.6	8.4	29.	4.	1.0	9.0	139.	7.0	43.4	0.10	0.08	0.14	189.	8.5	135.	.001	.017	.003	.001	.001	.001	0.82
19	UNNAMED 1	2.3	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
20	UNNAMED	2.5	10.3	20.	4.	0.8	10.5	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
20	GW GAIN	5.9	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
21	UNNAMED	3.1	10.3	20.	5.	1.0	9.0	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
21	GW GAIN	5.9	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
22	UNNAMED	3.9	10.3	20.	5.	1.0	9.0	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
23	UNNAMED	5.3	10.3	20.	3.	0.8	9.5	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16

TABLE 17 -WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 31 MAY, 1976 - Case 1 12.0 HOUR

SEG	TEMP	TSS	COLIF	BOD	D O	D O	P H	CO2	PO4P	NH3N	NO3N	ALKA	TDS	TBTY	HARD	CHRM	ZINC	COPR	VNDM	CDM	ARSC	ORGN
	C	MG/L	MPN/00	MG/L	MG/L	0/0		MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L
1	9.4	387.	2.	0.5	9.5	89.	7.1	8.42	0.39	0.11	0.18	142.	428.	17.9	140.	.001	.017	.151	.001	.001	.001	1.30
2	8.9	368.	2.	0.5	9.8	93.	7.2	6.89	0.37	0.12	0.18	142.	420.	17.8	141.	.001	.017	.146	.001	.001	.001	1.28
3	9.0	336.	2.	0.5	10.0	95.	7.2	6.07	0.35	0.13	0.18	144.	401.	17.5	143.	.001	.017	.133	.001	.001	.001	1.26
4	8.7	299.	2.	0.6	10.1	96.	7.2	5.88	0.31	0.13	0.17	147.	376.	17.0	145.	.001	.016	.117	.001	.001	.001	1.24
5	8.1	224.	2.	0.6	10.2	94.	7.3	4.77	0.23	0.12	0.15	150.	330.	13.8	148.	.001	.013	.087	.001	.001	.001	1.32
6	8.1	215.	2.	0.6	10.3	96.	7.4	4.04	0.23	0.13	0.15	149.	326.	13.8	149.	.001	.013	.085	.001	.001	.001	1.30
7	9.1	216.	5.	0.9	10.5	100.	7.7	2.33	0.25	0.13	0.14	149.	332.	13.4	149.	.001	.019	.083	.001	.001	.001	1.31
8	9.9	208.	5.	0.9	10.4	102.	7.8	1.52	0.25	0.14	0.14	149.	332.	13.4	149.	.001	.019	.083	.001	.001	.001	1.30
9	9.1	249.	18.	2.1	10.4	99.	7.6	2.69	0.35	0.15	0.17	156.	354.	13.7	150.	.001	.043	.073	.001	.001	.001	1.25
10	10.2	242.	20.	2.3	10.4	102.	7.7	2.06	0.37	0.16	0.18	157.	359.	13.7	150.	.001	.048	.071	.001	.001	.001	1.23
11	11.2	231.	22.	2.6	10.4	105.	7.8	1.67	0.39	0.16	0.17	158.	364.	13.8	151.	.001	.053	.069	.001	.001	.001	1.22
12	9.8	182.	5.	0.9	10.5	102.	7.9	1.19	0.23	0.14	0.14	151.	319.	12.1	150.	.001	.019	.074	.001	.001	.001	1.33
13	10.1	120.	4.	0.7	10.4	101.	8.0	1.00	0.17	0.13	0.13	156.	278.	8.8	157.	.001	.014	.053	.001	.001	.001	0.97
14	13.6	28.	24.	1.9	8.9	95.	8.0	0.77	0.04	0.10	0.16	136.	187.	10.8	133.	.008	.019	.008	.001	.001	.001	0.62
15	11.6	63.	14.	1.3	9.8	99.	8.0	1.06	0.10	0.12	0.14	147.	223.	9.1	146.	.004	.017	.025	.001	.001	.001	0.76
16	11.1	61.	13.	1.2	10.0	100.	8.0	1.05	0.09	0.12	0.14	148.	222.	8.7	147.	.004	.016	.025	.001	.001	.001	0.73
17	14.0	165.	5.	1.0	9.2	99.	7.0	8.61	0.45	0.09	0.13	139.	463.	6.0	138.	.001	.019	.002	.001	.001	.001	1.03
18	10.9	78.	4.	1.0	9.6	96.	7.2	5.78	0.23	0.09	0.14	139.	288.	6.7	135.	.001	.017	.004	.001	.001	.001	0.78
19	11.8	68.	4.	1.0	9.9	101.	7.4	3.64	0.21	0.10	0.15	139.	278.	9.0	135.	.001	.017	.004	.001	.001	.001	0.75
20	10.7	60.	12.	1.2	10.1	100.	7.9	1.14	0.10	0.12	0.14	148.	225.	8.6	147.	.004	.016	.023	.001	.001	.001	0.72
21	10.3	60.	11.	1.1	10.2	101.	7.9	1.12	0.10	0.12	0.14	149.	224.	8.5	148.	.004	.016	.023	.001	.001	.001	0.71
22	10.1	60.	11.	1.1	10.3	101.	8.0	1.09	0.10	0.13	0.14	149.	224.	8.5	148.	.004	.016	.023	.001	.001	.001	0.71
23	10.0	60.	11.	1.1	10.4	101.	7.9	1.12	0.10	0.13	0.14	150.	224.	8.5	148.	.004	.016	.022	.001	.001	.001	0.71

TABLE 18 - INFLOW QUALITY DATA OF UPPER BLACKFOOT RIVER BASIN - 27-31 MAY,1976 -Case 2

SEG	NAME	INFLOW CFS	TEMP C	TSS MG/L	COLIF MPN/00	BOD MG/L	DO MG/L	ALKA MG/L	PH	TIC MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	TDS MG/L	TBTY FTU	HARD MG/L	CHRM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	DIAMOND CR	49.6	8.1	109.	2.	0.5	9.0	129.	7.0	40.4	0.09	0.10	0.20	207.	20.5	130.	.001	.021	.002	.001	.001	.001	1.42
1	STEWART CR	9.8	6.9	72.	2.	0.5	9.0	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
1	TIMBER CR	18.4	6.9	72.	2.	0.5	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
1	UNNAMED	1.0	7.8	100.	3.	0.5	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
2	UNNAMED	3.0	7.8	100.	3.	0.8	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
3	BEAR CANYON	5.0	7.2	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
3	UNNAMED	2.0	7.8	100.	3.	0.8	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
4	HORNET CR	11.0	6.9	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
4	UNNAMED	0.2	8.1	100.	3.	0.8	9.5	163.	7.0	51.0	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
5	COYOTE CR	7.0	6.9	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
5	UNNAMED 1	0.2	7.5	35.	3.	0.8	9.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
5	TERRACE CR	1.5	6.9	25.	3.	0.8	9.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
5	CAMPBELL CR	20.0	6.1	15.	3.	0.8	9.5	159.	7.7	40.5	0.03	0.05	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.75
5	UNNAMED 2	1.5	6.9	20.	3.	0.8	9.5	136.	7.7	34.6	0.04	0.05	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.75
6	YELLOWJACKET	3.0	6.9	25.	2.	0.8	10.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
6	UNNAMED	0.2	7.9	30.	4.	1.0	10.5	136.	8.0	33.6	0.04	0.07	0.10	220.	15.0	165.	.001	.005	.010	.001	.001	.001	1.16
7	UNNAMED	3.0	7.2	500.	100.	10.0	9.0	159.	7.7	40.5	1.00	0.04	0.08	500.	1.9	160.	.002	.200	.010	.0	.0	.0	1.76
9	CABIN CR	1.5	6.9	500.	100.	10.0	9.5	191.	8.3	46.3	1.00	0.20	0.32	500.	13.5	157.	.001	.200	.010	.001	.001	.001	1.03
9	UNNAMED	0.4	7.5	500.	100.	10.0	9.5	191.	8.3	46.3	1.00	0.20	0.32	500.	13.5	157.	.001	.200	.010	.001	.001	.001	1.03
10	UNNAMED	0.3	7.5	500.	100.	10.0	9.5	191.	8.3	46.3	1.00	0.20	0.32	500.	13.5	157.	.001	.200	.010	.001	.001	.001	1.03
11	UNNAMED	0.2	7.8	500.	100.	10.0	9.7	179.	8.3	43.4	1.00	0.03	0.06	500.	14.5	170.	.001	.200	.010	.001	.001	.001	1.20
12	KENDELL CR	10.0	6.1	15.	2.	0.5	10.5	159.	7.7	40.5	0.03	0.04	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.76
12	MOSQUITO CR	0.5	7.5	15.	2.	0.5	10.5	171.	8.0	42.2	0.02	0.07	0.12	190.	1.7	163.	.002	.005	.010	.0	.0	.0	1.13
12	UNNAMED	0.1	9.4	30.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.03	0.06	210.	14.5	170.	.001	.005	.010	.001	.001	.001	1.20
13	TIMOTHY CR	6.2	8.3	33.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.10	0.16	170.	10.0	120.	.001	.005	.010	.001	.001	.001	0.55
13	GW GAIN	35.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
14	LANES CR	160.6	12.8	25.	26.	2.0	8.0	136.	8.0	33.4	0.04	0.10	0.16	188.	11.0	133.	.008	.020	.008	.001	.001	.001	0.62
14	UNNAMED 1	1.6	8.3	30.	2.	0.5	9.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
14	UNNAMED 2	1.4	8.3	30.	2.	0.5	9.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
14	BACON CR	9.2	8.9	35.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.10	0.16	170.	10.0	120.	.001	.005	.010	.001	.001	.001	0.55
15	MILL CR	5.1	7.5	17.	2.	0.5	10.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	UNNAMED 1	11.4	9.4	15.	1.	0.2	10.0	164.	7.2	46.7	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	UNNAMED 2	0.7	9.4	30.	2.	0.5	9.5	164.	7.2	46.7	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	GW GAIN	13.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
16	UNNAMED	3.2	10.0	17.	3.	0.5	10.0	164.	7.2	46.6	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
16	GW GAIN	13.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
17	ANGUS CR	6.6	11.9	19.	5.	1.0	9.0	139.	6.8	48.1	0.10	0.08	0.13	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.04
17	UNNAMED 1	0.9	11.9	19.	5.	1.0	9.0	139.	6.8	48.1	0.10	0.08	0.13	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.04
18	UNNAMED 1	5.5	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
18	UNNAMED 2	4.0	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
18	UNNAMED 3	3.6	8.4	29.	4.	1.0	9.0	139.	7.0	43.4	0.10	0.08	0.14	189.	8.5	135.	.001	.017	.003	.001	.001	.001	0.82
19	UNNAMED 1	2.3	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
20	UNNAMED	2.5	10.3	20.	4.	0.8	10.5	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
20	GW GAIN	5.9	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
21	UNNAMED	3.1	10.3	20.	5.	1.0	9.0	190.	7.0	58.6	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
21	GW GAIN	5.9	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
22	UNNAMED	3.9	10.3	20.	5.	1.0	9.0	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
23	UNNAMED	5.3	10.5	20.	3.	0.8	9.5	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16

TABLE 19 -WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 31 MAY, 1976- Case 2 12.0 HOUR

SEG	TEMP C	TSS MG/L	COLIF MPN/00	BOD MG/L	D O MG/L	D O 0/0	PH	CO2 MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	ALKA MG/L	TDS MG/L	TBTY MG/L	HARD MG/L	CHRM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	8.4	94.	2.	0.5	9.5	89.	7.1	8.42	0.07	0.11	0.18	142.	206.	17.9	140.	.001	.017	.002	.001	.001	.001	1.30
2	8.9	93.	2.	0.5	9.6	93.	7.2	6.89	0.07	0.12	0.18	142.	207.	17.8	141.	.001	.017	.002	.001	.001	.001	1.28
3	9.0	91.	2.	0.5	10.0	95.	7.2	6.07	0.07	0.13	0.18	144.	207.	17.5	143.	.001	.017	.002	.001	.001	.001	1.26
4	8.7	89.	2.	0.6	10.1	96.	7.2	5.88	0.07	0.13	0.17	147.	207.	17.0	145.	.001	.016	.003	.001	.001	.001	1.24
5	8.1	72.	2.	0.6	10.2	94.	7.3	4.77	0.06	0.12	0.15	150.	206.	13.8	148.	.001	.013	.004	.001	.001	.001	1.32
6	8.1	70.	2.	0.6	10.3	96.	7.4	4.04	0.06	0.13	0.15	149.	206.	13.8	149.	.001	.013	.004	.001	.001	.001	1.30
7	9.1	83.	5.	0.9	10.5	100.	7.7	2.33	0.09	0.13	0.14	149.	216.	13.4	149.	.001	.019	.004	.001	.001	.001	1.31
8	9.9	82.	5.	0.9	10.4	102.	7.8	1.52	0.09	0.14	0.14	149.	216.	13.4	149.	.001	.019	.004	.001	.001	.001	1.30
9	9.1	134.	18.	2.1	10.4	99.	7.6	2.69	0.21	0.15	0.17	156.	253.	13.7	150.	.001	.043	.005	.001	.001	.001	1.25
10	10.2	138.	20.	2.3	10.4	102.	7.7	2.06	0.24	0.16	0.18	157.	262.	13.7	150.	.001	.048	.005	.001	.001	.001	1.23
11	11.2	138.	22.	2.6	10.4	105.	7.8	1.67	0.26	0.16	0.17	158.	270.	13.8	151.	.001	.053	.006	.001	.001	.001	1.22
12	9.8	76.	5.	0.9	10.5	102.	7.9	1.19	0.09	0.14	0.14	151.	217.	12.1	150.	.001	.019	.005	.001	.001	.001	1.33
13	10.1	54.	4.	0.7	10.4	101.	8.0	1.00	0.07	0.13	0.13	156.	209.	8.8	157.	.001	.014	.007	.001	.001	.001	0.97
14	13.6	28.	24.	1.9	8.9	95.	8.0	0.77	0.04	0.10	0.16	136.	187.	10.8	133.	.008	.019	.008	.001	.001	.001	0.62
15	11.6	37.	14.	1.3	9.8	99.	8.0	1.06	0.06	0.12	0.14	147.	196.	9.1	146.	.004	.017	.007	.001	.001	.001	0.76
16	11.1	37.	13.	1.2	10.0	100.	8.0	1.05	0.06	0.12	0.14	148.	196.	8.7	147.	.004	.016	.007	.001	.001	.001	0.73
17	14.0	19.	5.	1.0	9.2	99.	7.0	8.61	0.10	0.09	0.13	139.	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.03
18	10.9	29.	4.	1.0	9.6	96.	7.2	5.78	0.10	0.09	0.14	139.	189.	8.7	135.	.001	.017	.004	.001	.001	.001	0.78
19	11.3	29.	4.	1.0	9.9	101.	7.4	3.64	0.10	0.10	0.15	139.	189.	9.0	135.	.001	.017	.004	.001	.001	.001	0.75
20	10.7	36.	12.	1.2	10.1	100.	7.9	1.14	0.06	0.12	0.14	148.	196.	8.6	147.	.004	.016	.007	.001	.001	.001	0.72
21	10.3	37.	11.	1.1	10.2	101.	7.9	1.12	0.06	0.12	0.14	149.	196.	8.5	148.	.004	.016	.007	.001	.001	.001	0.71
22	10.1	37.	11.	1.1	10.3	101.	8.0	1.09	0.06	0.13	0.14	149.	196.	8.5	148.	.004	.016	.007	.001	.001	.001	0.71
23	10.0	38.	11.	1.1	10.4	101.	7.9	1.12	0.06	0.13	0.14	150.	196.	8.5	148.	.004	.016	.007	.001	.001	.001	0.71

first to prescribe water quality standards which should be met at different points of the stream system. These standards will depend and vary with the uses to which water is intended to be put. Once suitable standards have been specified, the pollution abatement problem for the water course should be studied as a whole, including the entire watershed, to determine which wastes should be fully treated or eliminated at their source and which may be allowed to go partially treated or untreated for the best economical solution. This can be well achieved for the study basin with the help of the model built for it. The model can also assist in analyzing critical pollution events.

The model can provide much information on many water quality constituents and for many points along the stream. Further, it can output information in tabular as well as graphical form. The graphic outputs are very helpful in the efficient interpretation of model results.

For acceptability of the model, the cost of modeling should be no greater than the benefits derived by use of the model. In view of the very high cost of quality management by monitoring water qualities, it is unlikely that the cost constraint will become critical in the case of water quality model.

In order to reduce computer costs for the model of the study basin 3-hourly model outputs were obtained to find the time it takes for the ecosystem to reach a steady state situation. The inflow water quality data from arbitrary waste discharges and actual discharges combined for the period of 27-31 May, 1976 were utilized for this purpose. The plots of 3-hourly simulations for TSS for 27 and 28 May, 1976 have been given in figures 27 and 28 while similar plots for coliform, BOD, PO_4-P, TDS,

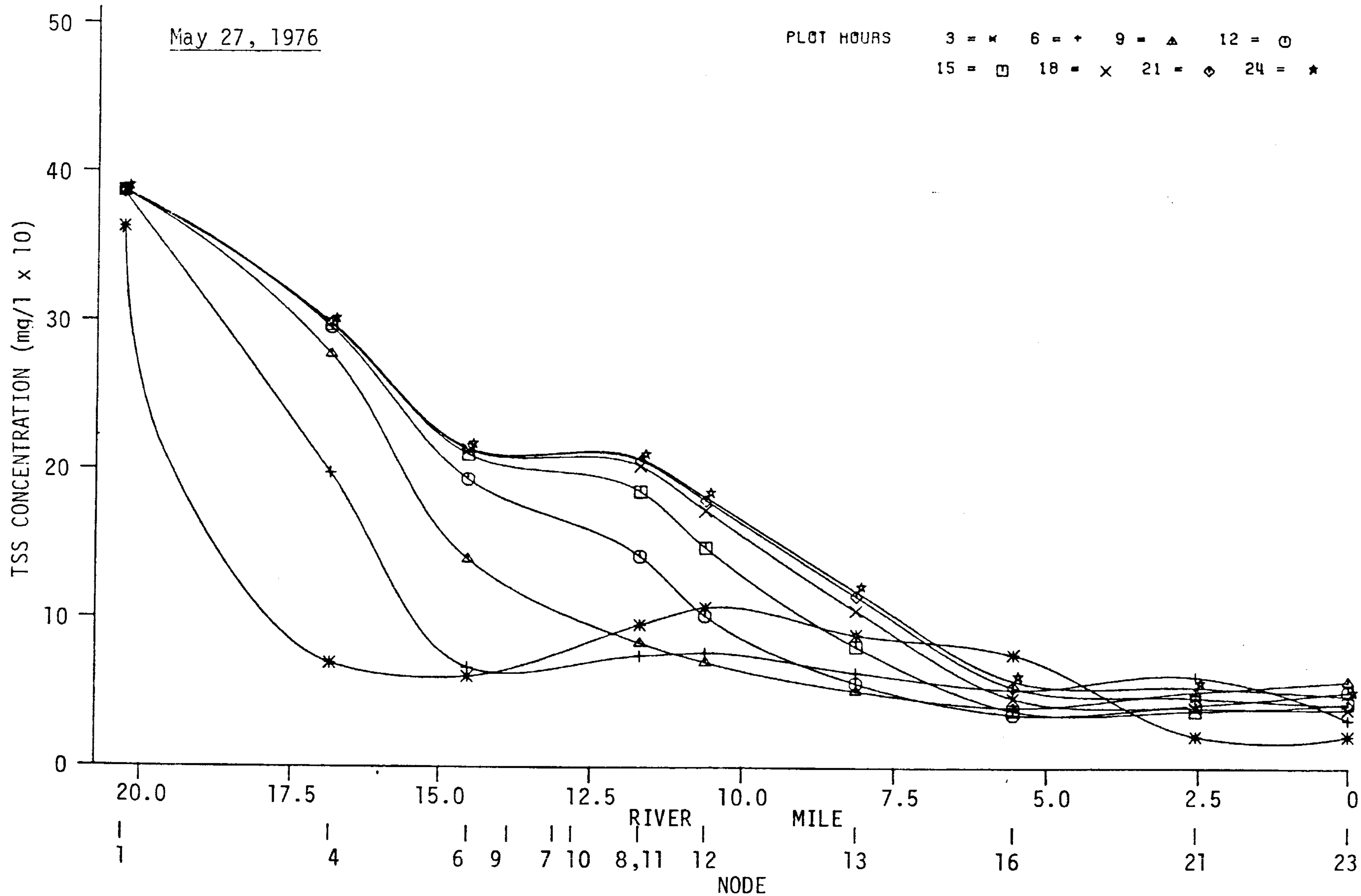

FIGURE 27 - LONGITUDINAL PLOT OF TSS, UPPER BLACKFOOT RIVER BASIN

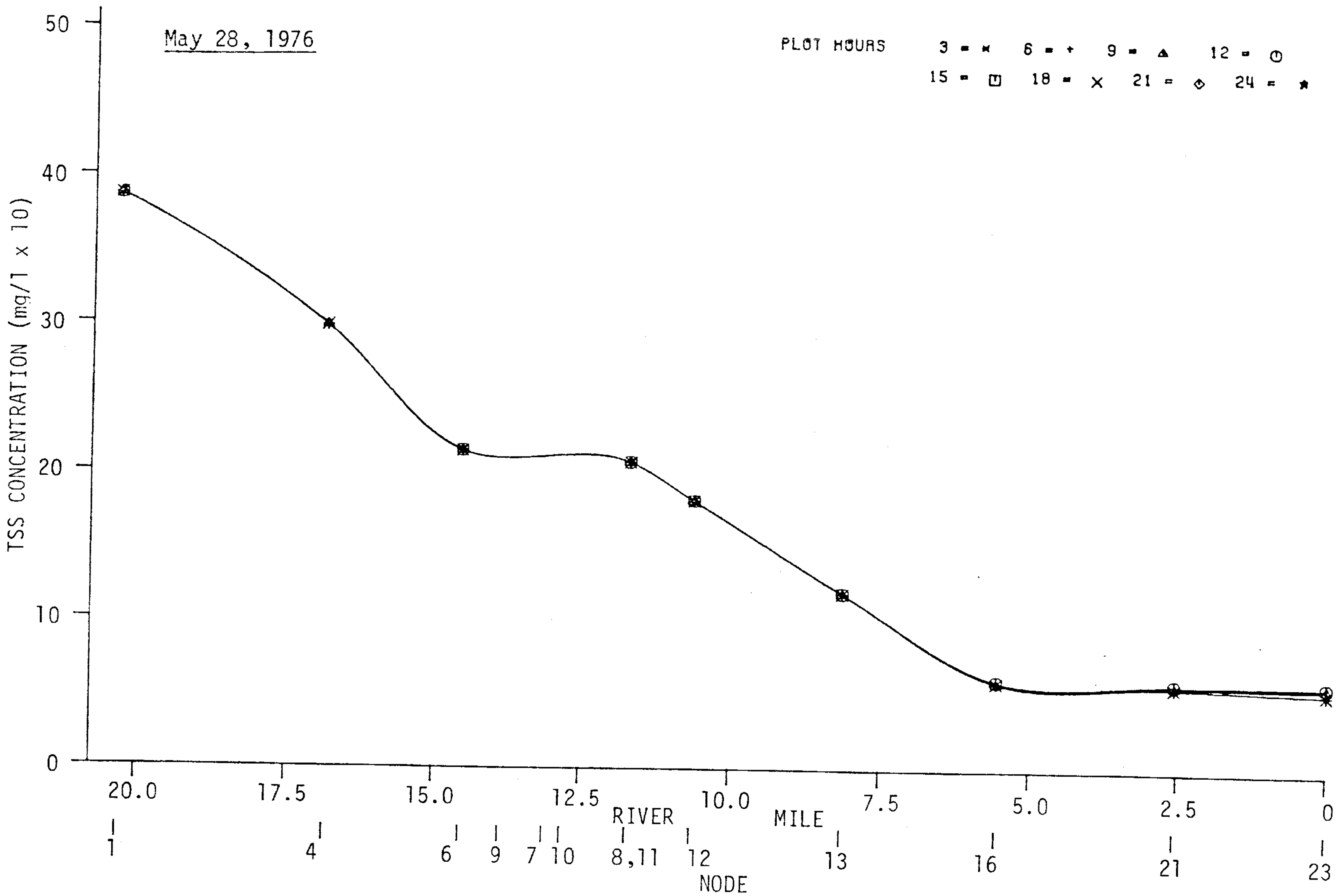

FIGURE 28 - LONGITUDINAL PLOT OF TSS, UPPER BLACKFOOT RIVER BASIN

zinc and copper have been attached as Appendix E. It will be seen from these plots that the ecosystem of the study area reaches a steady state situation after 36 hours for all water quality constituents. The model simulations, therefore, may be limited to 36 for the Upper Blackfoot River to obtain the impact of any constant waste discharge. This can certainly reduce considerably the computer time and cost. The time required to reach a steady state situation will be different for different basins.

The model may also be able to assist in the planning of phosphate mining and processing provided detailed programs of various activities associated with different plans are available and information on the location, quantities, time and the type of waste inputs resulting from them is provided by the mining companies. With this information the model can simulate the impacts of different mining operation plans on the water quality of the Upper Blackfoot River basin. The relative effects of various mining schemes on the water quality of the river system can thus be obtained with the help of the model. These effects can then be evaluated to come up with a suitable plan of development.

The model can also be adapted to assist in the planning and management of other activities like grazing, irrigation, timber harvesting and recreation after required data is collected and made available. The model can thus have a wider scope of application than for phosphate mining.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

There are plans to expand the phosphate mining and processing activities in the southeastern part of Idaho over the period extending to the year 2000. Implementation of these plans will have environmental impacts which may be short term or long term, reversible or irreversible, adverse or beneficial. The phosphate mining and processing operations would most likely have adverse effects on water quality of the streams draining the area. These adverse impacts can however, be avoided or minimized by adopting suitable management practices. The purpose of this study was to provide a technique which could assist in the management of future phosphate mining operations. The Upper Blackfoot River basin where extensive hydrologic, water quality and weather data have been collected was selected for development of this technique.

The present status of water quality of study area was examined by statistical analyses of the observed data. It was concluded that the water quality of the streams is generally good.

After a thorough survey of the available literature on available water quality models for streams, Chen and Wells' model used for Boise River studies was selected as a basis for model construction for the Upper Blackfoot River basin. Chen and Wells' model was modified suitably for application to the study area. This model is a steady state model and is based on the concept of Constant Stirred Tank Reactor (CSTR) and on the Law of Conservation of Mass. Certain valid assumptions and simplifications were made in the mathematical representations of the physical, chemical and biological processes taking place in the ecosystem of the study area and affecting the water quality changes. A partial differential equation resulted for each water quality parameter.

The Upper Blackfoot River basin was divided into 23 main parts such that the segment length of the main channel for each part satisfied the condition of retention time being approximately equal to the time step used in numerical solution of the partial differential equations. The time-step adopted was 1.0 hour.

A computer program was prepared for solving the partial differential equations and outputting the simulated water qualities for each segment node in tabular as well as graphical form.

Two periods, (i) 27-31 May, 1976 and (ii) 23-30 September, 1976 were selected for refining and testing the model. The September, 1976 data were used for calibration purpose whereas the May, 1976 data were utilized for verification of the model. The hydrologic, hydraulic, water quality and weather data to be inputted into the model were prepared for the two periods from the field data and using standard analytical techniques in the case of missing data. The water qualities simulated by the model were compared with their observed values for model verification. Model simulations were considered satisfactory considering the data limitations and the complexity of the ecosystem.

The technique of model application for management of the phosphate mining and processing operations in the Upper Blackfoot River basin has been illustrated by model simulations of two cases of arbitrary waste inputs at selected points where mining operations may be expanded or started.

It has been indicated as to how the model may be able to assist also in the planning of phosphate mining operations. The model can also be adaped to the planning and management of other activities like grazing, irrigation, timber harvesting and recreation to avoid or reduce their impacts on water quality.

Three hourly model simulations were made to determine the minimum number of computational time steps required to reach a steady state situation. Steady state conditions will be simulated after 36 hours of model operation.

Conclusions

The following general conclusions can be drawn from the study:

1. The present water qualities of the streams in the Upper Blackfoot River basin are generally good. This shows that the impacts of current activities in the area on water quality are negligible.

2. There is considerable interaction between surface and ground waters in the study area.

3. The future of phosphate mining and processing operations are likely to have adverse effects on water quality if carried out without suitable management plans.

4. The water quality model which has been developed for the

study area can be a good tool in the preparation of management plans for phosphate mining in the area. Some water quality and hydrologic data will have to be collected during application of the model.

5. The model will require refinement after collection of more data where it was missing or was insufficient.

6. The model can be adapted to the planning and management of other current or proposed human activities like grazing, irrigation, timber harvesting and recreation in the study area.

Recommendations

Recommendations concerning the application of the water quality model and collection of related data for the Upper Blackfoot River basin are stated below.

1. The data collection programs of the various agencies in the Upper Blackfoot River basin relating to hydrologic, water quality and weather parameters should be better coordinated. This will ensure economies in data gathering, will provide sufficient data in space and time and will give coverage of all the desired parameters to meet the requirements of all the participating agencies.

2. Following suggestions are made for the collection of specific data which would enable improvement and refinement of the water quality model:

a) <u>Hydrologic and water quality data</u>: Hydrologic data are extremely important for determining the hydraulic geometry and for evaluating the physical processes affecting concentrations of water quality constituents. These data should, therefore, be collected for the remaining major tributaries of the basin. These are Lanes Creek, Bacon Creek, Timothy Creek, Angus Creek before its confluence with Blackfoot River, Campbell Creek, Timber Creek and Hornet Creek. Water quality data covering all the required parameters should also be observed at these sites along with hydrologic observations. These data may be collected twice a month for a period of 2-3 years.

Discharge data should be collected regularly at three water quality stations maintained by the Idaho Department of Health and Welfare above the Narrows.

Four more hydrologic and water quality stations should be established at the following points on the main stem of the river.

i) Blackfoot River above the confluence with Angus Creek,

ii) Diamond Creek below confluence of the two channels near the location of Nodes 8 and 11,

iii) On two channels of Diamond Creek just after their bifurcation below Node 6, and

iv) Diamond Creek at the location of Node 2.

Collection of the above data should extend over 2 to 3 years. Sufficient data appears to have been collected by the U. S. Forest Service for the tributaries at the existing stations. It may now be more useful to start collecting data at other sites proposed above instead of the present sites.

U. S. Forest Service and the Idaho Department of Health and Welfare should not maintain both stations on the Blackfoot River at and below the Narrows as they are very close to each other. One station would appear to be sufficient and would provide an economic saving.

Water quality data in the study area are deficient in respect of certain parameters, for example, DO, BOD, coliform, phytoplankton, zooplankton, benthic elements. It would be a good idea to review the existing data collection systems in the basin and evolve a unified program to be managed by the interested agencies.

b) Weather data: Three weather stations should be maintained in the basin to collect data on at least those climatic elements which enter into the model. These stations should be located at the following places:

i) Trail Guard Station,

ii) Diamond Creek valley - at the old station maintained by Greiner Environmental Sciences, Inc.

iii) Johnson Weather Station - by upgrading the existing station to cover all the required elements.

3. With the collection of additional hydrologic data stream loss and gain studies should be conducted to better understand the hydrologic behavior of the basin. This will help in improving the accuracy of the inflows and outflows into the various segments.

4. After collection of further data proposed above, the water quality model should be improved upon.

5. After colletion of the recommended data technical studies should be carried out to select index stations which can be used for estimation of data for the remaining streams. The index stations should be as few as possible consistant with the required accuracy. These index stations should then be maintained during the period of operation of the model.

   If it is desired to build a model for another basin, data collection should be started with a good network of stations. Analytical studies should be conducted after a year's data are available, to select the index stations. At least two years data would be required to finalize the selection of these stations.

6. Studies should be started to understand the relationships between the time and level of various activities - phosphate mining, grazing, timber harvesting, irrigation - and the amount of their wastes which are discharged into the streams.

ABBREVIATIONS

EPA	Environmental Protection Agency
mg/l or MG/L	milligrams per litre
ml	milli-litre
DO	dissolved oxygen
JTU	Jackson turbidity unit
FTU	Formazin turbidity unit
NH_3-N	ammonia - nitrogen
NO_2-N	nitrite - nitrogen
NO_3-N	nitrate - nitrogen
ppm	parts per million
DF	Douglas fir
LP	lodgepole pine
AF	Alpine fir
MBF	million board feet
cfs	cubic feet per second
BOD	biological oxygen demand
$KJ/m^2.hr$	kilo joules per square meter per hour
$cal/cm^2.min$	calories per square centimeter per minute
mb	millibar
CO_2	carbon dioxide
TIC	total inorganic carbon
SD	standard deviation
TDS	total dissolved solids
TSS	total suspended solids
colif	coliform bacteria

PO_4-P	orthophosphate (phosphorous)
Alka	total alkalinity as $CaCO_3$
Hard	total hardness as $CaCO_3$
TBTY	turbidity
CHRM	chromium
COPR	copper
VNDM	vanadium
CDM	cadmium
ARSC	arsenic
ORGN	organic nitrogen
MPN/OO	mean probability number per 100 ml
Temp	temperature
USFS	U. S. Forest Service
GES	Greiner Engineering Sciences, Inc.

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APPENDIX A

Listing of Computer Program for Water Quality Model for Upper Blackfoot River System.

```
C      COMPUTER PROGRAM FOR WATER QUALITY MODEL FOR UPPER BLACKFOOT RIVER
C
C
C
C                  MAIN
C
C         MAIN PERFORMS WATER QUALITY SIMULATIONS
C
C**** MULTIPLIERS
      COMMON/AMULTP/OSMLT
C
C**** ENVIRONMENTAL QUALITY PARAMETERS
C
      COMMON    WTEMP(50),WTSS(50),WCOLIF(50),WBOD(50),WO2(50),WTIC(50),
     1WPO4(50),WALKA(50),WNH3(50),WNO2(50),WNO3(50),WTDS(50),WTBTY(50),
     2WHARD(50),WCHRM(50),WZINC(50),WCOPR(50),WVNDM(50),WCDM(50),
     3WARSC(50),WORGN(50),WTOTKN(50),WPH(50),WCO2(50)
C
C**** CHANGING RATES OF ENVIRONMENTAL QUALITIES
C
      COMMON    WTEMDT(50),WTSSDT(50),WCOLDT(50),WBODDT(50),WO2DT(50),
     1WTICDT(50),WPO4DT(50),WALKDT(50),WNH3DT(50),WNO2DT(50),WNO3DT(50),
     2WTDSDT(50),WTBYDT(50),WHRDDT(50),WCRMDT(50),WZNCDT(50),WCPRDT(50),
     3WVDMDT(50),WCDMDT(50),WASCDT(50),WONDT(50),WTKNDT(50)
C
C**** ENVIRONMENTAL QUALITIES AT T + DELT
C
      COMMON    WTEMPT(50),WTSST(50),WCOLT(50),WBODT(50),WO2T(50),WTICT(5
     10),WPO4T(50),WALKT(50),WNH3T(50),WNO2T(50),WNO3T(50),WTDST(50),
     2WTBYT(50),WHRDT(50),WCRMT(50),WZNCT(50),WCPRT(50),WVDMT(50),
     3WCDMT(50),WARST(50),WORGNT(50),WTKNT(50)
C
C**** ANSWERS STORAGE FOR PRINTING AND PLOTTING
C
      COMMON         PNAME(25),JHISTO,JINDEX(10),JSTATN(10,3),HOUR(51),
     1HISTOG(10,3,51),NPROFL,NINDEX(10),NSTATN(10,11),PHOUR(3),
     2PROFIL(10,11,3)
C
C**** TIME
C
      COMMON/ECOTIM/DELT,DELT2,DELT6,ND,NQ,NDAY1,NDAY2,NPERDY,NDAY,
     1IWTAPE,NPRNT,NPHOUR,NDHIST,KDAY,METHOD,IPUDA,IPUHR,IOTAPE,ITSCH
C
C**** INPUT WATER QUALITIES
C
      COMMON/ECOIN/TITLE(20),TEMPIN(50),TSSIN(50),COLIN(50),BODIN(50),
     1O2IN(50),TICIN(50),PO4IN(50),ALKAIN(50),NH3IN(50),NO2IN(50),
     2NO3IN(50),TDSIN(50),TBTYIN(50),HARDIN(50),CHRMIN(50),ZINCIN(50),
```

```
     3COPRIN(50),VNDMIN(50),CDMIN(50),ARSNIN(50),ORGNIN(50),TKNIN(50)
C
C**** COEFFICIENTS
C
      COMMON/COEF/WBODK,WCOLIK,WNH3K,WNO2K,C10,O2NH3,O2NO2,CO2BOD,
     1VC1,VC2,VC3,WDNK,WPO4K
C
C**** SOLAR ENERGY AND HEAT EXCHANGE
C
      COMMON/SOLAR/ NWZONE,JWZONE(5,2),RAD(100),HEAT(100),EVAPA,
     1EVAPB,ST(24,5),QN(24,5),QNS(24,5),AP(24,5),DBT(24,5),EA(24,5),
     2WS(24,5),QAT(24,5)
C
C****  HYDRAULIC PARAMETERS
C
      COMMON/HYD/Q(50),QIN(50),QOUT(50),VOLM(50),VEL(50),DEPTH(50),
     1WIDTH(50),SAREA(50),LINK(50,3),H1(50),H2(50),V1(50),V2(50),W1(50),
     2W2(50),NQIN(50),XLNGTH(50),NSEG,NREACH,NBRNCH(50),QNO(50),
     3VOLM2(50)
C
C**** REAERATION,QUALITY INDEX,OTHER
C
      COMMON/OTHER/REAO2(50),NHYDRO,IHYDRO,RSCOUR(50),SCOUR(50),
     2TAVG(50),TAVS(50)
      COMMON/SOLAR1/HEAT1(50,30)
      COMMON/TSTEP/STEP
C
C**** INDEXING VARIABLES
C
      DIMENSION   YY(50,24),YYP(50,22),YYT(50,22),YYIN(50,22)
      DIMENSION PNAM1(25)
      DIMENSION MONTH(10)
C
C**** EQUIVALENCE
C
      EQUIVALENCE (YY(1,1),WTEMP(1)),(YYP(1,1),WTEMPT(1)),
     1(YYT(1,1),WTEMPT(1)),(YYIN(1,1),TEMPIN(1))
C
C**** DATA STATEMENT
C
      DATA  PNAM1/4HTEMP,3HTSS,4HCOLF,3HBOD,3HD O,3HTIC,3HPO4,4HALKA,
     1  3HNH3,3HNO2,3HNO3,3HTDS,4HTBTY,4HHARD,4HCHRM,4HZINC,4HCOPR,4HVND
     2M,3HCDM,4HARSC,4HORGN,4HTOKN,2HPH,3HCO2,3HSAT/
      DO 7001 KK=1,25
      PNAME(KK)=PNAM1(KK)
 7001 CONTINUE
      DATA NP/21/,NADVEC/21/
```

```
      READ(5,110) (MONTH(I),I=1,5),NUMBER
  110 FORMAT(5A4,I2)
C
C****CALL DATA TO READ GENERAL CONTROL CARDS,SYSTEM GEOMETRY,ETC.
C
      CALL DATA
C
C
C*****          START MAJOR COMPUTATIONS
C
C
      READ(IWTAPE) NPEROD,NWZONE,JWZONE,NDAYS,EVAPA,EVAPB
      KODE=1
      KDAY=NDAY1
      NOB=NPERDY
      NFREQ=1
      DO 400 I=1,NSEG
      DO 400 K=1,NP
      YYT(I,K)=YY(I,K)
  400 CONTINUE
      STEP=1.
C
      CALL FLOW
C
C
C**** DAILY CYCLE LOOP
C
C**** DIURNAL SOLAR ENERGY INPUT FROM IWTAPE
C
   61 READ(IWTAPE)((QNS(J,K),QAT(J,K), AP(J,K), DBT(J,K), EA(J,K),
     1  WS(J,K), J=1,NOB), K=1,NWZONE)
C
      IPOINT=0
      LPOINT=0
      DO 1000 ND=1,NDAY
C
C**** DIURNAL TIME STEPS
C
      DO 500 NC=1,NPERDY
      NF=NC
      NA=NC
C**** HEAT EXCHANGE AND SHORT WAVE ENERGY FOR ALL JUNCTIONS
C
   92 DO 80 N=1,NWZONE
      J1=JWZONE(N,1)
      J2=JWZONE(N,2)
      DO 80 J=J1,J2
```

```
      EVAPA=3.495E-9
      EVAPB=1.308E-9
      TA=WTEMP(J)
      ES=EXP(2.3026*(7.5*TA/(TA+237.3)+.7858))
      HV=598.1-.57*TA
      ROS=1000.-(((TA-3.98)**2*(TA+283.))/(503.57*(TA+67.26)))
      EV=(WS(NF,N)*EVAPB+EVAPA)*(ES-EA(NF,N))
      IF(EV.LT.0.)  EV=0.
      QE=ROS*HV*EV
      RB=6.1E-4*AP(NF,N)*(TA-DBT(NF,N))/(ES-EA(NF,N))
      QC=QE*RB
      QW=1.3056E-11*(TA+273.)**4.
      HEAT1(J,NQ)=QAT(NQ,N)+QNS(NQ,N)-QW-QE-QC
   80 CONTINUE
C
C**** QUALITY AND ECOLOGIC SIMULATION
C
      CALL ECOSYS(NA)
C
C**** WRITE ANSWERS AS THEY ARE CALCULATED
C
      IF((NQ.LE.NPRNT).OR.(MOD(NQ,NPHOUR).NE.0)) GO TO 991
    1 TIME=FLOAT(NQ)
      WRITE(6,2)
  2   FORMAT('1')
      WRITE(6,321) (MONTH(I),I=1,5),TIME
  321 FORMAT(T6,'TABLE     -',
     1          'WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BA
     2SIN - ',5A4,3X,F5.1,1X,'HOUR'////)
      WRITE(6,323)
  323 FORMAT(
     1' SEG    TEMP  TSS COLIF  BOD  D O   D O P H CO2  PO4P NH3N NO3N AL
     2KA TDS   TBTY HARD CHRM ZINC COPR VNDM CDM  ARSC ORGN'//
     3'         C    MG/L MPN/00 MG/L MG/L  O/O      MG/L MG/L MG/L MG/L MG
     4/L MG/L MG/L MG/L MG/L MG/L MG/L MG/L MG/L MG/L MG/L'//)
      DO 142 J=1,NSEG
      T=WTEMP(J)
      DOS=14.5532-0.38217*T+0.0054258*T*T
      DOS=DOS*OSMLT
      DOS=100.*WO2(J)/DOS
      WRITE(6,324) J,WTEMP(J),WTSS(J),WCOLIF(J),WBOD(J),WO2(J),DOS,WPH(J
     1),WCO2(J),WPO4(J),WNH3(J),WNO3(J),WALKA(J),WTDS(J),WTBTY(J),
     2WHARD(J),WCHRM(J),WZINC(J),WCOPR(J),WVNDM(J),WCDM(J),WARSC(J),
     3WORGN(J)
  324 FORMAT(I4,F7.1,2F5.0,F6.1,F5.1,F6.0,F4.1,4F5.2,2F5.0,F5.1,F5.0,
     16(1X,F4.3),F5.2/)
  142 CONTINUE
```

```
C
C**** STORE ANSWERS FOR TIME HISTOGRAPHS
C
 991   IF(NQ.LT.NDAY-1) GO TO 100
       IF(MOD(NQ,NFREQ).NE.0) GO TO 100
  90   IPOINT=IPOINT+1
       HOUR(IPOINT)=FLOAT(KDAY)+FLOAT(NQ)/FLOAT(NPERDY)
       DO 92 K=1,JHISTO
       IND=JINDEX(K)
       DO 92 N=1,3
       J=JSTATN(K,N)
       IF(J.EQ.0) GO TO 92
       HISTOG(K,N,IPOINT)=YY(J,IND)
   92  CONTINUE
C
C****STORE ANSWERS FOR PROFILE PLOTS
C
  100  IF(NQ.NE.NDAY) GO TO 108
       IF(MOD(NQ,NPERDY/3).NE.0) GO TO 108
       LPOINT=LPOINT+1
       IF(LPOINT.GT.3) GO TO 108
       PHOUR(LPOINT)=FLOAT(NQ)
       DO 102 K=1,NPROFL
       IND=NINDEX(K)
       DO 102 L=1,9
       J=NSTATN(K,L)
       IF(J.EQ.0) GO TO 102
       PROFIL(K,L,LPOINT)=YY(J,IND)
  102  CONTINUE
  108  CONTINUE
C
C      END OF DIURNAL LOOP
C
  500  CONTINUE
C
C      END OF DAILY LOOP
       KDAY=KDAY+1
C
 1000  CONTINUE
C
       CALL PLOTER(IPOINT)
C
       STOP
       END
C
C
       SUBROUTINE DATA
```

```
C
C         SUBROUTINE DATA READS BASIC INPUT DATA
C
C**** MULTIPLIERS
C
      COMMON /AMULTP/GSMLT
C**** ENVIRONMENTAL QUALITY PARAMETERS
C
      COMMON    WTEMP(50),WTSS(50),WCOLIF(50),WBOD(50),WO2(50),WTIC(50),
     1WPO4(50),WALKA(50),WNH3(50),WNO2(50),WNO3(50),WTDS(50),WTBTY(50),
     2WHARD(50),WCHRM(50),WZINC(50),WCOPR(50),WVNDM(50),WCDM(50),
     3WARSC(50),WORGN(50),WTOTKN(50),WPH(50),WCO2(50)
C
C**** CHANGING RATES OF ENVIRONMENTAL QUALITIES
C
      COMMON    WTEMDT(50),WTSSDT(50),WCOLDT(50),WBODDT(50),WO2DT(50),
     1WTICDT(50),WPO4DT(50),ALKADT(50),WNH3DT(50),WNO2DT(50),WNO3DT(50),
     2WTDSDT(50),WTBYDT(50),WHRDDT(50),WCRMDT(50),WZNCDT(50),WCPRDT(50),
     3WVDMDT(50),WCDMDT(50),WASCDT(50),WONDT(50),WTKNDT(50)
C
C**** ENVIRONMENTAL QUALITIES AT T + DELT
C
      COMMON    WTEMPT(50),WTSST(50),WCOLT(50),WBODT(50),WO2T(50),WTICT(5
     10),WPO4T(50),ALKAT(50),WNH3T(50),WNO2T(50),WNO3T(50),WTDST(50),
     2WTBYT(50),WHRDT(50),WCRMT(50),WZNCT(50),WCPRT(50),WVDMT(50),
     3WCDMT(50),WARST(50),WORGNT(50),WTKNT(50)
C
C**** ANSWERS STORAGE FOR PRINTING AND PLOTTING
C
      COMMON         PNAME(25),JHISTO,JINDEX(10),JSTATN(10,3),HOUR(51),
     1HISTOG(10,3,51),NPROFL,NINDEX(10),NSTATN(10,11),PHOUR(3),
     2PROFIL(10,11,3)
C
C**** TIME
C
      COMMON/ECOTIM/DELT,DELT2,DELT6,ND,NQ,NDAY1,NDAY2,NPERDY,NDAY,
     1IWTAPE,NPENT,NPHOUR,NDHIST,KDAY,METHOD,IPUDA,IPUHR,IOTAPE,ITSCH
C
C**** INPUT WATER QUALITIES
C
      COMMON/ECOIN/TITL(20),TEMPIN(50),TSSIN(50),COLIN(50),BODIN(50),
     1O2IN(50),TICIN(50),PO4IN(50),ALKAIN(50),WNH3IN(50),WNO2IN(50),
     2WNO3IN(50),TDSIN(50),TBTYIN(50),HARDIN(50),CHRMIN(50),ZINCIN(50),
     3COPRIN(50),VNDMIN(50),CDMIN(50),ARSNIN(50),ORGNIN(50),TKNIN(50)
C
C**** COEFFICIENTS
C
```

```
      COMMON/COEF/WBODK,WCOLIK,WNH3K,WNO2K,Q10,O2NH3,O2NO2,CO2BOD,
     1VC1,VC2,VC3,WONK,WPO4K
C
C**** SOLAR ENERGY AND HEAT EXCHANGE
C
      COMMON/SOLAR/ NWZONE,JWZONE(5,2),RAD(100),HEAT(100),EVAPA,
     1EVAPB,ST(24,5),QN(24,5),QNS(24,5),AP(24,5),DBT(24,5),EA(24,5),
     2WS(24,5),QAT(24,5)
C
C**** HYDRAULIC PARAMETERS
C
      COMMON/HYD/Q(50),QIN(50),QOUT(50),VOLM(50),VEL(50),DEPTH(50),
     1WIDTH(50),SAREA(50),LINK(50,3),H1(50),H2(50),V1(50),V2(50),W1(50),
     2W2(50),NQIN(50),XLNGTH(50),NSEG,NREACH,NBRNCH(50),QNC(50),
     3VOLM2(50)
C
C****  REAERATION,QUALITY INDEX,OTHER
C
      COMMON/OTHER/REAC2(50),NHYDRO,IHYDRO,RSCOUR(50),SCOUR(50),
     2TAVG(50),TAVS(50)
C
C**** INDEXING VARIABLES
C
      DIMENSION MONTH(10)
C
      DIMENSION   YY(50,24),YYP(50,22),YYT(50,22),YYIN(50,22)
C
C**** EQUIVALENCE
C
      EQUIVALENCE (YY(1,1),WTEMP(1)),(YYP(1,1),WTEMDT(1)),
     1(YYT(1,1),WTEMPT(1)),(YYIN(1,1),TEMPIN(1))
C
      DATA TEMPO/293.15/,RK1/4.45E-07/,RK2/4.7E-11/
C
      RDELT(X,Y)=(EXP(X*Y)-1.)/DELT
C
C**** READ GENERAL CONTROL CARDS
C
      READ(5,60) NUMBER,(MONTH(I),I=1,5)
   60 FORMAT(I3,5A4)
      READ(5,260)(TITL(I),I=1,20)
  260 FORMAT(10A4)
      READ(5,230) NDAY1,NDAY2,NPRNT,NPHOUR,IHYDRO,IWTAPE,METHOD,NDAY,
     1NPERDY,IPUDA,IPUHR,ICTAPE,ITSCH
  230 FORMAT(16I5 )
      DO 2 I=1,4
      READ(5,210) JINDEX(I),(JSTATN(I,J),J=1,3)
```

```
      IF(JINDEX(I).EQ.0)GO TO 4
      JHISTO=I
    2 CONTINUE
    4 DO 6 N=1,10
      READ(5,210) NINDEX(N),(NSTATN(N,J),J=1,9)
      IF(NINDEX(N).EQ.0)GO TO 8
      NPROFL=N
    6 CONTINUE
    8 CONTINUE
  210 FORMAT(16I5)
C
C**** INITIALIZATIONS
C**** INITIALIZE DAILY CYCLE LOOP AND DIURNAL TIME STEP PARAMETERS
C
      DELT=86400./FLOAT(NPERDY)
      DELT2=DELT/2.0
      DELT6=DELT/6.0
C
C**** WRITE GENERAL CONTROL INFORMATION
C
      WRITE(6,301) (TITL(I),I=1,20)
  301 FORMAT(2X,10A4,50X,'WATER QUALITY STUDY'/
     12X,10A4,50X,'PHOSPHATE MINING IMPACTS'//)
      WRITE(6,315) NDAY1,NDAY2,NPERDY,        IWTAPE,NPRNT,NPHOUR,
     1IHYDRO
  315 FORMAT(1H0,T15,'BEGINNING FROM DAY',I10/
     1        1H0,T15,'ENDING ON DAY',I10/
     2        1H0,T15,'COMPUTATIONS PER DAY',I10/
     31H0,T15,'METHOD OF INTEGRATION-MULTIPLE X-STEP, SINGLE TIME STEP'/
     4        1H0,T15,'WEATHER TAPE NO.',I10/
     5        1H0,T15,'DAYS OF SIMULATION BEFORE PRINTOUT BEGINS',I10/
     6        1H0,T15,'PRINT FREQUENCY,HOUR INTERVAL',I10/
     7        1H0,T15,'HYDROLOGIC CYCLE',I10,' DAYS'/)
      WRITE(6,22)
   22 FORMAT('1',8(/))
      WRITE(6,340) NUMBER,(MONTH(I),I=1,5)
  340 FORMAT(T30,'TABLE',I3,'- WATER QUALITY PLOTS FOR STUDY BASIN - ',
     15A4////)
      WRITE(6,341)
  341 FORMAT(T20,'A- TIME HISTORY PLOTS'//)
      WRITE(6,342)
  342 FORMAT(T25,'PLOT',12X,'PARAMETER',16X,'NODES'/)
      DO 3 I=1,JHISTO
      J=JINDEX(I)
      WRITE(6,343) I,J,PNAME(J),(JSTATN(I,K),K=1,3)
  343 FORMAT(23X,I4,12X,I4,3X,A4,8X,11I5/)
    3 CONTINUE
```

```
      WRITE(6,345)
  345 FORMAT(//T20,'B- CONCENTRATION PROFILES'//)
      WRITE(6,346)
  346 FORMAT(T25,'PLOT',12X,'PARAMETER',30X,'NODES'/)
      DO 7 I=1,NPROFL
      J=NINDEX(I)
      WRITE(6,343) I,J,PNAME(J),(NSTATN(I,K),K=1,9)
    7 CONTINUE
C
C
C
      CALL WEATHR(NPERDY,IWTAPE)
C
C
C**** CONNECTIVITY AND SYSTEM GEOMETRY
C
      READ(5,250) NSEG,NREACH
  250 FORMAT(2I5)
      DO 40 I=1,NSEG
      READ(5,240) N1,N2,N3,N4,XLNGTH(N1),RSCOUR(N1)
      LINK(N1,1)=N2
      LINK(N1,2)=N3
      LINK(N1,3)=N4
      XLNGTH(N1)=XLNGTH(N1)*5280.
C     N2 AND N3 REPRESENT UPSTREAM SEGMENTS-
C     N4 REPRESENTS DOWNSTREAM SEGMENT
   40 CONTINUE
  240 FORMAT(4I5,2F5.0)
      DO 42 I=1,NREACH
      READ(5,241) ISEG1,ISEG2,HH1,HH2,VV1,VV2,WW1,WW2
      DO 43 J=ISEG1,ISEG2
      H1(J)=HH1
      H2(J)=HH2
      V1(J)=VV1
      V2(J)=VV2
      W1(J)=WW1
      W2(J)=WW2
   43 CONTINUE
   42 CONTINUE
  241 FORMAT(2I5,6F5.0)
C
C
C**** READ COEFFICIENTS
C
C     DECAY AND TEMPERATURE COEFFICIENTS
C
   80 READ(5,200)WBODK,DETSK,WCOLIK,WONK,WNH3K,WNO2K,WPO4K,
```

```
     1Q10,VC1,VC2,VC3,OSMLT
      IF(VC1.EQ.0.0) VC1=3.33
      IF(VC2.EQ.0.0) VC2=1.33
      IF(VC3.EQ.0.0) VC3=1.0
      IF(OSMLT.EQ.0.0)OSMLT=0.909
  200 FORMAT(16F5.0)
      WRITE(6,100)
  100 FORMAT(1H1,T5,'SYSTEM COEFFICIENTS')
      WRITE(6,110) WBODK,WCOLIK,WONK,WNH3K,WNO2K,WPO4K,
     1Q10,VC1,VC2,VC3,OSMLT
  110 FORMAT(//,T11,'DECAY TEMPERATURE AND REAERATION COEFF.'//
     1T15,'BOD, PER DAY',T40,F10.3,/
     2T15,'COLIFORM, PER DAY',T40,F10.3/T15,'ORGANIC NITROGEN, PER DAY',
     2T40,F10.3/T15,'NH3-N, PER DAY',T40,F10.3/
     3T15,'NO2-N, PER DAY',T40,F10.3/T15,'PO4 DEPOSITION, PER DAY',T40,F
     310.3/T15,'TEMP COEF, Q10',T40,F10.3/
     4T15,'REAERATION COEFF - VC1',T40,F10.3/
     5T15,'REAERATION COEFF - VC2',T40,F10.3/
     6T15,'REAERATION COEFF - VC3',T40,F10.3/
     7T15,'OXYGEN SAT. COEFF',T40,F10.3)
C
C     STOICHIOMETRIC EQUIVALENCE OF CHEMICAL TRANSFORMATIONS
C
      READ(5,200)        O2NH3,O2NO2,CO2BOD
      WRITE(6,320)        O2NH3,O2NO2,CO2BOD
  320 FORMAT(//T11,'STOICHIOMETRIC EQUIVALENCE OF CHEMICAL TRANSFORMATIO
     1N'//                          T15,'OXYGEN/NH3',T60,F10.3/
     2T15,'OXYGEN/NO2',T60,F10.3/T15,'CO2/BOD',T60,F10.3)
C
C**** READ INITIAL WATER QUALITY CONDITIONS IN THE ECOSYSTEM BY ZONE
C
      DO 10 I=1,NSEG
      READ(5,220) J1,J2,TEM,TSS,COLIF,BOD,O2,PO4,ALKA,XPH,XNH3,
     1XNO2,XNO3,TDS,TBTY,HARD,CHRM,ZINC,COPR,VNOM,CDM,ARSC,
     2TOTP,TOTKN
  220 FORMAT(2I5,12F5.0/(10F5.0))
      IF(J1.EQ.0) GO TO 500
C
C**** CALCULATE TOTAL INORGANIC CARBON, AND CO2
C
      TEMP=TEM+273.15
      IF(ABS(TEMP-TEMPO).LE.1.0) GO TO 16
      Z=-3404.71/TEMP+14.8435-0.032786*TEMP
      RK1=10.**Z
      Z=-2902.39/TEMP+6.498-0.02379*TEMP
      RK2=10.**Z
   16 H=10.**(-XPH)
```

```
      ALPHA=(1.+2.*RK2/H)/(H/RK1+1.+RK2/H)
      ALPHA1=1./(1.+RK1/H+RK1*RK2/(H*H))
      ALK=ALKA/50000.
      TIC=ALK/ALPHA*12000.
      CO2=ALPHA1*TIC
      DO 11 J=J1,J2
      WTEMP(J)=TEM
      WTSS(J)=TSS
      WCOLIF(J)=COLIF
      WBOD(J)=BOD
      WO2(J)=O2
      WTIC(J)=TIC
      WCO2(J)=CO2
      WPO4(J)=PO4
      WALKA(J)=ALKA
      WNH3(J)=XNH3
      WNO2(J)=XNO2
      WNO3(J)=XNO3
      WPH(J)=XPH
      WTDS(J)=TDS
      WTBTY(J)=TBTY
      WHARD(J)=HARD
      WCHRM(J)=CHRM
      WZINC(J)=ZINC
      WCOPR(J)=COPR
      WVNDM(J)=VNDM
      WCDM(J)=CDM
      WARSC(J)=ARSC
      WTOTKN(J)=TOTKN
      WORGN(J)=WTOTKN(J)-WNH3(J)
   11 CONTINUE
   10 CONTINUE
  500 CONTINUE
C
C**** UNIT CONVERSION
C
      Y=DELT/86400.
      WBODK=-RDELT(-WBODK,Y)
      WCOLIK=-RDELT(-WCOLIK,Y)
      WONK=-RDELT(-WONK,Y)
      WNH3K=-RDELT(-WNH3K,Y)
      WNO2K=-RDELT(-WNO2K,Y)
      WPO4K=WPO4K/86400
C
C**** WRITE INITIAL CONDITIONS
C
      WRITE(6,23)
```

```
 23   FORMAT('1')
      READ(5,60) NUMBER,(MONTH(I),I=1,5)
      WRITE(6,422) NUMBER,(MONTH(I),I=1,5)
 422  FORMAT(T21,'TABLE',I3,'- INITIAL WATER QUALITY CONDITIONS FOR STUD
     1Y BASIN - ',5A4////
     1' NODE TEMP  TSS COLIF  BOD  DO  ALKA PH  CO2  PO4P NH3N NO3N  TDS
     2 TBTY  HARD CHRM  ZINC COPR VNDM CDM  APSC ORGN'//
     3'       C    MG/L MPN/00 MG/L MG/L MG/L     MG/L MG/L MG/L MG/L MG/L
     4 FTU   MG/L MG/L  MG/L MG/L MG/L MG/L MG/L MG/L'//)
      DO 90 N=1,NSEG
      WRITE(6,430) N,WTEMP(N),WTSS(N),WCOLIF(N),WBOD(N),WO2(N),WALKA(N),
     1WPH(N),WCO2(N),WPO4(N),WNH3(N),WNO3(N),WTDS(N),WTBTY(N),WHARD(N),
     2WCHRM(N),WZINC(N),WCOPR(N),WVNDM(N),WCDM(N),WAPSC(N),WORGN(N)
 430  FORMAT(I4,F6.1,F5.0,1X,F4.0,1X,F5.1,1X,F4.1,F5.0,F4.1,1X,F4.2,1X,
     1 F4.2,2F5.2,F5.0,F5.1,F6.0,1X,F4.3,2X,F4.3,4(1X,F4.3),F5.2/)
  90  CONTINUE
      RETURN
      END
C
C
      SUBROUTINE WEATHR (NPERDY,IWTAPE)
C
      COMMON INDEX(7),ALPHA(20),IDAY(10),DATA(50,6,2)
      COMMON/SAVE/ NSEAS, NOBS, ITAPE, LAT, LONG, IPRT,NINT
      DIMENSION JWZONE(5,2)
      DIMENSION MONTH(10)
      DOUBLE PRECISION  JB(8)
      DATA JB/'1-3','4-6','7-9','10-12','13-15','16-18','19-21','22-24'/
      REAL LAT, LONG
C  ** INITIALIZE NECESSARY VARIABLES
      ITAPE=IWTAPE
      NOBS=NPERDY
      DO 7 J = 1, 5
      INDEX(J) = 1
    7 CONTINUE
      INDEX(7) = 0
C  ** READ AND WRITE RUN DATA
      READ(5,400) NUMBER,(MONTH(I),I=1,5)
 400  FORMAT(I3,5A4)
      READ(5,501) ALPHA
      READ(5,509) EVAPA,EVAPB
 509  FORMAT(2F10.0)
      READ(5,503) NZONE,NSEAS,NDAYS,IPRT,NSET,INDEX(6)
C
      IF( ITAPE .GT. 0 ) REWIND ITAPE
      DO 200 L = 1, NZONE
 131  WRITE(6,601) ALPHA
```

```
      WRITE(6,603) NZONE,NSEAS,NDAYS,NOBS,ITAPE,IPRT
  135 READ(5,505) NZ,(JWZONE(NZ,JJ),JJ=1,2),LAT,LONG
  136 WRITE(6,606) NZ,(JWZONE(NZ,JJ),JJ=1,2),LAT,LONG
  137 M = 0
      NK=NOBS/NSET
      WRITE(6,2)
    2 FORMAT('1',8(/))
      WRITE(6,604) NUMBER,(MONTH(I),I=1,5)
  604 FORMAT(T20,'TABLE',I3,'- WEATHER DATA FOR STUDY BASIN - ',5A4////)
      WRITE(6,605)
      DO 150 J = 1, NSEAS
      DO 140 K=1,NSET
      READ(5,507) IDAY(J),CC,AP,DB,DP,WS
      AP=AP*33.864
      WS=0.4470*WS
      DB=(DB-32.)*5./9.
      DP=(DP-32.)*5./9.
  138 WRITE(6,607) JB(K),IDAY(J),AP,CC,WS,DB,DP
  139 DO 140 LL=1,NK
      M = M + 1
      DATA(M,1,1) = AP
      DATA(M,2,1) = CC
      DATA(M,3,1) = WS
      DATA(M,4,1) = DB
      DATA(M,5,1) = WB
      DATA(M,6,1) = DP
  140 CONTINUE
  150 CONTINUE
      NINT = NOBS * NSEAS
      CALL HEAT
  200 CONTINUE
C ** END OF RAW DATA INPUT
      IF( ITAPE .LE. 0 ) RETURN
C  **  REFORMAT DATA FOR INPUT TO MAIN PROGRAM
      REWIND ITAPE
      DO 210 L = 1, NZONE
      READ(ITAPE)( ( DATA(J,K,L), K = 1, 6 ), J = 1, M )
  210 CONTINUE
      REWIND ITAPE
      WRITE(ITAPE) NSEAS,NZONE,JWZONE,NDAYS
     * ,EVAPA,EVAPB
      DO 220 N = 1, NINT, NOBS
      MAX = N + NOBS - 1
      WRITE(ITAPE) ((( DATA(J,K,L), K = 1, 6 ), J=N,MAX),L = 1, NZONE )
  220 CONTINUE
      REWIND ITAPE
C ** INPUT FORMAT STATEMENTS
```

```
501 FORMAT( 20A4 )
503 FORMAT( 16I5 )
505 FORMAT(3I5,13F5.0)
507 FORMAT( I5, 15F5.0 )
C ** OUTPUT FORMAT STATEMENTS
601 FORMAT(1H1,40X,'    ENERGY INPUT ANALYSIS'//35X,20A4)
603 FORMAT( /// T11, 'NUMBER OF ZONES',T35, I5 /
    1  T11, 'NUMBER OF PERIODS',T35, I5 /
    2 T11,'NO DAYS PER PERIOD',T35,I5/
    3  T11, 'COMPUTATIONS PER DAY',T35, I5 /
    4  T11, 'OUTPUT TAPE UNIT',T35, I5 /
    5  T11, 'PRINTING OPTION',T35, I5 )
606 FORMAT( /// T11, 'INPUT ZONE',T30, I5 /  T11,'SEGMENTS',T30,2I5/
    1  T11, 'LATITUDE',T30,F5.1 / T11, 'LONGITUDE',T30,F5.1)
605 FORMAT(
    2T11,'  PERIOD      DAY OF    ATMOSPHERE    CLOUD        WIND     DRY BULB
    3      DEW POINT'/
    4T11,'               YEAR      PRESSURE     COVER        SPEED  TEMPERATU
    5RE TEMPERATURE'//
    6T36,'MB        TENTHS      M/SEC        C              C'//)
607 FORMAT(12X,A6,I8,5F11.1/)
    RETURN
    END
C
C
    SUBROUTINE HEAT
C
    COMMON INDEX(7),ALPHA(20),IDAY(10),AP(50),CLD(50),WS(50),DBT(50),
   1WBT(50),DPT(50),EA(50),QS(50),QNS(50),QAT(50),WC(50),KL(50)
    COMMON/SAVE/ NSEAS, NOBS, ITAPE, LAT, LONG, IPRT
    REAL LAT, LONG
    REAL ALPH(6), BETA(6), ATWO(4), BTWO(4), DUST(4,2)
    DATA ALPH / 5.70,4.00,0.757,-5.41,-15.29,-30.43/,
   A  BETA/ 0.620,0.842,1.107,1.459,1.898,2.449/,
   B  ATWO/ 1.18,2.20,0.95,0.35 / ,
   C  BTWO /-0.77,-0.97,-0.75,-0.45/,
   D  DUST /0.06,0.06,0.05,0.07,0.08,0.10,0.07,0.08 /
    VPS(THA)=EXP(2.3026*(7.5*THA/(THA+237.3)+.7858))
    NINT=NOBS*NSEAS
117 DO 119 J = 1, NINT
    EA(J) = VPS( DPT(J) )
    WC(J)=.85*EXP(.110+.0614*DPT(J))
119 CONTINUE
121 NHRS = 24 / NOBS
    HRS = FLOAT( NHRS )
    SRO = 0.0
    SSO = 0.0
```

```
      CONE = 3.14159 * LAT / 180.0
      TC = FLOAT( ( IFIX(LONG) / 15 ) * 15 )
      TC = ( LONG - TC ) / 15.0
C  ** ENTER MAIN CALCULATION LOOP
      LL = 0
  125 DO 135 JK = 1, NSEAS
      L = IDAY(JK)
      LL = LL + 1
      KK = L / 92 + 1
C  ** SET UP DAILY VALUES
      R = 1.0 + 0.017 * COS( 1.72E-2 * FLOAT( 181 - L ) )
      DEL = 0.409 * COS( 1.72E-2 * FLOAT( 172 - L ) )
      CTWO = SIN(CONE) * SIN(DEL)
      CTRI = COS(CONE) * COS(DEL)
      HSR = - 3.82 *ARCOS( ( SIN(SRO) - CTWO ) / CTRI ) + TC
      HSS = 3.82 *ARCOS( ( SIN(SSO) - CTWO ) / CTRI ) + TC
      TIME = -12.0
      QONE = 0.0
      RONE = 0.0
      NN = NOBS * ( LL - 1 )
C  ** ENTER INTERVAL LOOP
      DO 133 K = 1, NOBS
      SUMQ = 0.0
      RSUM = 0.0
      N = NN + K
      M = 1
      IF( CLD(N) .LT. 0.1 ) GO TO 127
      M = 2 + INT( ( CLD(N) - 0.101 ) / 0.40 )
  127 CS = 1.0 - 0.65*CLD(N) ** 2
C  ** ENTER HOUR LOOP
      DO 131 J = 1, NHRS
      TIME = TIME + 1.0
      IF( TIME .LE. HSR .OR. TIME .GE. HSS )   GO TO 131
      AL =ARSIN( SIN(CONE) * SIN(DEL) + COS(CONE) * COS(DEL) *
     A  COS( 0.262 * TIME ) )
      IF( AL .LE. 0.0 .OR. AL .GE. 1.57 ) GO TO 131
      TEMP = AP(N) / 1013.0
      CM =  TEMP / ( SIN(AL) +  0.15 * ( 57.3 * AL + 3.885 ) **
     A  ( -1.253 ) )
      TEMP = 0.17 * EXP( -0.88 * CM ) + 0.129
      AI = EXP( - ( 0.465 + 0.134 * WC(N) ) * TEMP * CM )
      TEMP = 0.421 * EXP( -0.721 * CM ) + 0.179
      AII = EXP( - ( 0.465 + 0.134 * WC(N) ) * TEMP * CM )
      QO=.3233*SIN(AL)/R**2
      FSC = ATWO(1) * ( 57.3 * AL ) ** BTWO(1)
      RFC = ATWO(M) * ( 57.3 * AL ) ** BTWO(M)
      IF( RFC .GT. 1.0 ) RFC = 1.00
```

```
      MM = 1
      IF( CM .GT. 1.5 ) MM = 2
      TEMP = AII + 0.5 * ( 1.0 -AI - DUST(KK,MM) )
      TEMP = TEMP / ( 1.0 - 0.5 * RSD * ( 1.0 - AI + DUST(KK,MM) ))
      QTWO = QO * TEMP * CS
      SUMQ = SUMQ + 0.5 * ( QONE + QTWO )
      RTWO = QTWO * ( 1.0 - REF )
      RSUM = RSUM + 0.5*( RONE + RTWO )
      QONE = QTWO
      RONE = RTWO
  131 CONTINUE
      RTEMP = 0.0
      IF( SUMQ .GT. 0.0 ) RTEMP = RSUM / SUMQ
      IF( INDEX(7) .LE. 0 ) QS(N) = SUMQ / HRS
      QNS(N) = RTEMP * QS(N)
  133 CONTINUE
  135 CONTINUE
C ** NET ATMOSPHERIC
      DO 149 J = 1, N
      QAT(J)=1.236E-16*(1.0+.17*CLD(J)**2)
     A  * ( DBT(J) + 273.0 ) ** 6
  149 CONTINUE
C ** WRITE OUTPUTS
  175 IF( ITAPE .LE. 0 )  RETURN
      WRITE(ITAPE) ( QNS(J), QAT(J), AP(J), DBT(J), EA(J), WS(J), J=1,N)
      RETURN
      END
C
C
      SUBROUTINE FLOW
C
C*******  FLOW ROUTINE PERFORMS HYDRODYNAMIC COMPUTATIONS
C
C**** HYDRAULIC PARAMETERS
C
      COMMON/HYD/Q(50),QIN(50),QOUT(50),VOLM(50),VEL(50),DEPTH(50),
     1WIDTH(50),SAREA(50),LINK(50,3),H1(50),H2(50),V1(50),V2(50),W1(50),
     2W2(50),NQIN(50),XLNGTH(50),NSEG,NREACH,NBRNCH(50),QNO(50),
     3VOLM2(50)
C
C**** INPUT WATER QUALITIES
C
      COMMON/ECOIN/TITL(20),TEMPIN(50),TSSIN(50),COLIN(50),BODIN(50),
     1O2IN(50),TICIN(50),PO4IN(50),ALKAIN(50),WNH3IN(50),WNO2IN(50),
     2WNO3IN(50),TDSIN(50),TBTYIN(50),HARDIN(50),CHRMIN(50),ZINCIN(50),
     3COPRIN(50),VNDMIN(50),CDMIN(50),APSNIN(50),ORGNIN(50),TKNIN(50)
C
```

```
      COMMON/COEF/WBODK,WCOLIK,WNH3K,WNO2K,Q10,O2NH3,O2NO2,CO2BOD,
     1VC1,VC2,VC3,WONK,WPO4K
C
C**** REAERATION,QUALITY INDEX,OTHER
C
      COMMON/OTHER/REAC2(50),NHYDRO,IHYDRO,RSCOUR(50),SCOUR(50),
     2TAVG(50),TAVS(50)
C
C****INPUT WATER QUALITIES
C
      COMMON/INQUAL/TEM,TSS,COLIF,BOD,O2,TIC,PO4,ALKA,XNH3,XNO2,XNO3,
     1TDS,TRTY,HARD,CHRM,ZINC,COPR,VNDM,CDM,ARSC,ORGN
C
      COMMON/ECOTIM/DELT,DELT2,DELT6,NO,NQ,NDAY1,NDAY2,NPERDY,NDAY,
     1IWTAPE,NPENT,NPHOUR,NDHIST,KDAY,METHOD
      COMMON/TSTEP/STEP
C
      DIMENSION XIN(22),YYIN(50,22),RETIME(50)
      DIMENSION MONTH(10)
      EQUIVALENCE (XIN(1),TEM),(YYIN(1,1),TEMPIN(1))
C
      DO 40 I=1,NSEG
      QOUT(I)=0.
      NBRNCH(I)=0
      NQIN(I)=0
      QIN(I)=0.
      QNO(I)=0
 40   CONTINUE
C
C****READ OUTFLOWS BY SEGMENT
C
      WRITE(6,2)
    2 FORMAT('1',8(/))
      READ(5,70) NUMB1,NUMB2,NUMB3,NUMB4,(MONTH(I),I=1,5)
   70 FORMAT(4I3,5A4)
      WRITE(6,228) NUMB1,(MONTH(I),I=1,5)
  228 FORMAT(T20,'TABLE',I3,'- OUTFLOW DATA OF UPPER BLACKFOOT RIVER'/
     1T23,'          BASIN - ',5A4////
     2T20,'FROM      TO     OUTFLOW              NAME'//T37,'CFS'//)
      ISEG=0
      DO 45 I=1,200
      READ(5,230) NTO,NO,QO,N1,N2,N3,N4,N5,N6
  230 FORMAT(2I5,F5.1,2X,6A4)
      IF(NTO.EQ.0) GO TO 47
      WRITE(6,232) NTO,NO,QO,N1,N2,N3,N4,N5,N6
  232 FORMAT(20X,I2,6X,I2,6X,F4.1,4X,6A4/)
      IF(NO.GT.0) QNO(NO)=QO
```

```
      IF(NTO.EQ.ISEG) GO TO 46
      ISEG=NTO
 46   QOUT(ISEG)=QOUT(ISEG)+QO
      NBRNCH(ISEG)=NO
 45   CONTINUE
 47   CONTINUE
C
C****READ INFLOWS AND THEIR WATER QUALITIES BY SEGMENT
C
      WRITE(6,23)
  23  FORMAT('1')
      WRITE(6,450) NUMB2,(MONTH(I),I=1,5)
 450  FORMAT(T24,'TABLE',I3,'- INFLOW QUALITY DATA OF UPPER BLACKFOOT',
     1' RIVER BASIN - ',5A4////
     1' SEG     NAME         INFLOW TEMP TSS   COLIF BOD  DO ALKA  PH  TIC PO
     24P NH3N NO3N  TDS TBTY HARD CHRM ZINC COPR VNDM  CDM ARSC ORGN'/
     4'                       CFS     C   MG/L MPN/00 MG/LMG/L MG/L     MG/L MG
     5/L MG/L MG/L MG/L  FTU MG/L MG/L MG/L MG/L MG/L MG/L MG/L MG/L'/)
      ISEG=0
      N=0
      DO 50 K=1,200
      READ(5,240) NTO,N1,N2,N3,Q1,TEM,TSS,COLIF,BOD,O2,PO4,ALKA,XPH,
     1XNH3,XNO2,XNO3,TDS,TBTY,HARD,CHRM,ZINC,COPP,VNDM,CDM,ARSC,TOTP,
     2TOTKN
 240  FORMAT(I5,3A4,3X,2F5.1,2F5.0,2F5.1,F5.2,F5.0,F5.1,2F5.2/F5.2,F5.0,
     1F5.1,F5.0,6F5.3,2F5.2)
      ORGN=TOTKN-XNH3
      IF(NTO.EQ.0) GO TO 54
C
C**** CALCULATE TOTAL INORGANIC CARBON
C
      TEMP=TEM+273.15
      IF(ABS(TEMP-TEMPO).LE.1.0) GO TO 56
      TEMPO=TEMP
      Z=-3404.71/TEMP+14.8435-0.032786*TEMP
      RK1=10.**Z
      Z=-2902.39/TEMP+6.498-0.02379*TEMP
      RK2=10.**Z
   56 H=10.**(-XPH)
      ALPHA=(1.+2.*RK2/H)/(H/RK1+1.+RK2/H)
      ALK=ALKA/50000.
      TIC=ALK/ALPHA*12000.
      WRITE(6,435) NTO,N1,N2,N3,Q1,TEM,TSS,COLIF,BOD,O2,ALKA,XPH,TIC,PO4
     1,XNH3,XNO3,TDS,TBTY,HARD,CHRM,ZINC,COPR,VNDM,CDM,ARSC,ORGN
 435  FORMAT(I4,1X,3A4,F6.1,F5.1,F6.0,F5.0,F5.1,F4.1,F5.0,F4.1,1X,F4.1,
     13F5.2,1X,F4.0,F5.1,1X,F4.0,6(1X,F4.3),F5.2)
      IF(NTO.EQ.ISEG) GO TO 42
```

```
      N=N+1
      ISEG=NTO
      NQIN(ISEG)=N
      DO 43 J=1,21
   43 YYIN(N,J)=0.
   42 QIN(ISEG)=QIN(ISEG)+Q1
      DO 44 J=1,21
   44 YYIN(N,J)=YYIN(N,J)+XIN(J)*Q1*DELT*STEP
   50 CONTINUE
   54 CONTINUE
C
C
C**** EVALUATE HYDRAULIC PARAMETERS
C
      WRITE(6,2)
      WRITE(6,999) NUMB3,(MONTH(I),I=1,5)
  999 FORMAT(T15,'TABLE',I3,'- FLOW CALCULATIONS FOR UPPER BLACKFOOT RIV
     1ER BASIN - ',5A4////
     1                    T12,'SEG   UPPER   UPPER   SEG-A    INFLOW   OUTFLO
     2W   FLOW FROM  FLOW FROM  TOT INFLOW     FLOW'/
     3T17,'SEG-1  SEG-2  REC.FLOW  SEG-A                 SEG-1       SEG-2
     4  INTO SEG    THROUGH'//
     5T42,'CFS     CFS         CFS          CFS          CFS         CFS'//)
      DO 55 I=1,NSEG
      NUP1=LINK(I,1)
      NUP2=LINK(I,2)
      NO=NBRNCH(I)
      IF(NO.GT.0) QIN(NO)=QIN(NO)+QNO(NO)
      QUP1=0.
      QUP2=0.
      IF(NUP1.EQ.0) QUP1=0.
      IF(NUP2.EQ.0) QUP2=0.
      IF(NUP1.GT.0) QUP1=Q(NUP1)
      IF(NUP2.GT.0) QUP2=Q(NUP2)
      IF(NO.EQ.0) QN=0.
      IF(NO.GT.0) QN=QNO(NO)
      Q(I)=QUP1+QUP2+QIN(I)-QOUT(I)
      WRITE(6,9999) I,NUP1,NUP2,NO,QN ,QOUT(I),QUP1,QUP2,QIN(I),Q(I)
 9999 FORMAT(11X,I3,I5,5X,I2,6X,I2,5X,F5.1,3X,F5.1,6X,F6.1,4X,F6.1,6X,
     1F6.1,5X,F6.1)
      DEPTH(I)=H1(I)*Q(I)**H2(I)
      WIDTH(I)=W1(I)*Q(I)**W2(I)
      IF(DEPTH(I).GT.0.8) GO TO 85
      DO=DEPTH(I)
      DEPTH(I)=0.8
      WIDTH(I)=DO*WIDTH(I)
   85 VOLM(I)=WIDTH(I)*DEPTH(I)*XLNGTH(I)
```

```
      VEL(I)=V1(I)*Q(I)**V2(I)
      SAREA(I)=WIDTH(I)*XLNGTH(I)
      REAO2(I)=(VC1*(VEL(I)**VC3))/DEPTH(I)**VC2
      RETIME(I)=VOLM(I)/(Q(I)*3600)
 55   CONTINUE
C
C****WRITE THE HYDRAULIC CONDITIONS
C
      WRITE(6,23)
      WRITE(6,62) NUMP4,(MONTH(I),I=1,5)
   62 FORMAT(T18,'TABLE',I3,'- HYDRAULIC CONDITIONS OF UPPER BLACKFOOT R
     1IVER BASIN - ',5A4////
     1                                   T11,'SEG    INFLOW   OUTFLOW  FLOW    VELOCITY
     2  LENGTH  DEPTH WIDTH  SAREA      VOLUME        REAO2 RETENTION'/
     3T32,'THROUGH',64X,'TIME'//
     4T19,'CFS      CFS      CFS       FPS        FT      FT      FT     SQ FT
     5    CU FT      1/DAY      HRS'//)
      DO 65 I=1,NSEG
      WRITE(6,63) I,QIN(I),QOUT(I),Q(I),VEL(I),XLNGTH(I),DEPTH(I),
     1WIDTH(I),SAREA(I),VOLM(I),REAO2(I),RETIME(I)
   63 FORMAT(10X,I3,F8.1,F9.1,F7.1,F9.2,1PE12.3,0PF5.1,F6.1,1PE11.3,
     1E10.3,0PF9.3,F7.2/)
      REAO2(I)=REAO2(I)/86400.
      VOLM2(I)=VOLM(I)+(Q(I)+QOUT(I))*DELT*STEP
 65   CONTINUE
      QOUT(NSEG)=Q(NSEG)+QOUT(NSEG)
      RETURN
      END
C
C
      SUBROUTINE ECOSYS(NA)
C
C**********  ECOSYS SIMULATES THE DYNAMIC ECOLOGIC PROCESSES
C
C
C**** MULTIPLIERS
C
      COMMON /AMULTP/DSMLT
C
C**** ENVIRONMENTAL QUALITY PARAMETERS
C
      COMMON   WTEMP(50),WTSS(50),WCOLIF(50),WBOD(50),WO2(50),WTIC(50),
     1WPO4(50),WALKA(50),WNH3(50),WNO2(50),WNO3(50),WTDS(50),WTBTY(50),
     2WHARD(50),WCHRM(50),WZINC(50),WCOPR(50),WVNDM(50),WCOM(50),
     3WARSC(50),WORGN(50),WTOTKN(50),WPH(50),WCO2(50)
C
C**** CHANGING RATES OF ENVIRONMENTAL QUALITIES
```

```
C
      COMMON    WTEMDT(50),WTSSDT(50),WCOLDT(50),WBODDT(50),WO2DT(50),
     1WTICDT(50),WPO4DT(50),ALKADT(50),WNH3DT(50),WNO2DT(50),WNO3DT(50),
     2WTDSDT(50),WTBYDT(50),WHRDDT(50),WCRMDT(50),WZNCDT(50),WCPRDT(50),
     3WVDMDT(50),WCDMDT(50),WASCDT(50),WONDT(50),WTKNDT(50)
C
C**** ENVIRONMENTAL QUALITIES AT T + DELT
C
      COMMON    WTEMPT(50),WTSST(50),WCOLT(50),WBODT(50),WO2T(50),WTICT(5
     10),WPO4T(50),ALKAT(50),WNH3T(50),WNO2T(50),WNO3T(50),WTDST(50),
     2WTBYT(50),WHRDT(50),WCRMT(50),WZNCT(50),WCPRT(50),WVDMT(50),
     3WCDMT(50),WARST(50),WORGNT(50),WTKNT(50)
C
C**** ANSWERS STORAGE FOR PRINTING AND PLOTTING
C
      COMMON         PNAME(25),JHISTO,JINDEX(10),JSTATN(10,3),HOUR(51),
     1HISTOG(10,3,51),NPROFL,NINDEX(10),NSTATN(10,11),PHOUR(3),
     2PROFIL(10,11,3)
C
C**** TIME
C
      COMMON/ECOTIM/DELT,DELT2,DELT6,ND,NO,NDAY1,NDAY2,NPERDY,NDAY,
     1IWTAPE,NPRNT,NPHOUR,NDHIST,KDAY,METHOD,IPUDA,IPUHR,IOTAPE,ITSCH
C
C**** INPUT WATER QUALITIES
C
      COMMON/ECOIN/TITL(20),TEMPIN(50),TSSIN(50),COLIN(50),BODIN(50),
     1O2IN(50),TICIN(50),PO4IN(50),ALKAIN(50),WNH3IN(50),WNO2IN(50),
     2WNO3IN(50),TDSIN(50),TBTYIN(50),HARDIN(50),CHRMIN(50),ZINCIN(50),
     3COPRIN(50),VNDMIN(50),CDMIN(50),ARSNIN(50),ORGNIN(50),TKNIN(50)
C
C**** REAERATION,QUALITY INDEX,OTHER
C
      COMMON/OTHER/REAR2(50),NHYDRO,IHYDRO,RSCOUR(50),SCOUR(50),
     2TAVG(50),TAVS(50)
C
C**** COEFFICIENTS
C
      COMMON/COEF/WBODK,WCOLIK,WNH3K,WNO2K,Q10,O2NH3,O2NO2,CO2BOD,
     1VC1,VC2,VC3,WONK,WPO4K
C
C**** SOLAR ENERGY AND HEAT EXCHANGE
C
      COMMON/SOLAR/ NWZONE,JWZONE(5,2),RAD(100),HEAT(100),EVAPA,
     1EVAPB,ST(24,5),QN(24,5),QNS(24,5),AP(24,5),DBT(24,5),EA(24,5),
     2WS(24,5),CAT(24,5)
C
```

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C**** HYDRAULIC PARAMETERS
C
      COMMON/HYD/Q(50),QIN(50),QOUT(50),VOLM(50),VEL(50),DEPTH(50),
     1WIDTH(50),SAREA(50),LINK(50,3),H1(50),H2(50),V1(50),V2(50),W1(50),
     2W2(50),NQIN(50),XLNGTH(50),NSEG,NREACH,NBRNCH(50),QNO(50),
     3VOLM2(50)
      COMMON/SOLAR1/HEAT1(50,30)
C
      COMMON/TSTEP/STEP
C
C**** INDEXING VARIABLES
C
      DIMENSION   YY(50,24),YYP(50,22),YYT(50,22),YYIN(50,22)
      DIMENSION YYT1(50,22)
C
C**** EQUIVALENCE
C
      EQUIVALENCE (YY(1,1),WTEMP(1)),(YYP(1,1),WTEMPT(1)),
     1(YYT(1,1),WTEMPT(1)),(YYIN(1,1),TEMPIN(1))
C
      DATA NADVEC/21/,NP/21/
      NSTEP=IFIX(1./STEP)
C
      DO 50 JA=1,NSTEP
      DO  5 I=1,NSEG
      DO 10 J=1,NADVEC
   10 YYP(I,J)=0.
    5 CONTINUE
      DO 30 I=1,NSEG
      NUP1=LINK(I,1)
      NUP2=LINK(I,2)
      DO 25 K=1,NADVEC
C
C**** CHANGE DUE TO INPUT AND OUTPUT(QIN AND QOUT)
C
      N=NQIN(I)
      IF(N.LE.0) GO TO 24
      YYP(I,K)=YYP(I,K)+YYIN(N,K)
   24 IF(NUP1.EQ.0) GO TO 28
      YYP(I,K)=YYP(I,K)+YYT(NUP1,K)*Q(NUP1)*DELT*STEP
   28 IF(NUP2.EQ.0) GO TO 29
      YYP(I,K)=YYP(I,K)+YYT(NUP2,K)*Q(NUP2)*DELT*STEP
   29 YYT1(I,K)=(YYP(I,K)+YY(I,K)*VOLM(I))/VOLM2(I)
  26  NO=NBRNCH(I)
      IF(NO.LE.0) GO TO 27
      TRAN=-YYT(I,K)*QNO(NO)*DELT*STEP
      YYP(NO,K)=YYP(NO,K)-TRAN
```

```
   27 YYP(I,K)=0.
   25 CONTINUE
C
C**** DECAY, CHEMICAL SUCCESSIONS, AND ASSOCIATED C N O P BUDGET
C
      AVF=3.281E-3*SAREA(I)/VOLM(I)
      F10=Q10**(WTEMPT(I)-20.)
      WBODDT(I)=-WBODK*F10*WBODT(I)*DELT*STEP
      WCOLDT(I)=-WCOLIK*F10*WCOLT(I)*DELT*STEP
      WTICDT(I)=CO2BOD*WBODDT(I)*STEP
      WONDT(I)=-WONK*F10*WORGNT(I)*DELT*STEP
      WNH3DT(I)=-WNH3K*F10*WNH3T(I)*DELT*STEP-WONDT(I)
      WNO2DT(I)=-WNO2K*F10*WNO2T(I)*DELT*STEP-WNH3DT(I)
      WNO3DT(I)=WNO2K*F10*WNO2T(I)*DELT*STEP
      WO2DT(I)=WBODDT(I)+O2NH3*WNH3DT(I)-O2NO2*WNO2K*F10*WNO2T(I)*DELT*S
     1TEP
      WPO4DT(I)=-WPO4K*WPO4T(I)*DELT*STEP
C
C**** EXCHANGE AT THE AIR-WATER INTERFACE
C
      F=SAREA(I)/VOLM2(I)
      T=WTEMPT(I)
   36 DI=14.5532-0.38217*T+0.0054258*T*T
       DI=DI*OSMLT
      SATO2=DI
      SATCO2=0.9891-3.311E-2*T+4.354E-4*T*T
      WTEMDT(I)=3.28E-3*HEAT1(I,NA)*F*DELT*STEP
      WO2DT(I)=WO2DT(I)+(SATO2-WO2T(I))*REAO2(I)*F10*DELT*STEP
      WTICDT(I)=WTICDT(I)+(SATCO2-WCO2(I))*0.9*REAO2(I)*DELT*F10*STEP
C
C**** SETTLING VELOCITY OF TSS#2*10-5 FT/SEC
C
      S=2.E-5*F
      IF(S*DELT.GT.1.)S=1./DELT
      SCOUR(I)=0.
      S=S*WTSST(I)*DELT*STEP
      D=VEL(I)/8.
      IF(D.GT.1.0) D=1.0
      SCOUR(I)=D*RSCOUR(I)
      WTSSDT(I)=-S+SCOUR(I)*AVF*DELT*STEP
   30 CONTINUE
      DO 100 I=1,NSEG
      DO 100 K=1,NADVEC
      YYT(I,K)=YYT1(I,K)+YYP(I,K)
  100 CONTINUE
C
C**** UPDATE QUALITY AND ECOLOGIC VARIABLES
```

```
C
      DO 99 N=1,NSEG
      DO 95 L=1,NP
   95 YY(N,L)=YYT(N,L)
   99 CONTINUE
   50 CONTINUE
      CALL PH
      RETURN
      END
C
C
      SUBROUTINE PH
C
C**** ENVIRONMENTAL QUALITY PARAMETERS
C
      COMMON    WTEMP(50),WTSS(50),WCOLIF(50),WBOD(50),WO2(50),WTIC(50),
     1WPO4(50),WALKA(50),WNH3(50),WNO2(50),WNO3(50),WTDS(50),WTBTY(50),
     2WHARD(50),WCHRM(50),WZINC(50),WCOPR(50),WVNDM(50),WCDM(50),
     3WARSC(50),WORGN(50),WTOTKN(50),WPH(50),WCO2(50)
C
C**** CHANGING RATES OF ENVIRONMENTAL QUALITIES
C
      COMMON    WTEMDT(50),WTSSDT(50),WCOLDT(50),WBODDT(50),WO2DT(50),
     1WTICDT(50),WPO4DT(50),ALKADT(50),WNH3DT(50),WNO2DT(50),WNO3DT(50),
     2WTDSDT(50),WTBYDT(50),WHPDDT(50),WCRMDT(50),WZNCDT(50),WCPRDT(50),
     3WVDMDT(50),WCDMDT(50),WASCDT(50),WONDT(50),WTKNDT(50)
C
C**** ENVIRONMENTAL QUALITIES AT T + DELT
C
      COMMON    WTEMPT(50),WTSST(50),WCOLT(50),WBODT(50),WO2T(50),WTICT(5
     10),WPO4T(50),ALKAT(50),WNH3T(50),WNO2T(50),WNO3T(50),WTDST(50),
     2WTBYT(50),WHRDT(50),WCRMT(50),WZNCT(50),WCPRT(50),WVDMT(50),
     3WCDMT(50),WAPST(50),WORGNT(50),WTKNT(50)
C
C**** ANSWERS STORAGE FOR PRINTING AND PLOTTING
C
      COMMON         PNAME(25),JHISTO,JINDEX(10),JSTATN(10,3),HOUR(51),
     1HISTOG(10,3,51),NPROFL,NINDEX(10),NSTATN(10,11),PHOUR(3),
     2PROFIL(10,11,3)
C
C
C**** HYDRAULIC PARAMETERS
C
      COMMON /HYD/Q(50),QIN(50),QOUT(50),VOLM(50),VEL(50),DEPTH(50),
     1WIDTH(50),SAREA(50),LINK(50,3),H1(50),H2(50),V1(50),V2(50),W1(50),
     2W2(50),NQIN(50),XLNGTH(50),NSEG,NREACH,NBRNCH(50),QNP(50),
     3VOLM2(50)
```

```
C
      REAL*8 EXHCO3,EXCO3
      DATA TEMPO/0.0/
      DATA UO/100.0/
C
      DO 1000 N=1,NSEG
      U=2.5E-03
      ALK=ALKAT(N)/5.E+04
      XC=WTICT(N)/12000.
C
C***** TEMPERATURE ADJUSTMENT FOR THERMODYNAMIC CONSTANTS
C
      TEMP=WTEMPT(N)+273.15
      IF(ABS(TEMP-TEMPO).LE.1.0) GO TO 20
      Z=-5242.39/TEMP+35.3944-0.00835*TEMP-11.8261*ALOG10(TEMP)
      PKWO=10.**Z
      Z=-3404.71/TEMP+14.8435-0.032786*TEMP
      PK10=10.**Z
      Z=-2902.39/TEMP+6.498-0.02379*TEMP
      PK20=10.**Z
      TEMPO=TEMP
   20 CONTINUE
C
C**** CALCULATE THE UNEXTENDED DEBYE HUCKEL TERM
C
      IF(ABS(UO-U).LT.0.1) GO TO 22
      QQ=SQRT(U)
      A=-2.0304*QQ
      B=-0.5085*QQ
      DH14=B/(1.+1.3124*QQ)
      DH245=A/(1.+1.4765*QQ)
C
C**** CALCULATE THE EXTENDED DEBYE HUCKEL TERM
C
      EXHCO3=4.7456945D-03+4.1607623D-02*U-9.2848432D-03*U*U
      EXCO3=1.2056653D-02+9.715745D-02*U-2.0677462D-02*U*U
C
C**** LOG OF ACTIVITY COEFFICIENTS
C
      XGHCO3=DH14+EXHCO3
      XGCO3=DH245+EXCO3
      XH2CO3=0.0755*U
C
C**** ACTIVITY COEFFICIENTS
C
      GHCO3=10.**XGHCO3
      GCO3=10.**XGCO3
```

```
      GH2CO3=10.**XH2CO3
      GOH=GHCO3
      UO=U
   22 CONTINUE
C
C**** MODIFIED THERMODYNAMIC CONSTANTS
C
      RKW=RKWC/GOH
      RK1=RK1C*GH2CO3/GHCO3
      RK2=RK2C*GHCO3/GCO3
C
C**** PH EVALUATION
C
      XJ=-WPH(N)+2.1
      DO 101 L=1,150
      XJ=XJ-0.1
      H=10.**XJ
      BICARB=XC*H*RK1/(H*RK1+RK1*RK2+H*H)
      FF=BICARB*(H+2.*RK2)/H + RKW/H -ALK + H
      IF(FF)101,102,102
  101 CONTINUE
  102 XJ=XJ+0.1
    8 DO 303 L=1,110
      XJ=XJ-0.01
      H=10.**XJ
      BICARB=XC*H*RK1/(H*RK1+RK1*RK2+H*H)
      FF=BICARB*(H+2.*RK2)/H + RKW/H -ALK + H
      IF(FF) 303,305,305
  303 CONTINUE
  305 WPH(N)=-XJ+0.01
C
C**** EVALUATE CO2 CONCENTRATION
C
      ALPHA1=1./(1.+RK1/H+RK1*RK2/(H*H))
      WCO2(N)=ALPHA1*WTICT(N)
 1000 CONTINUE
C
      RETURN
      END
C
C
         SUBROUTINE PLOTER(IPOINT)
C
      COMMON    VTEMP(50),WTSS(50),WCOLIF(50),WBOD(50),WO2(50),WTIC(50),
     1WPO4(50),WALKA(50),WNH3(50),WNO2(50),WNO3(50),WTDS(50),WTRTY(50),
     2WHARD(50),WCHRM(50),WZINC(50),WCOPR(50),WVNDM(50),WCDM(50),
     3WARSC(50),WCRGN(50),WTOTKN(50),WPH(50),WCO2(50)
```

```
      COMMON     WTEMDT(50),WTSSDT(50),WCOLDT(50),WBODDT(50),WO2DT(50),
     1WTICDT(50),WPO4DT(50),WALKDT(50),WNH3DT(50),WNO2DT(50),WNO3DT(50),
     2WTDSDT(50),WTBYDT(50),WHRDDT(50),WCRMDT(50),WZNCDT(50),WCPRDT(50),
     3WVDMDT(50),WCDMDT(50),WASCDT(50),WONDT(50),WTKNDT(50)
      COMMON     WTEMPT(50),WTSST(50),WCOLT(50),WBODT(50),WO2T(50),WTICT(5
     10),WPO4T(50),WALKT(50),WNH3T(50),WNO2T(50),WNO3T(50),WTDST(50),
     2WTBYT(50),WHRDT(50),WCRMT(50),WZNCT(50),WCPRT(50),WVDMT(50),
     3WCDMT(50),WARST(50),WCRGNT(50),WTKNT(50)
      COMMON         PNAME(25),JHISTO,JINDEX(10),JSTATN(10,3),HOUR(51),
     1HISTOG(10,3,51),NPROFL,NINDEX(10),NSTATN(10,11),PHOUR(3),
     2PROFIL(10,11,3)
C
      DIMENSION  HIST(60),HR(60),NODE(15),PROF(15),ANODE(15)
      DIMENSION TITLE(20)
      DIMENSION TITLE1(20)
C
      READ(5,180) (TITLE1(I),I=1,10)
  180 FORMAT(10A4)
      CALL PLOTS(0,0,10)
      IF(JHISTO.EQ.0) GO TO 501
C
C     TIME HISTORY PLOTS
C
      CALL PLOT(6.,-15.,-3)
      CALL PLOT(0.,3.3,-3)
  500 DO 55 K=1,JHISTO
      DO 56 N=1,3
      DO 57 I=1,IPOINT
      HR(I)=HOUR(I)
      HIST(I)=HISTOG(K,N,I)
   57 CONTINUE
      IF((N.GT.1).OR.(K.GT.1)) GO TO 110
      HRIV=151.
      HRDV=.25
  110 IF(N.GT.1) GO TO 120
      GO TO (1,2,3,4),K
    1 HISTIV=2.0
      HISTDV=3.
      GO TO 120
    2 HISTIV=5.0
      HISTDV=1.2
      GO TO 120
    3 HISTIV=5.
      HISTDV=1.
      GO TO 120
    4 HISTIV=0.
      HISTDV=2.
```

```
  120 IF(N.GT.1) GO TO 160
 150  CALL AXIS(0.,0.,'DAYS',-4,8.,0.,HRIV,HRDV)
      CALL AXIS(0.,0.,'MG/L OR UNIT',+12,5.5,90.,HISTIV,HISTDV)
  160 IF(N.EQ.1) NO=11
      IF(N.EQ.2) NO=3
      IF(N.EQ.3) NO=2
      HR(IPOINT+1)=HRIV
      HR(IPOINT+2)=HRDV
      HIST(IPOINT+1)=HISTIV
      HIST(IPOINT+2)=HISTDV
      CALL FLINE(HR,HIST,-IPOINT,1,3,NO)
   56 CONTINUE
      READ(5,170) (TITLE(I),I=1,20)
  170 FORMAT(20A4)
      CALL  SYMBOL(0.5,-1.0,.1,TITLE,0.,80)
      CALL  SYMBOL(0.5,4.9,.1,TITLE1,0.,40)
      CALL  SYMBOL(-1.5,-2.0,.14,13,0.,-1)
      CALL  SYMBOL(9.5,-2.0,.14,13,0.,-1)
      CALL  SYMBOL(-1.5,6.5,.14,3,0.,-1)
      CALL  SYMBOL(9.5,6.5,.14,3,0.,-1)
      CALL  SYMBOL(4.5,4.9,.07,'          PLOT NODES        6 = *    ',0.,33)
      CALL  SYMBOL(999.,999.,.07,'13 = +   23 =   ',0.,14)
      CALL  SYMBOL(999.,999.,.07,2,0.,-1)
  130 CALL  PLOT(12.,0.,-3)
   55 CONTINUE
C
 501  IF(NPROFL.EQ.0) GO TO 1000
C     CONCENTRATION PROFILE PLOTS
C
      READ(5,180) (TITLE1(I),I=1,10)
      CALL  PLOT(12.,-15.,-3)
      CALL  PLOT(0.,3.3,-3)
      DO 203 K=1,NPROFL
      DO 202 N=1,3
      DO 201 I=1,9
      ANODE(I)=FLOAT(I)
      PROF(I)=PROFIL(K,I,N)
  201 CONTINUE
      IF((N.GT.1).OR.(K.GT.1)) GO TO 310
      ANODIV=1.
      ANODDV=1.
  310 IF(N.GT.1) GO TO 400
      GO TO (11,12,13,14,15,16,17,18,19,20),K
   11 PROFIV=2.
      PROFDV=3.
      GO TO 400
   12 PROFIV=0.
```

```
      PROFDV=40.
      GO TO 400
 13   PROFIV=5.
      PROFDV=1.3
      GO TO 400
 14   PROFIV=0.
      PROFDV=.07
      GO TO 400
 15   PROFIV=0.
      PROFDV=.07
      GO TO 400
 16   PROFIV=100.
      PROFDV=40.
      GO TO 400
 17   PROFIV=0.
      PROFDV=.007
      GO TO 400
 18   PROFIV=0.
      PROFDV=.004
      GO TO 400
19      PROFIV=5.
      PROFDV=1.
      GO TO 400
20    PROFIV=0.
      PROFDV=2.
400   IF(N.GT.1) GO TO 420
416   CALL AXIS(0.,0.,'NODE',-4,8.,0.,ANODIV,ANODDV)
      CALL AXIS(0.,0.,'MG/L OR UNIT',+12,5.5,90.,PROFIV,PROFDV)
420   IF(N.EQ.1) NO=11
      IF(N.EQ.2) NO=3
      IF(N.EQ.3) NO=2
      ANODE(10)=ANODIV
      ANODE(11)=ANODDV
      PROF(10)=PROFIV
      PROF(11)=PROFDV
      CALL FLINE(ANODE,PROF,-9,1,1,NO)
202   CONTINUE
      READ(5,170) (TITLE(I),I=1,20)
      CALL SYMBOL(0.3,-1.0,.1,TITLE,0.,80)
      CALL SYMBOL(0.5,4.9,.1,TITLE1,0.,40)
      CALL SYMBOL(-1.5,-2.0,.14,13,0.,-1)
      CALL SYMBOL(9.5,-2.0,.14,13,0.,-1)
      CALL SYMBOL(-1.5,6.5,.14,3,0.,-1)
      CALL SYMBOL(9.5,6.5,.14,3,0.,-1)
      CALL SYMBOL(4.5,4.9,.07,'          PLOT HOURS        8 = *   ',0.,33)
      CALL SYMBOL(999.,999.,.07,'16 = +  24 =   ',0.,14)
      CALL SYMBOL(999.,999.,.07,2,0.,-1)
```

```
      CALL SYMBOL(0.,-.5,.07,'1          4            6     ',0.,34)00001365
      CALL SYMBOL(999.,999.,.07,'       8            12       ',0.,31)00001366
      CALL SYMBOL(999.,999.,.07,'     13            16        ',0.,31)00001367
      CALL SYMBOL(999.,999.,.07,'  21              23',0.,20)         00001368
  410 CALL PLOT(12.,0.,-3)                                            00001369
  203 CONTINUE                                                        00001370
 1000 CONTINUE                                                        00001371
      CALL PLOT(6.,0.,999)                                            00001372
      RETURN                                                          00001373
      END                                                             00001374
```

APPENDIX B

Polynomial Equations Relating Weather Data of Diamond Creek Station and Pocatello

Polynomial Equations

X - Value for Pocatello

Y - Value for Diamond Creek Station

A. Wind Speed

i)	1- 3 hours	$Y = 5.4728 + .41542X - .02885X^2$
ii)	4- 6 hours	$Y = 5.0277 + .15101X - .00691X^2$
iii)	7- 9 hours	$Y = 3.5369 + .05513X + .01459X^2$
iv)	10-12 hours	$Y = 3.9322 + .22950X + .00795X^2$
v)	13-15 hours	$Y = 4.6230 + .33783X + .00568X^2$
vi)	16-18 hours	$Y = 4.9294 + .21915X + .00378X^2$
vii)	19-21 hours	$Y = 6.9687 + .35152X - .02831X^2$
viii)	22-24 hours	$Y = 6.7378 + .55399X - .04268X^2$

B. Dry Bulb Temperature

i)	1- 3 hours	$Y = -43.106 + 2.6810X - .02050X^2$
ii)	4- 6 hours	$Y = 12.151 + .25519X + .00588X^2$
iii)	7- 9 hours	$Y = 5.1350 + .38061X + .00460X^2$
iv)	10-12 hours	$Y = -101.39 + 3.9717X - .02397X^2$
v)	13-15 hours	$Y = 242.25 - 5.0580X + .03565X^2$
vi)	16-18 hours	$Y = 150.64 - 2.9408X + .02338X^2$
vii)	19-21 hours	$Y = -102.71 + 4.2262X - .02754X^2$
viii)	22-24 hours	$Y = -48.510 + 2.7605X - .02007X^2$

C. Dew Point Temperature

i)	1- 3 hours	$Y = -41.062 + 3.3545X - .03916X^2$
ii)	4- 6 hours	$Y = -6.8711 + 1.2010X - .00767X^2$
iii)	7- 9 hours	$Y = 4.6896 + .26299X + .00916X^2$
iv)	10-12 hours	$Y = 2.6931 + .72432X + .00124X^2$
v)	13-15 hours	$Y = 6.6492 + .78423X + .00227X^2$
vi)	16-18 hours	$Y = -4.9152 + 1.4376X - .01053X^2$
vii)	19-21 hours	$Y = 2.2767 + .88129X - .00219X^2$
viii)	22-24 hours	$Y - -9.5226 + 1.5884X - .01391X^2$

APPENDIX C

Computer Output from Water Quality Model Simulation for Upper Blackfoot River System for September, 1976 Resulting in Model Calibration.

Water Quality Study of Phosphate Mining Impacts, Upper Blackfoot River Basin, Southeastern Idaho.

General Data for Model

Beginning day of simulation	267
Ending day of simulation	273
Computations per day	24
Method of solution of partial differential equations	multiple x-step, single t-step
Weather tape number	11
Days of simulation before printout begins	6
Print frequency (hour interval)	12
Number of weather zones	1
Printing option	2
Segments	1 to 23
Latitude	42.8^{o} N
Longitude	111.3^{o} W

TABLE C1- WATER QUALITY PLOTS FOR STUDY BASIN - 29-30 SEPTEMBER,1976

A- TIME HISTORY PLOTS

PLOT	PARAMETER		NODES		
1	1	TEMP	6	13	23
2	5	D O	6	13	23
3	23	PH	6	13	23
4	24	CO2	6	13	23

B- CONCENTRATION PROFILES

PLOT	PARAMETER		NODES								
1	1	TEMP	1	4	6	8	12	13	16	21	23
2	2	TSS	1	4	6	8	12	13	16	21	23
3	5	D O	1	4	6	8	12	13	16	21	23
4	7	PO4	1	4	6	8	12	13	16	21	23
5	11	NO3	1	4	6	8	12	13	16	21	23
6	12	TDS	1	4	6	8	12	13	16	21	23
7	16	ZINC	1	4	6	8	12	13	16	21	23
8	17	COPR	1	4	6	8	12	13	16	21	23
9	23	PH	1	4	6	8	12	13	16	21	23
10	24	CO2	1	4	6	8	12	13	16	21	23

TABLE C2 - WEATHER DATA FOR STUDY BASIN - SEPTEMBER,1976

PERIOD	DAY OF YEAR	ATMOSPHERE PRESSURE	CLOUD COVER	WIND SPEED	DRY BULB TEMPERATURE	DEW POINT TEMPERATURE
		MB	TENTHS	M/SEC	C	C
1-3	270	802.6	0.0	3.1	4.4	-1.1
4-6	270	802.6	0.0	2.5	0.6	-2.8
7-9	270	803.9	0.0	1.9	3.3	-1.1
10-12	270	805.6	0.0	2.9	14.4	1.1
13-15	270	804.9	0.0	3.8	17.8	0.6
16-18	270	803.9	0.0	3.6	16.7	1.1
19-21	270	803.3	0.0	3.6	12.2	0.6
22-24	270	802.9	0.0	3.8	6.1	-0.6

TABLE C3- OUTFLOW DATA OF UPPER BLACKFOOT RIVER BASIN - 23-30 SEPTEMBER,1976

FROM	TO	OUTFLOW	NAME
		CFS	
4	0	2.0	LOSS TO GW
5	0	2.0	LOSS TO GW
6	0	2.6	LOSS TO GW

TABLE C4- INITIAL WATER QUALITY CONDITIONS FOR STUDY BASIN - 23 SEPTEMBER, 1976

NODE	TEMP C	TSS MG/L	COLIF MPN/100	BOD MG/L	DO MG/L	ALKA MG/L	PH	CO2 MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	TDS MG/L	TBTY FTU	HARD MG/L	CHRM MG/L	ZINC MG/L	COPP MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	6.0	3.	1.	0.3	8.5	175.	8.0	1.34	0.06	0.04	0.09	190.	0.8	170.	.001	.010	.002	.001	.001	.001	0.86
2	6.0	3.	1.	0.3	8.5	175.	8.0	1.34	0.06	0.04	0.09	190.	0.8	170.	.001	.010	.002	.001	.001	.001	0.86
3	6.0	3.	1.	0.3	8.5	175.	8.0	1.34	0.06	0.04	0.09	190.	0.8	170.	.001	.010	.002	.001	.001	.001	0.86
4	6.0	3.	1.	0.3	8.5	175.	8.0	1.34	0.06	0.04	0.09	190.	0.8	170.	.001	.010	.002	.001	.001	.001	0.86
5	6.0	3.	1.	0.3	8.5	175.	8.0	1.34	0.06	0.04	0.09	190.	0.8	170.	.001	.010	.002	.001	.001	.001	0.86
6	6.0	3.	1.	0.3	8.5	175.	8.0	1.34	0.06	0.04	0.09	190.	0.8	170.	.001	.010	.002	.001	.001	.001	0.86
7	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
8	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
9	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
10	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
11	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
12	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
13	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
14	9.0	3.	1.	0.7	8.5	185.	8.5	0.41	0.04	0.04	0.10	200.	0.8	160.	.010	.010	.015	.001	.001	.001	0.56
15	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
16	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
17	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
18	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
19	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
20	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
21	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
22	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25
23	10.0	5.	3.	0.5	8.0	185.	7.4	5.14	0.06	0.05	0.13	205.	1.3	170.	.001	.022	.001	.001	.001	.001	1.25

TABLE C5- INFLOW QUALITY DATA OF UPPER BLACKFOOT RIVER BASIN - 23-30 SEPTEMBER,1976

SEG	NAME	INFLOW CFS	TEMP C	TSS MG/L	COLIF MPN/OO	BOD MG/L	DO MG/L	ALKA MG/L	PH	TIC MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	TDS MG/L	TBTY FTU	HARD MG/L	CHRM MG/L	ZINC MG/L	COPP MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	CRGN MG/L
1	DIAMOND CR	0.2	3.9	2.	1.	0.3	9.0	182.	7.5	43.3	0.10	0.04	0.09	195.	0.4	183.	.001	.016	.002	.001	.001	.001	1.38
1	STEWART CR	1.5	3.3	1.	1.	0.3	9.0	178.	7.5	47.2	0.05	0.04	0.09	189.	0.8	168.	.001	.010	.001	.001	.001	.001	0.78
1	TIMBER CR	3.5	3.3	1.	1.	0.3	9.0	178.	7.5	47.2	0.05	0.04	0.09	189.	0.8	168.	.001	.010	.001	.001	.001	.001	0.78
1	UNNAMED BASI	0.5	4.0	3.	1.	0.3	9.0	185.	7.5	49.1	0.03	0.04	0.09	205.	1.2	175.	.001	.010	.001	.001	.001	.001	0.78
2	UNNAMED BASI	1.0	4.0	3.	1.	0.3	9.0	185.	7.5	49.1	0.03	0.04	0.09	205.	1.2	175.	.001	.010	.001	.001	.001	.001	0.78
3	BEAR CANYON	0.2	3.3	1.	1.	0.3	9.0	178.	7.5	47.2	0.05	0.04	0.09	189.	0.8	168.	.001	.010	.001	.001	.001	.001	0.78
3	UNNAMED BASI	0.9	4.0	3.	1.	0.3	9.0	185.	7.5	49.1	0.03	0.04	0.09	205.	1.2	175.	.001	.010	.001	.001	.001	.001	0.78
4	HORNET CANYO	2.1	3.3	1.	1.	0.3	9.0	178.	7.5	47.2	0.05	0.04	0.09	189.	0.8	168.	.001	.010	.001	.001	.001	.001	0.78
4	UNNAMED BASI	0.2	4.0	2.	1.	0.3	9.0	185.	7.5	49.1	0.03	0.04	0.09	205.	1.2	175.	.001	.010	.001	.001	.001	.001	0.78
5	COYOTE CR	1.5	3.3	1.	1.	0.3	9.0	178.	7.5	47.2	0.05	0.04	0.09	189.	0.8	168.	.001	.010	.001	.001	.001	.001	0.78
5	TERRACE CANY	0.1	9.0	2.	1.	0.3	8.5	180.	8.2	43.8	0.05	0.04	0.09	180.	0.8	168.	.001	.010	.001	.001	.001	.001	0.96
5	CAMPBELL CAN	6.4	4.3	2.	1.	0.3	8.5	160.	8.5	38.5	0.07	0.03	0.09	190.	0.6	165.	.005	.010	.010	.001	.001	.001	0.97
5	UNNAMED BASI	0.1	6.0	2.	1.	0.5	8.5	160.	8.5	38.4	0.07	0.03	0.09	190.	0.6	165.	.005	.010	.010	.001	.001	.001	0.97
6	YELLOWJACKET	0.2	11.1	3.	1.	0.5	8.6	185.	8.9	43.4	0.10	0.04	0.10	178.	0.7	165.	.010	.010	.020	.001	.001	.001	0.16
7	UNNAMED BASI	0.1	6.0	2.	1.	0.8	8.5	160.	8.5	38.4	0.07	0.03	0.09	190.	0.6	165.	.005	.010	.010	.001	.001	.001	0.17
7	GW GAIN	4.0	11.0	0.	0.	0.0	7.5	190.	8.8	44.9	0.05	0.02	0.10	250.	0.0	130.	.010	.030	.020	.001	.001	.001	0.18
8	GW GAIN	5.8	11.0	0.	0.	0.0	7.5	190.	8.8	44.9	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
9	CABIN CR	0.7	10.0	2.	1.	1.0	8.8	181.	8.8	42.7	0.02	0.03	0.10	180.	0.7	165.	.010	.007	.020	.001	.001	.001	0.17
9	UNNAMED BASI	0.2	10.0	2.	1.	1.0	8.8	181.	8.8	42.7	0.02	0.03	0.10	180.	0.7	165.	.010	.007	.020	.001	.001	.001	0.17
9	GW GAIN	1.5	11.0	0.	0.	0.0	7.5	190.	8.8	44.9	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.19
10	UNNAMED BASI	0.1	10.0	2.	1.	1.0	8.8	181.	8.8	42.7	0.02	0.03	0.10	180.	0.7	165.	.010	.007	.020	.001	.001	.001	0.17
10	GW GAIN	1.5	11.0	0.	0.	0.0	7.5	190.	8.8	44.9	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
11	UNNAMED BASI	0.1	10.5	2.	1.	1.0	8.8	181.	8.8	42.7	0.01	0.03	0.10	180.	0.7	165.	.010	.007	.020	.001	.001	.001	0.17
11	GW GAIN	1.5	11.0	0.	0.	0.0	7.5	190.	8.8	44.9	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
12	KENDELL CR	4.5	4.4	1.	1.	0.5	8.5	150.	9.0	35.2	0.10	0.03	0.10	190.	0.3	160.	.010	.010	.020	.0	.0	.0	1.37
12	MOSQUITO CR	0.6	5.5	1.	1.	0.5	8.5	76.	8.5	18.3	0.08	0.02	0.08	190.	0.8	170.	.010	.009	.020	.001	.001	.001	0.98
12	GW GAIN	9.0	10.0	0.	0.	0.0	7.5	190.	8.2	46.2	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
13	TIMOTHY CR	2.4	9.0	2.	2.	0.5	8.8	178.	9.0	41.5	0.02	0.02	0.07	200.	0.8	160.	.010	.009	.015	.001	.001	.001	0.68
13	GW GAIN	13.0	10.0	0.	0.	0.0	7.5	190.	8.2	46.2	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
14	LANES CR	31.4	10.0	3.	2.	0.5	7.7	172.	8.5	41.2	0.06	0.12	0.10	207.	1.0	140.	.003	.004	.008	.001	.001	.005	0.73
14	UNNAMED BASI	0.3	9.4	5.	2.	0.5	8.0	208.	7.5	54.5	0.06	0.05	0.12	205.	0.9	150.	.001	.024	.001	.001	.001	.001	0.75
14	UNNAMED BASI	0.3	9.4	5.	2.	0.5	8.0	208.	7.5	54.5	0.06	0.05	0.12	205.	0.9	150.	.001	.024	.001	.001	.001	.001	0.75
14	BACON CR	2.4	9.0	2.	2.	0.5	8.8	193.	9.0	46.4	0.06	0.02	0.10	207.	1.0	140.	.010	.009	.015	.001	.001	.001	0.68
15	MILL CR	3.3	6.7	5.	2.	0.5	8.0	187.	7.2	53.8	0.06	0.05	0.13	210.	1.4	181.	.001	.019	.001	.001	.001	.001	1.40
15	UNNAMED BASI	6.0	7.0	5.	2.	0.5	8.0	187.	7.2	53.8	0.06	0.05	0.13	210.	1.4	181.	.001	.019	.001	.001	.001	.001	1.40
15	UNNAMED BASI	0.4	7.0	5.	2.	0.5	8.0	187.	7.2	53.8	0.06	0.05	0.13	210.	1.4	181.	.001	.001	.001	.001	.001	.001	1.40
15	GW GAIN	3.5	10.0	0.	0.	0.0	7.5	190.	8.2	46.2	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
16	UNNAMED BASI	2.1	6.7	5.	2.	0.5	8.0	187.	7.2	53.8	0.06	0.05	0.13	210.	1.4	181.	.001	.001	.001	.001	.001	.001	1.40
16	GW GAIN	3.5	10.0	0.	0.	0.5	7.5	190.	8.2	46.2	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
17	ANGUS CR	1.1	10.6	4.	2.	0.5	8.0	196.	7.5	51.3	0.07	0.05	0.13	200.	1.1	172.	.001	.024	.001	.001	.001	.001	1.35
17	UNNAMED BASI	0.2	10.6	4.	2.	0.5	8.0	196.	7.5	51.3	0.07	0.05	0.13	200.	1.1	172.	.001	.024	.001	.001	.001	.001	1.35
18	UNNAMED BASI	1.0	10.0	5.	2.	0.5	8.0	202.	7.5	52.9	0.06	0.05	0.13	202.	1.0	160.	.001	.024	.001	.001	.001	.001	1.05
18	UNNAMED BASI	0.7	10.0	5.	2.	0.5	8.0	202.	7.5	52.9	0.06	0.05	0.13	202.	1.0	160.	.001	.024	.001	.001	.001	.001	1.05
18	UNNAMED BASI	0.7	10.0	5.	2.	0.5	8.0	202.	7.5	52.9	0.06	0.05	0.13	202.	1.0	160.	.001	.024	.001	.001	.001	.001	1.05
19	UNNAMED BASI	0.5	10.0	5.	2.	0.5	8.0	202.	7.5	52.9	0.06	0.05	0.13	202.	1.0	160.	.001	.024	.001	.001	.001	.001	1.05
20	UNNAMED BASI	0.2	11.7	0.	3.	0.5	7.5	155.	7.3	42.4	0.09	0.05	0.13	198.	1.9	171.	.001	.024	.001	.001	.001	.001	1.10
20	GW GAIN	2.6	10.0	0.	0.	0.0	7.5	155.	8.2	46.2	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
21	UNNAMED BASI	0.2	11.7	0.	3.	0.8	7.5	155.	7.3	42.4	0.09	0.05	0.13	198.	1.9	171.	.001	.024	.001	.001	.001	.001	1.10
21	GW GAIN	2.6	10.0	0.	0.	0.0	7.5	190.	8.2	46.2	0.05	0.02	0.10	250.	0.0	180.	.010	.030	.020	.001	.001	.001	0.18
22	UNNAMED BASI	0.2	11.5	0.	4.	0.8	7.5	155.	7.3	42.4	0.09	0.05	0.13	198.	1.9	171.	.001	.024	.001	.001	.001	.001	1.10
23	UNNAMED BASI	0.3	11.3	0.	4.	0.5	7.5	155.	7.3	42.4	0.09	0.05	0.13	198.	1.9	171.	.001	.024	.001	.001	.001	.001	1.10

TABLE C6- FLOW CALCULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 23-30 SEPTEMBER,1976

SEG	UPPER SEG-1	UPPER SEG-2	SEG-A REC.FLOW	INFLOW SEG-A CFS	OUTFLOW CFS	FLOW FROM SEG-1 CFS	FLOW FROM SEG-2 CFS	TOT INFLOW INTO SEG CFS	FLOW THROUGH CFS
1	0	0	0	0.0	0.0	0.0	0.0	5.8	5.8
2	1	0	0	0.0	0.0	5.8	0.0	1.0	6.8
3	2	0	0	0.0	0.0	6.8	0.0	1.7	8.5
4	3	0	0	0.0	2.0	8.5	0.0	2.3	8.8
5	4	0	0	0.0	2.0	8.8	0.0	8.1	14.9
6	5	0	0	0.0	2.6	14.9	0.0	0.2	12.5
7	6	0	0	0.0	0.0	12.5	0.0	4.1	16.6
8	7	0	0	0.0	0.0	16.6	0.0	5.8	22.4
9	0	0	0	0.0	0.0	0.0	0.0	2.4	2.4
10	9	0	0	0.0	0.0	2.4	0.0	1.6	4.0
11	10	0	0	0.0	0.0	4.0	0.0	1.6	5.6
12	8	11	0	0.0	0.0	22.4	5.6	13.1	41.1
13	12	0	0	0.0	0.0	41.1	0.0	15.4	56.5
14	0	0	0	0.0	0.0	0.0	0.0	34.4	34.4
15	13	14	0	0.0	0.0	56.5	34.4	13.2	104.1
16	15	0	0	0.0	0.0	104.1	0.0	5.6	109.7
17	0	0	0	0.0	0.0	0.0	0.0	1.3	1.3
18	17	0	0	0.0	0.0	1.3	0.0	2.4	3.7
19	18	0	0	0.0	0.0	3.7	0.0	0.5	4.2
20	16	19	0	0.0	0.0	109.7	4.2	2.8	116.7
21	20	0	0	0.0	0.0	116.7	0.0	2.8	119.5
22	21	0	0	0.0	0.0	119.5	0.0	0.2	119.7
23	22	0	0	0.0	0.0	119.7	0.0	0.3	120.0

TABLE C7- HYDRAULIC CONDITIONS OF UPPER BLACKFOOT RIVER BASIN - 23-30 SEPTEMBER,1976

SEG	INFLOW	OUTFLOW	FLOW THROUGH	VELOCITY	LENGTH	DEPTH	WIDTH	SAREA	VOLUME	REAO2	RETENTION TIME
	CFS	CFS	CFS	FPS	FT	FT	FT	SQ FT	CU FT	1/DAY	HRS
1	5.8	0.0	5.8	1.50	6.917E 03	0.8	4.0	2.761E 04	2.209E 04	6.723	1.06
2	1.0	0.0	6.8	1.55	7.339E 03	0.8	4.5	3.329E 04	2.663E 04	6.961	1.09
3	1.7	0.0	8.5	1.63	6.230E 03	0.8	5.4	3.381E 04	2.705E 04	7.310	0.88
4	2.3	2.0	8.8	1.64	4.699E 03	0.8	5.6	2.622E 04	2.098E 04	7.365	0.66
5	8.1	2.0	14.9	1.84	5.174E 03	0.9	9.1	4.711E 04	4.407E 04	6.714	0.82
6	0.2	2.6	12.5	1.78	7.075E 03	0.8	8.7	6.165E 04	5.233E 04	7.351	1.16
7	4.1	0.0	16.6	1.62	7.498E 03	0.8	10.2	7.667E 04	6.133E 04	7.240	1.03
8	5.8	0.0	22.4	1.83	7.498E 03	0.8	12.2	9.139E 04	7.311E 04	8.196	0.91
9	2.4	0.0	2.4	0.73	4.330E 03	0.8	3.3	1.425E 04	1.140E 04	3.251	1.32
10	1.6	0.0	4.0	0.90	5.491E 03	0.8	4.4	2.439E 04	1.951E 04	4.017	1.35
11	1.6	0.0	5.6	1.03	5.914E 03	0.8	5.4	3.199E 04	2.559E 04	4.617	1.27
12	13.1	0.0	41.1	2.35	5.650E 03	0.8	17.4	9.827E 04	7.862E 04	10.538	0.53
13	15.4	0.0	56.5	2.68	1.315E 04	0.8	21.0	2.756E 05	2.205E 05	12.022	1.08
14	34.4	0.0	34.4	2.18	8.448E 03	0.8	15.7	1.324E 05	1.059E 05	9.789	0.86
15	13.2	0.0	104.1	2.90	7.128E 03	1.5	24.3	1.731E 05	2.558E 05	5.749	0.68
16	5.6	0.0	109.7	2.95	6.494E 03	1.5	24.8	1.610E 05	2.417E 05	5.715	0.61
17	1.3	0.0	1.3	0.78	6.072E 03	0.8	1.7	1.013E 04	8.106E 03	3.490	1.73
18	2.4	0.0	3.7	1.07	7.392E 03	0.8	3.5	2.565E 04	2.052E 04	4.777	1.54
19	0.5	0.0	4.2	1.11	1.014E 04	0.8	3.8	3.845E 04	3.076E 04	4.962	2.03
20	2.8	0.0	116.7	3.00	7.445E 03	1.5	25.4	1.891E 05	2.894E 05	5.676	0.69
21	2.8	0.0	119.5	3.02	8.395E 03	1.5	25.6	2.152E 05	3.318E 05	5.661	0.77
22	0.2	0.0	119.7	3.03	6.600E 03	1.5	25.6	1.693E 05	2.611E 05	5.660	0.61
23	0.3	0.0	120.0	3.03	6.864E 03	1.5	25.7	1.762E 05	2.720E 05	5.658	0.63

TABLE C8-WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 30 SEPTEMBER, 1976 12.0 HOUR

SEG	TEMP C	TSS MG/L	COLIF MPN/OO	BOD MG/L	D O MG/L	D O O/O	P H	CO2 MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	ALKA MG/L	TDS MG/L	TBTY MG/L	HARD MG/L	CHRM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	5.7	3.	1.	0.3	9.6	84.	7.6	3.76	0.05	0.04	0.09	179.	191.	0.8	169.	.001	.010	.001	.001	.001	.001	0.80
2	6.8	5.	1.	0.3	10.0	90.	7.6	3.27	0.05	0.05	0.09	180.	193.	0.9	170.	.001	.010	.001	.001	.001	.001	0.79
3	6.8	6.	1.	0.3	10.3	93.	7.6	3.05	0.05	0.05	0.09	180.	193.	0.9	170.	.001	.010	.001	.001	.001	.001	0.78
4	6.1	6.	1.	0.3	10.4	92.	7.6	2.98	0.05	0.05	0.09	180.	193.	0.9	170.	.001	.010	.001	.001	.001	.001	0.78
5	5.8	5.	1.	0.3	10.0	88.	7.8	1.84	0.06	0.05	0.09	172.	191.	0.8	168.	.003	.010	.004	.001	.001	.001	0.85
6	6.6	7.	1.	0.3	10.4	93.	7.9	1.61	0.06	0.05	0.09	172.	191.	0.8	168.	.003	.010	.005	.001	.001	.001	0.84
7	8.4	7.	1.	0.2	10.1	95.	8.1	1.06	0.05	0.05	0.09	176.	205.	0.6	171.	.004	.015	.008	.001	.001	.001	0.67
8	9.6	7.	1.	0.2	9.8	95.	8.2	0.75	0.05	0.04	0.09	180.	217.	0.4	173.	.006	.019	.011	.001	.001	.001	0.54
9	12.5	2.	0.	0.4	8.3	86.	8.7	0.23	0.04	0.03	0.10	187.	224.	0.3	174.	.010	.021	.020	.001	.001	.001	0.17
10	13.0	2.	0.	0.2	8.4	88.	8.7	0.25	0.04	0.02	0.10	188.	232.	0.2	176.	.010	.024	.020	.001	.001	.001	0.17
11	12.9	3.	0.	0.2	8.6	90.	8.6	0.27	0.04	0.02	0.10	188.	236.	0.1	177.	.010	.025	.020	.001	.001	.001	0.17
12	9.6	6.	0.	0.2	9.5	92.	8.3	0.60	0.06	0.04	0.10	178.	223.	0.3	174.	.008	.021	.015	.001	.001	.001	0.51
13	10.5	7.	0.	0.1	9.6	95.	8.3	0.64	0.05	0.03	0.10	181.	228.	0.3	174.	.008	.022	.016	.001	.001	.001	0.44
14	11.4	5.	2.	0.5	8.5	86.	8.4	0.45	0.06	0.12	0.10	175.	207.	1.0	140.	.008	.005	.008	.001	.001	.005	0.72
15	10.1	8.	1.	0.3	9.4	92.	8.0	1.14	0.06	0.07	0.10	180.	220.	0.6	164.	.008	.016	.012	.001	.001	.002	0.61
16	9.6	9.	1.	0.3	9.6	93.	8.0	1.17	0.06	0.07	0.10	180.	221.	0.6	165.	.008	.017	.012	.001	.001	.002	0.61
17	12.8	5.	2.	0.5	8.4	88.	7.5	3.58	0.07	0.06	0.13	196.	200.	1.1	172.	.001	.024	.001	.001	.001	.001	1.33
18	12.5	6.	2.	0.5	8.7	90.	7.6	3.33	0.06	0.07	0.13	200.	201.	1.0	164.	.001	.024	.001	.001	.001	.001	1.14
19	12.8	7.	2.	0.5	9.1	95.	7.7	2.83	0.06	0.07	0.13	200.	201.	1.0	164.	.001	.024	.001	.001	.001	.001	1.12
20	9.4	10.	1.	0.3	9.8	94.	8.0	1.17	0.06	0.07	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.61
21	9.1	11.	1.	0.3	10.0	95.	8.1	1.09	0.06	0.07	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.60
22	8.9	12.	1.	0.3	10.1	96.	8.1	1.07	0.06	0.07	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.60
23	8.8	14.	1.	0.3	10.3	97.	8.1	1.02	0.06	0.08	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.60

TABLE C9-WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 30 SEPTEMBER,1976 24.0 HOUR

SEG	TEMP	TSS	COLIF	BOD	D O	D O	P H	CO2	PO4P	NH3N	NO3N	ALKA	TDS	TBTY	HARD	CHRM	ZINC	COPR	VNDM	CDM	ARSC	ORGN
	C	MG/L	MPN/00	MG/L	MG/L	0/0		MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L	MG/L
1	3.1	3.	1.	0.3	9.7	79.	7.6	3.84	0.05	0.04	0.09	179.	191.	0.8	169.	.001	.010	.001	.001	.001	.001	0.80
2	3.2	5.	1.	0.3	10.1	83.	7.6	3.35	0.05	0.05	0.09	180.	193.	0.9	170.	.001	.010	.001	.001	.001	.001	0.79
3	3.4	6.	1.	0.3	10.3	85.	7.7	3.06	0.05	0.05	0.09	180.	193.	0.9	170.	.001	.010	.001	.001	.001	.001	0.78
4	3.6	6.	1.	0.3	10.4	86.	7.7	2.92	0.05	0.05	0.09	180.	193.	0.9	170.	.001	.010	.001	.001	.001	.001	0.78
5	4.0	5.	1.	0.3	9.9	83.	7.9	1.80	0.06	0.05	0.09	172.	191.	0.8	168.	.003	.010	.004	.001	.001	.001	0.85
6	4.4	7.	1.	0.3	10.3	87.	7.9	1.55	0.06	0.05	0.09	172.	191.	0.8	168.	.003	.010	.005	.001	.001	.001	0.83
7	6.0	7.	1.	0.2	9.9	88.	8.1	1.00	0.05	0.05	0.09	176.	205.	0.6	171.	.004	.015	.008	.001	.001	.001	0.67
8	7.3	7.	1.	0.2	9.7	88.	8.3	0.70	0.05	0.04	0.09	180.	217.	0.4	173.	.006	.019	.011	.001	.001	.001	0.54
9	9.5	2.	0.	0.4	8.4	81.	8.7	0.23	0.04	0.02	0.10	187.	224.	0.3	174.	.010	.021	.020	.001	.001	.001	0.17
10	9.1	2.	0.	0.2	8.5	81.	8.7	0.25	0.04	0.02	0.10	188.	232.	0.2	176.	.010	.024	.020	.001	.001	.001	0.17
11	9.0	3.	0.	0.2	8.7	83.	8.7	0.27	0.04	0.02	0.10	188.	236.	0.1	177.	.010	.025	.020	.001	.001	.001	0.17
12	7.7	6.	0.	0.2	9.4	87.	8.3	0.57	0.06	0.04	0.10	178.	223.	0.3	174.	.008	.021	.015	.001	.001	.001	0.51
13	8.0	7.	0.	0.1	9.6	89.	8.3	0.62	0.05	0.04	0.09	181.	228.	0.3	174.	.008	.022	.016	.001	.001	.001	0.44
14	9.2	5.	2.	0.5	8.6	83.	8.4	0.45	0.06	0.12	0.10	175.	207.	1.0	140.	.008	.005	.008	.001	.001	.005	0.72
15	8.4	8.	1.	0.3	9.3	87.	8.0	1.12	0.06	0.07	0.10	180.	220.	0.6	164.	.008	.016	.012	.001	.001	.002	0.61
16	8.6	9.	1.	0.3	9.4	89.	8.0	1.15	0.06	0.07	0.10	180.	221.	0.6	165.	.008	.017	.012	.001	.001	.002	0.61
17	9.2	5.	2.	0.5	8.5	81.	7.6	3.62	0.07	0.06	0.13	196.	200.	1.1	172.	.001	.024	.001	.001	.001	.001	1.34
18	8.7	6.	2.	0.5	8.7	82.	7.6	3.44	0.06	0.06	0.13	200.	201.	1.0	164.	.001	.024	.001	.001	.001	.001	1.14
19	8.2	7.	2.	0.5	9.1	85.	7.7	2.80	0.06	0.08	0.13	200.	201.	1.0	164.	.001	.024	.001	.001	.001	.001	1.11
20	8.9	10.	1.	0.3	9.5	91.	8.0	1.12	0.06	0.07	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.61
21	9.3	11.	1.	0.3	9.6	92.	8.1	1.05	0.06	0.07	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.60
22	9.7	12.	1.	0.3	9.6	93.	8.1	0.98	0.06	0.08	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.60
23	10.0	14.	1.	0.3	9.7	95.	8.1	0.93	0.06	0.08	0.10	181.	221.	0.6	165.	.007	.017	.012	.001	.001	.002	0.59

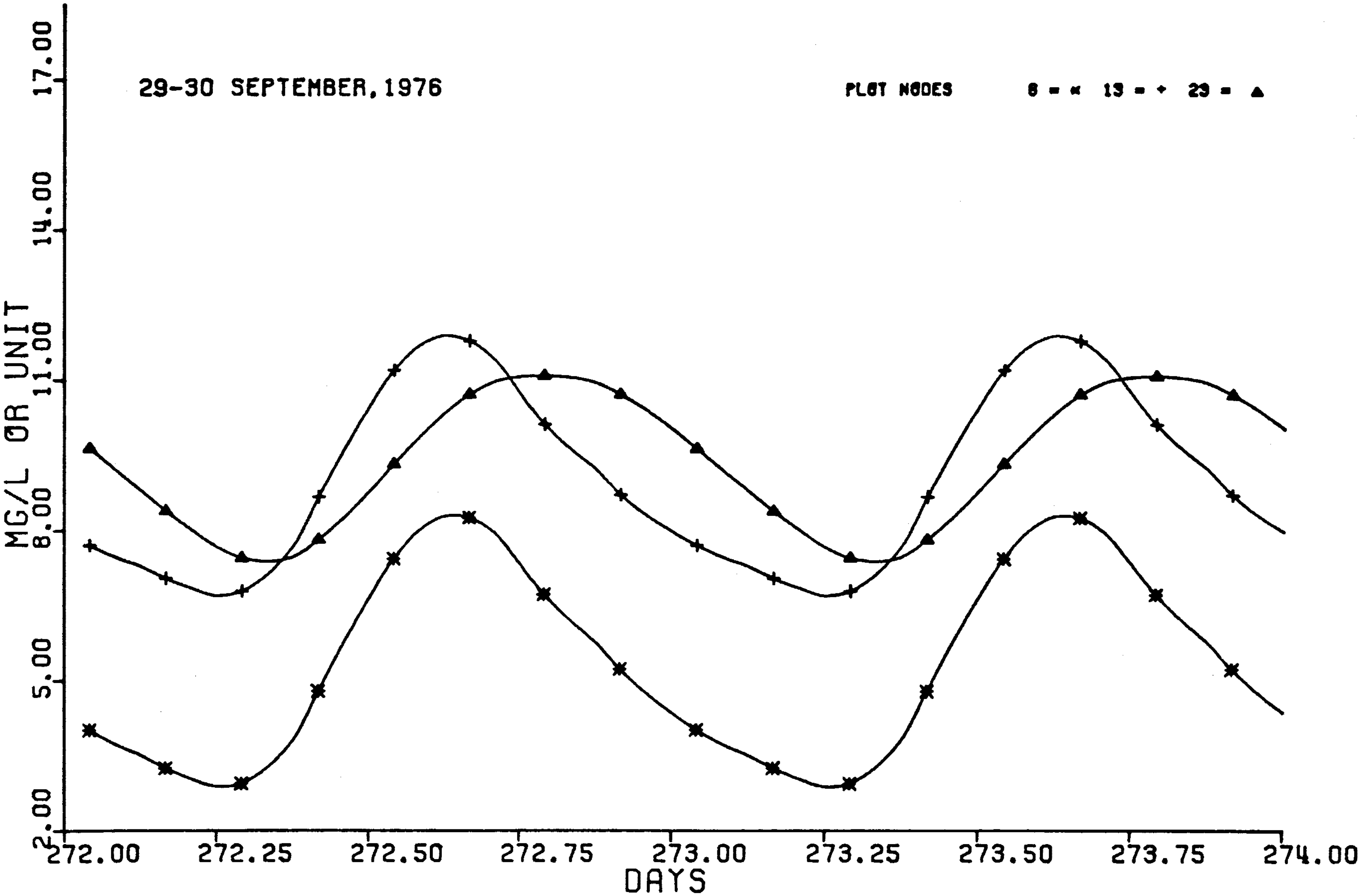

FIGURE C1-TIME PLOT OF TEMPERATURE (°C), UPPER BLACKFOOT RIVER BASIN

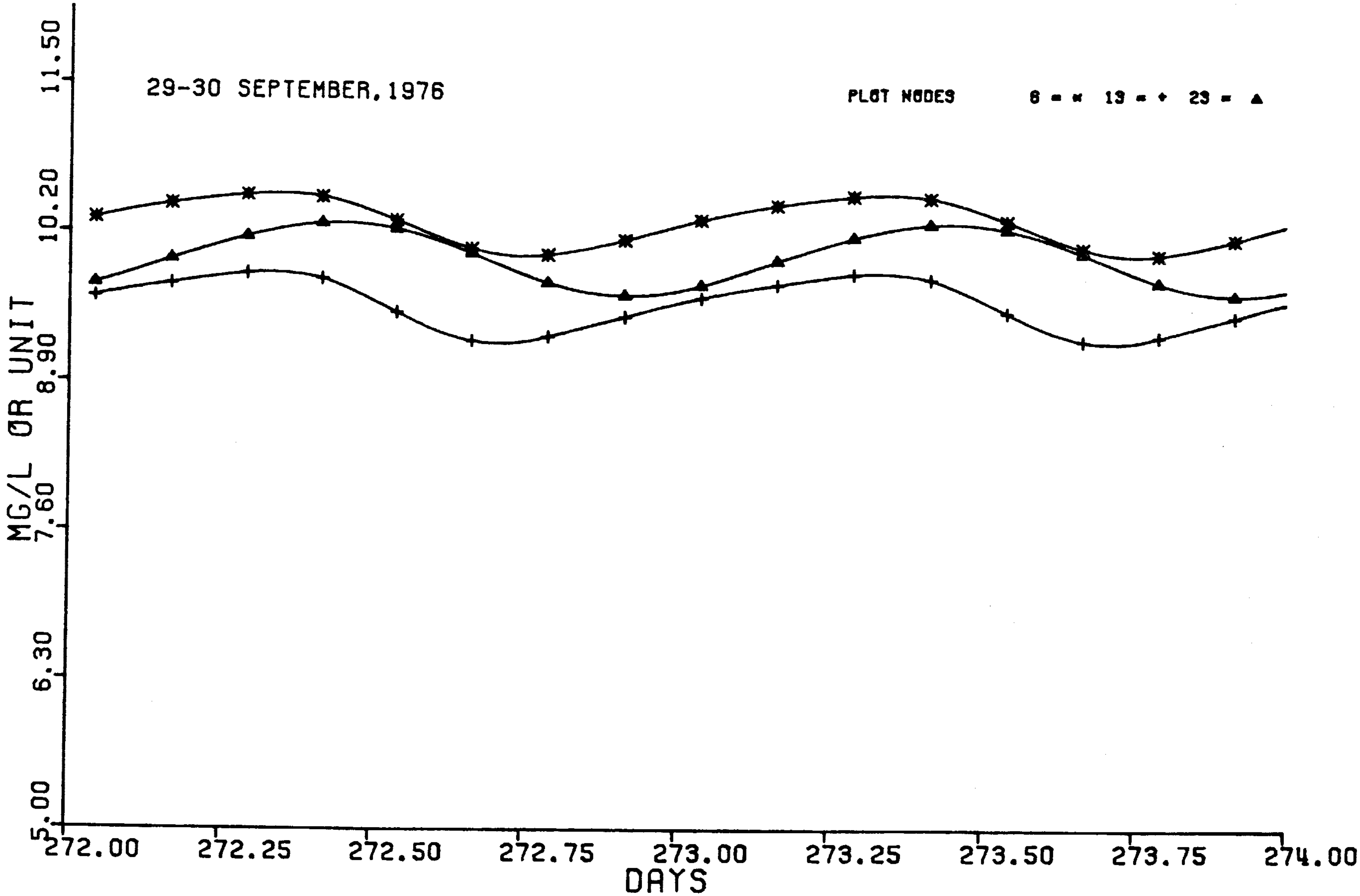

FIGURE C2-TIME PLOT OF DO (MG/L), UPPER BLACKFOOT RIVER BASIN

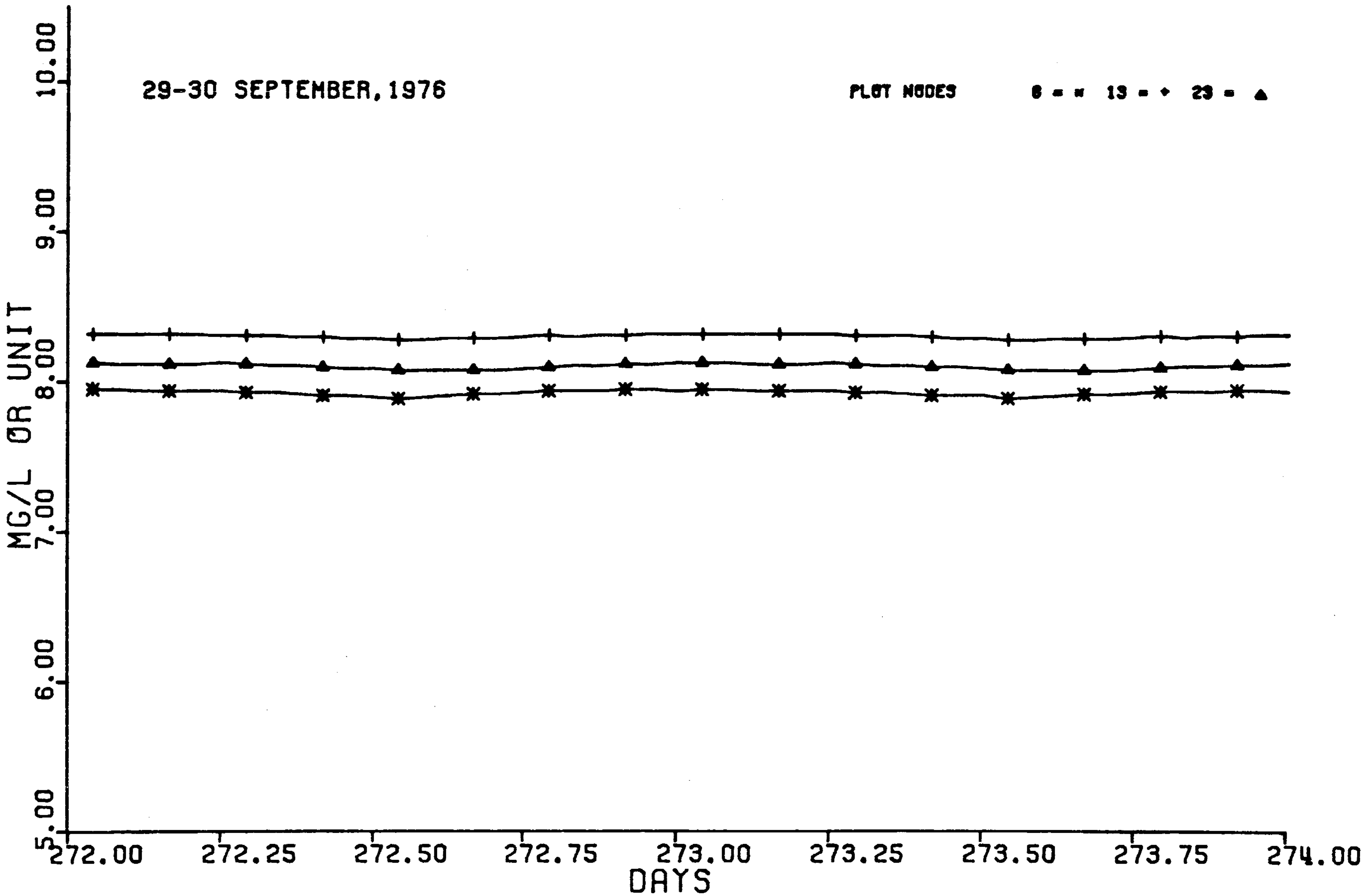

FIGURE C3-TIME PLOT OF PH, UPPER BLACKFOOT RIVER BASIN

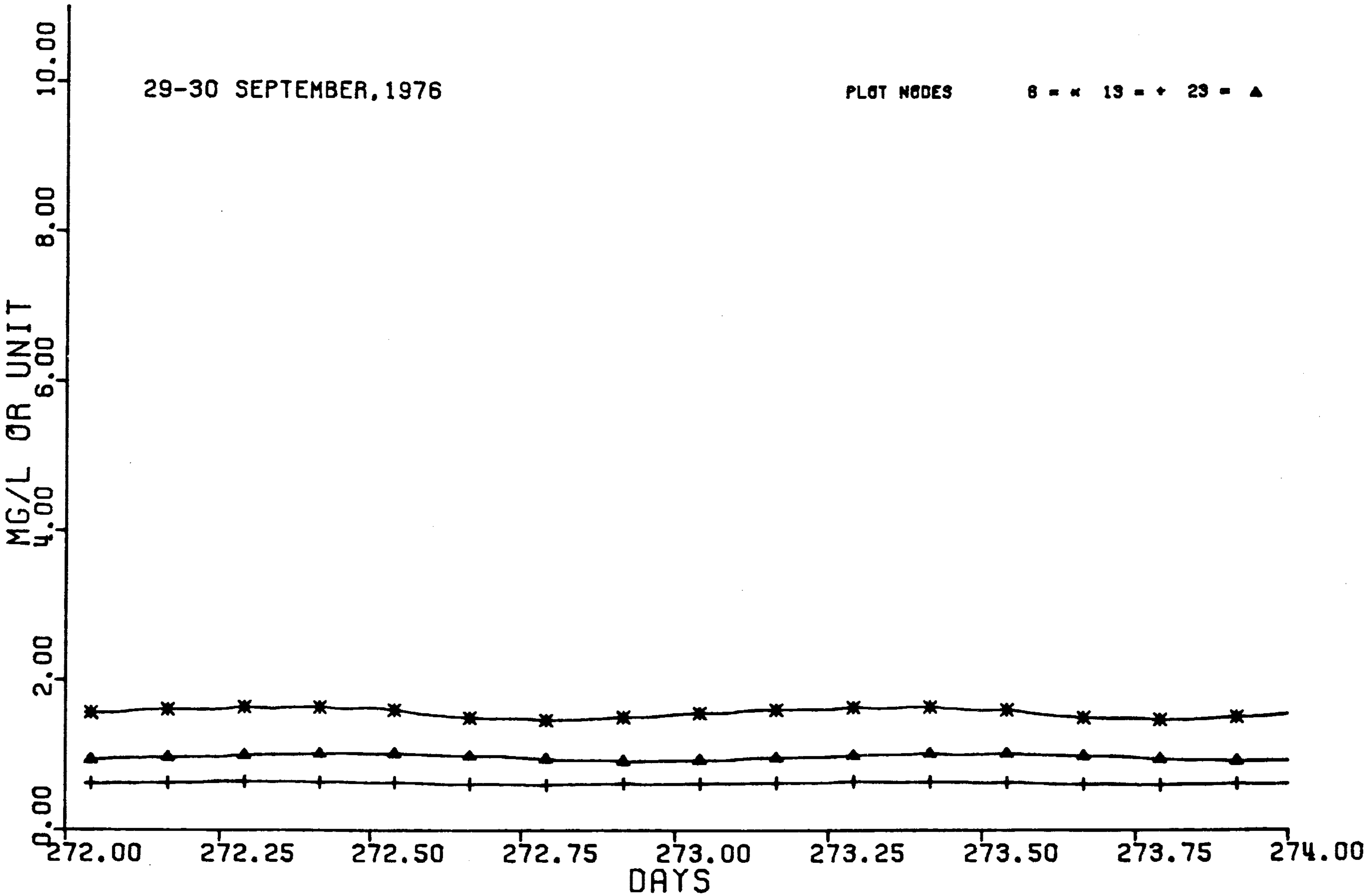

FIGURE C4-TIME PLOT OF CO2 (MG/L), UPPER BLACKFOOT RIVER BASIN

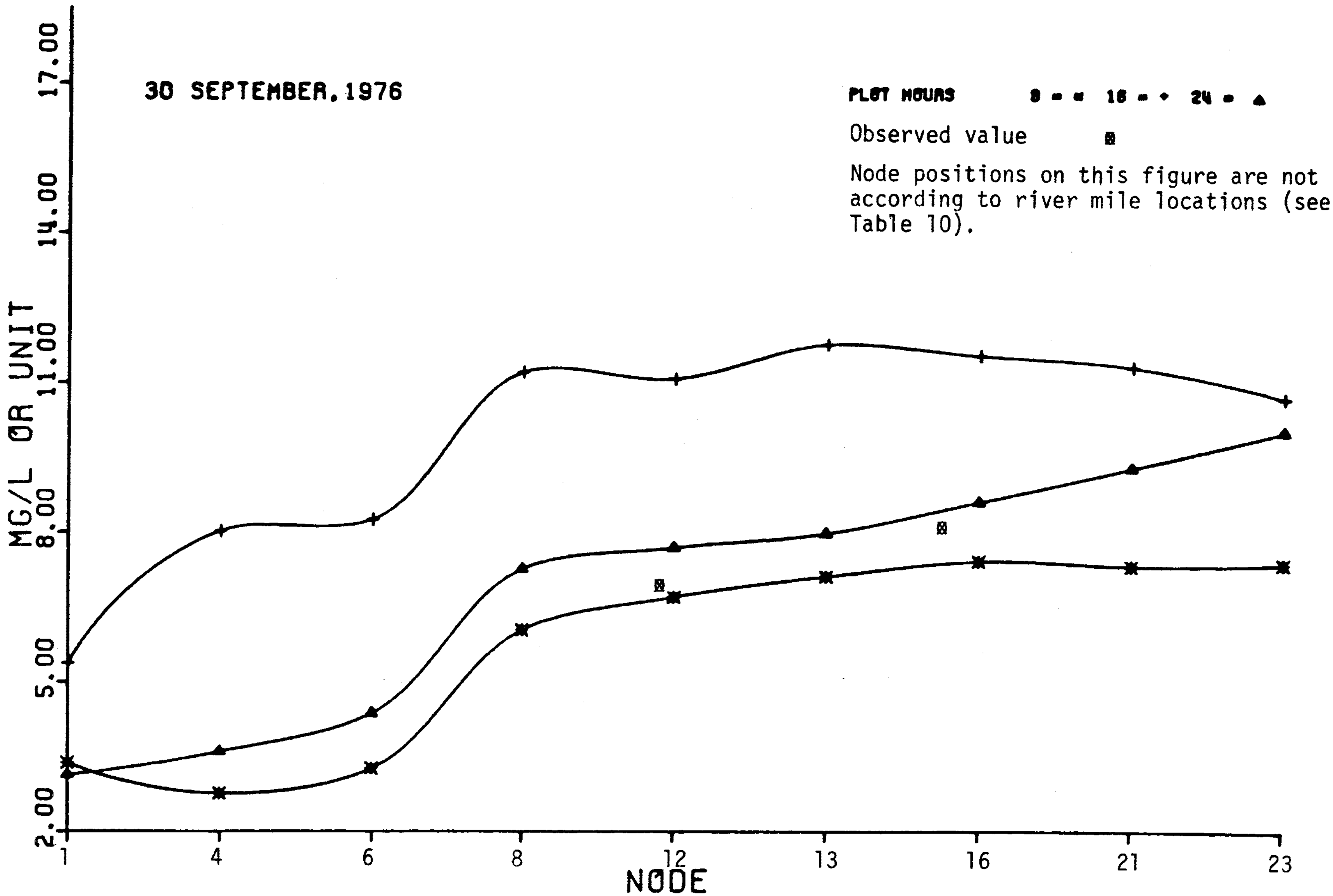

FIGURE C5 -LONGITUDINAL PLOT OF TEMPERATURE (°C), UPPER BLACKFOOT RIVER BASIN

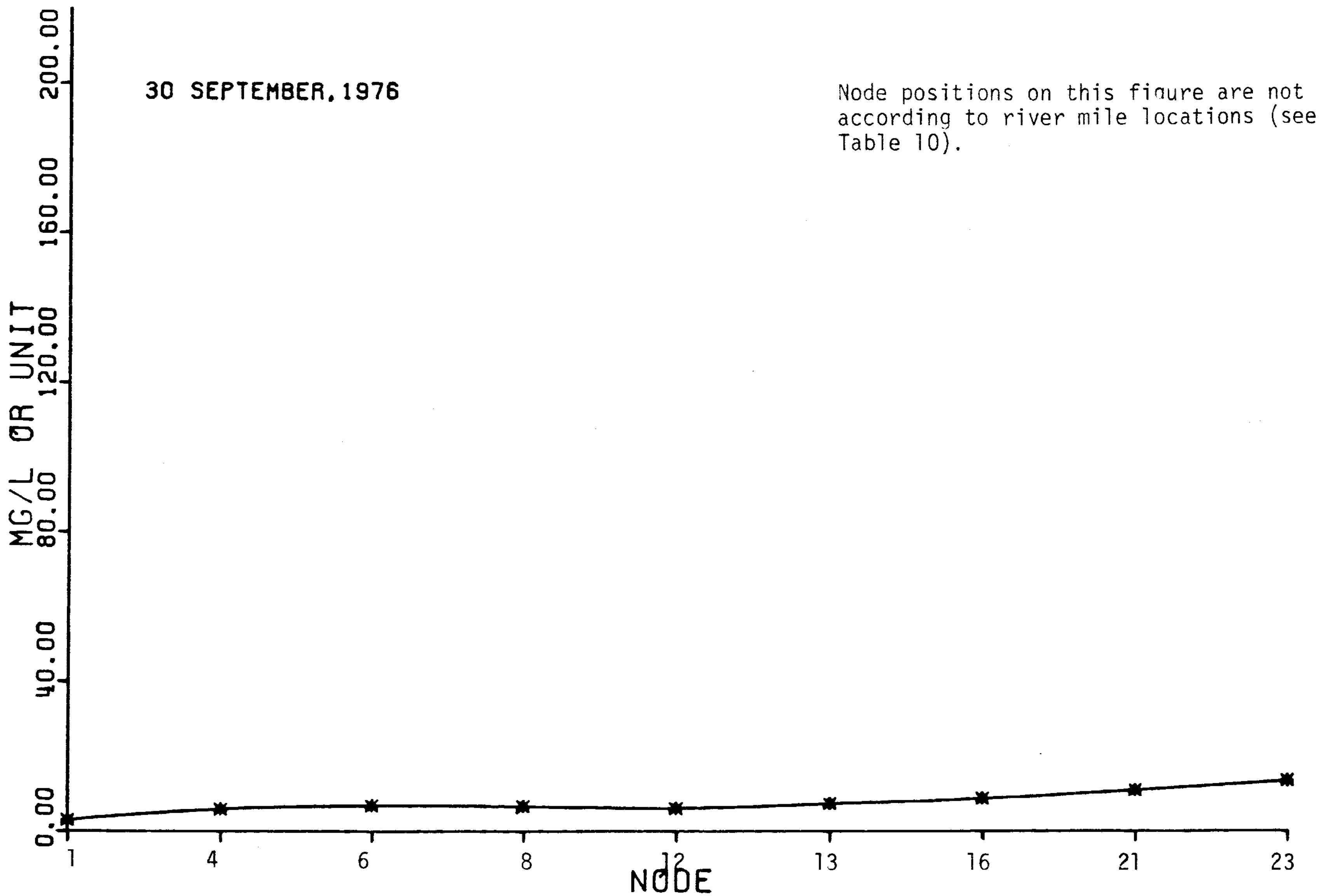

FIGURE C6-LONGITUDINAL PLOT OF TSS (MG/L), UPPER BLACKFOOT RIVER BASIN

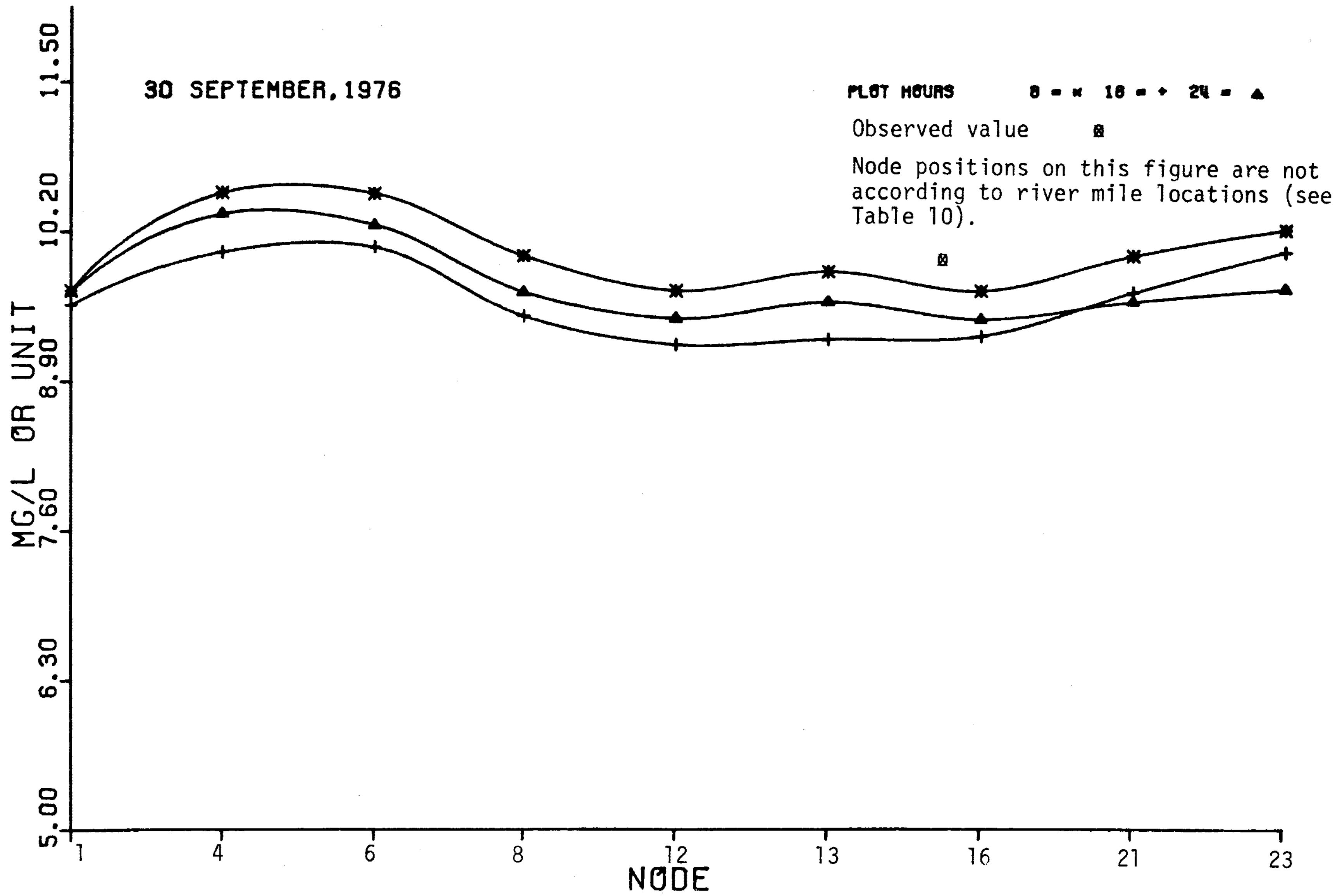

FIGURE C7-LONGITUDINAL PLOT OF DO (MG/L), UPPER BLACKFOOT RIVER BASIN

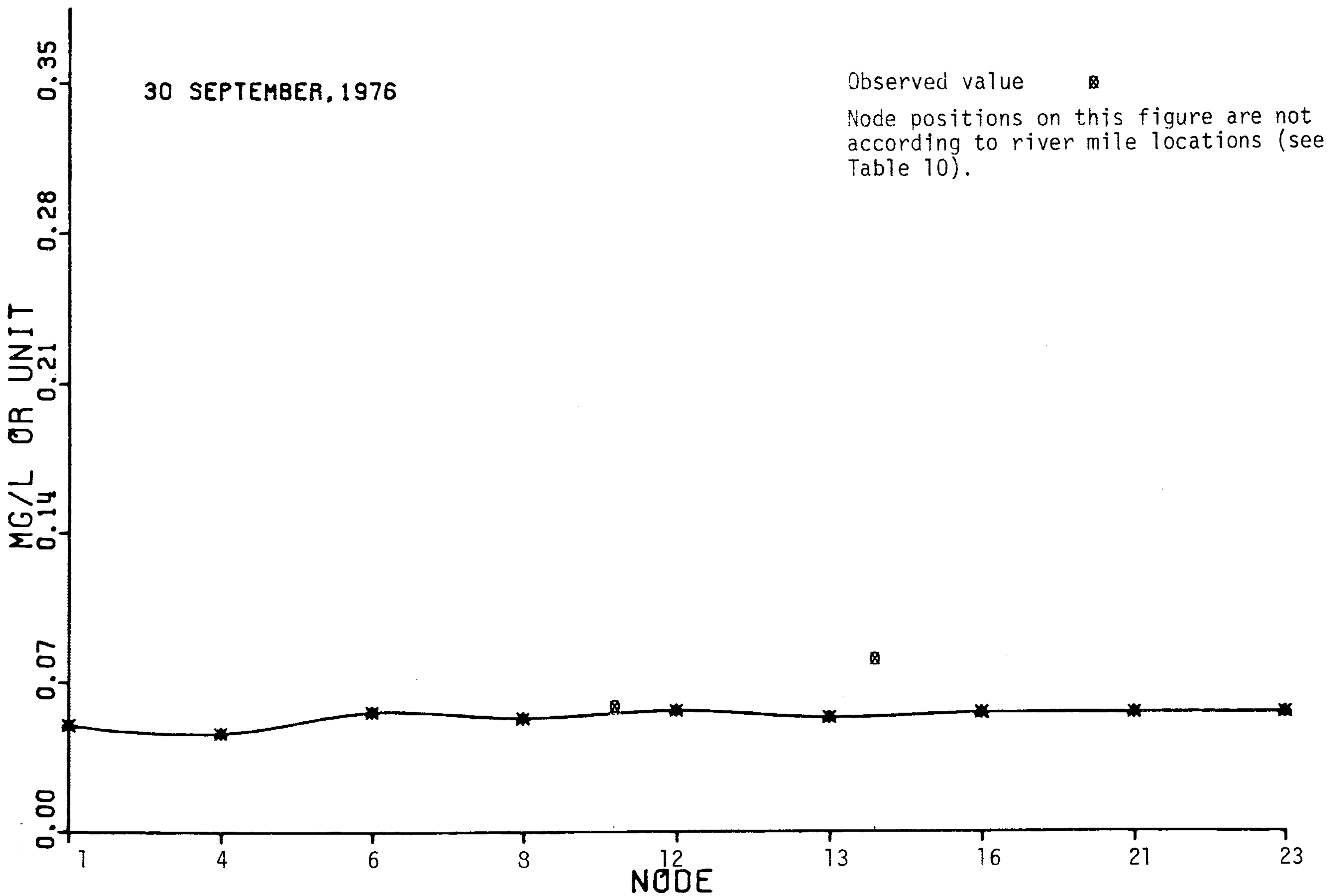

FIGURE C8-LONGITUDINAL PLOT OF PO4-P (MG/L), UPPER BLACKFOOT RIVER BASIN

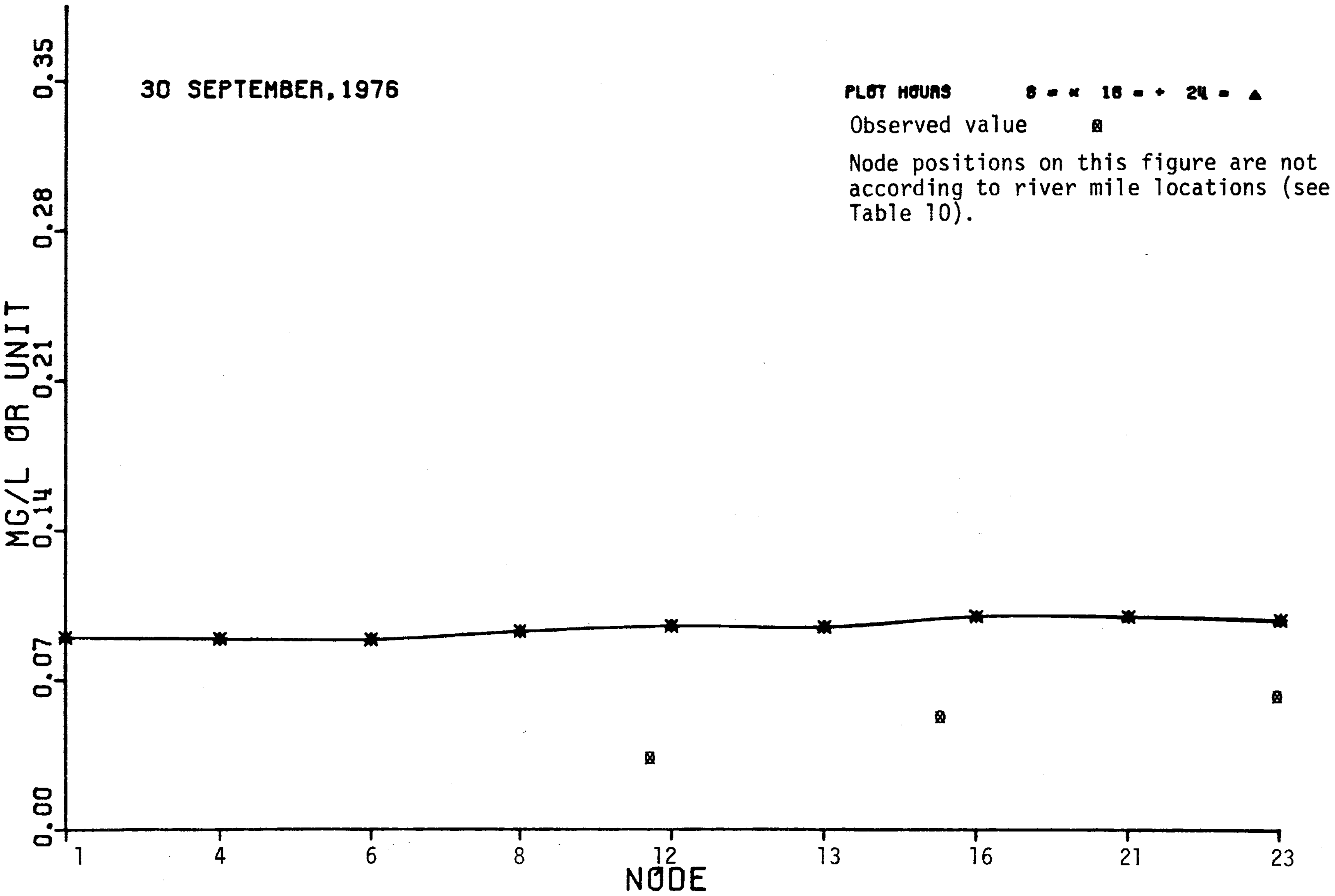

FIGURE C9-LONGITUDINAL PLOT OF NO3-N (MG/L), UPPER BLACKFOOT RIVER BASIN

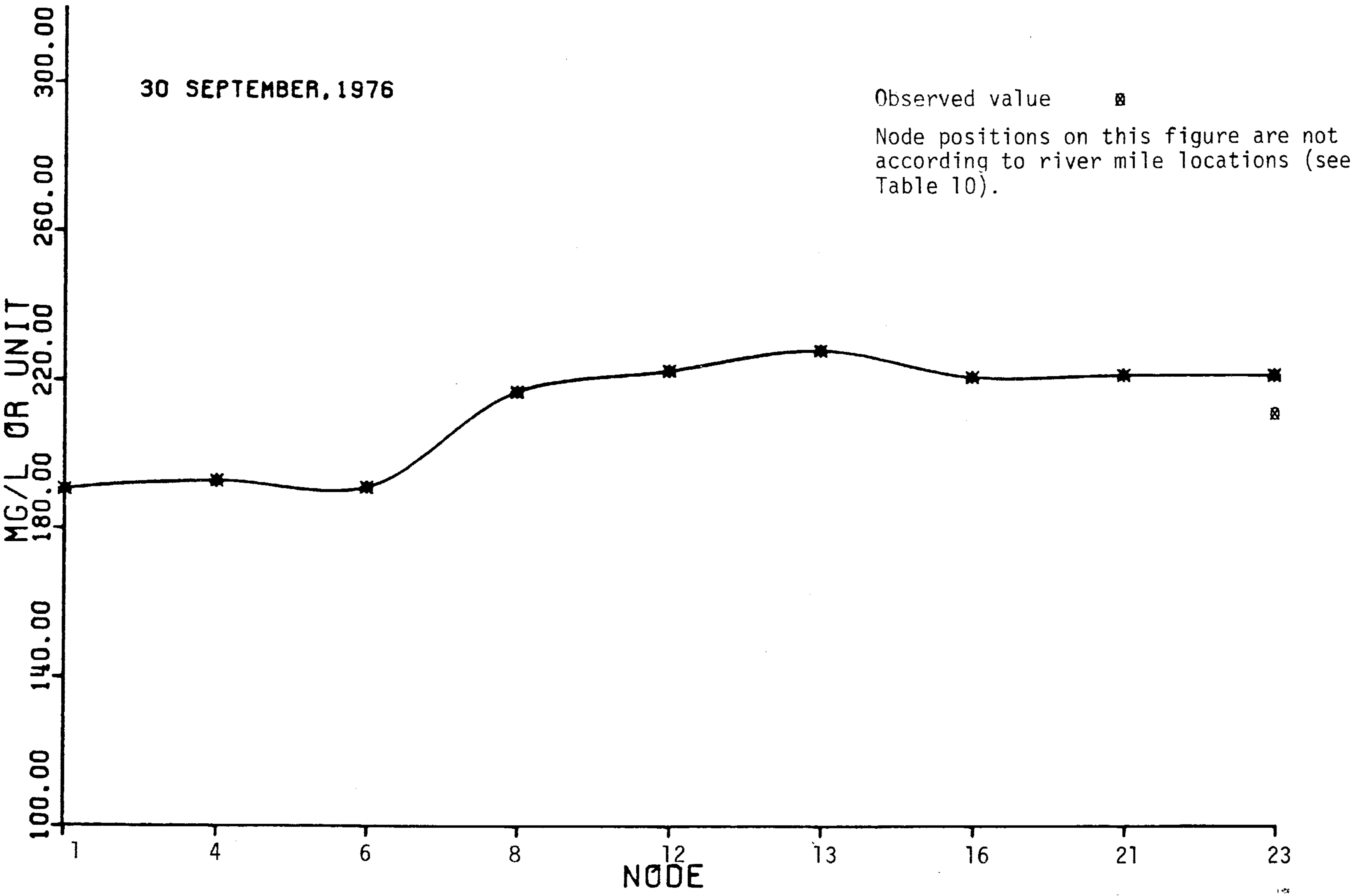

FIGURE C10–LONGITUDINAL PLOT OF TDS (MG/L), UPPER BLACKFOOT RIVER BASIN

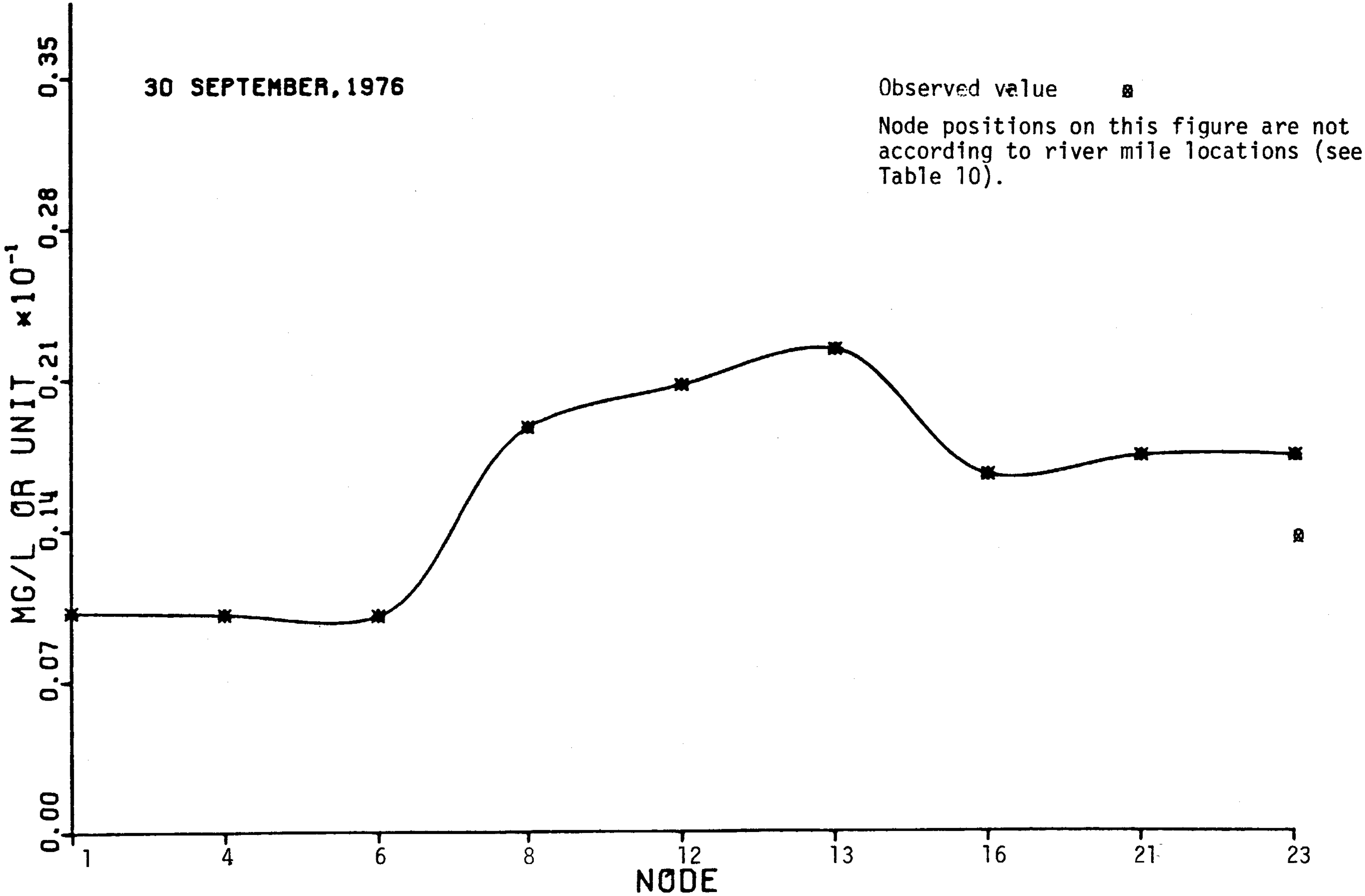

FIGURE C11-LONGITUDINAL PLOT OF ZINC (MG/L), UPPER BLACKFOOT RIVER BASIN

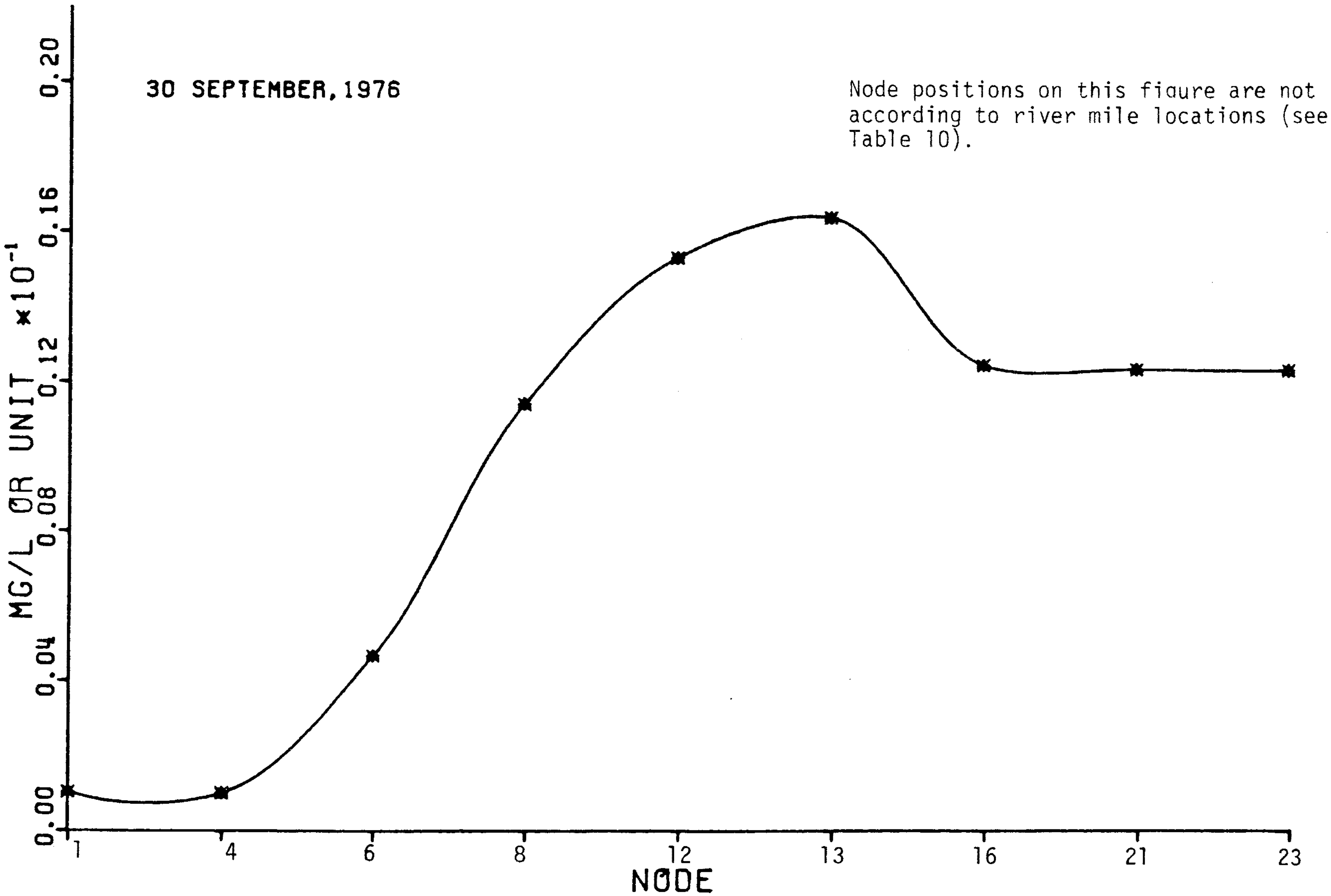

FIGURE C12-LONGITUDINAL PLOT OF COPPER (MG/L), UPPER BLACKFOOT RIVER BASIN

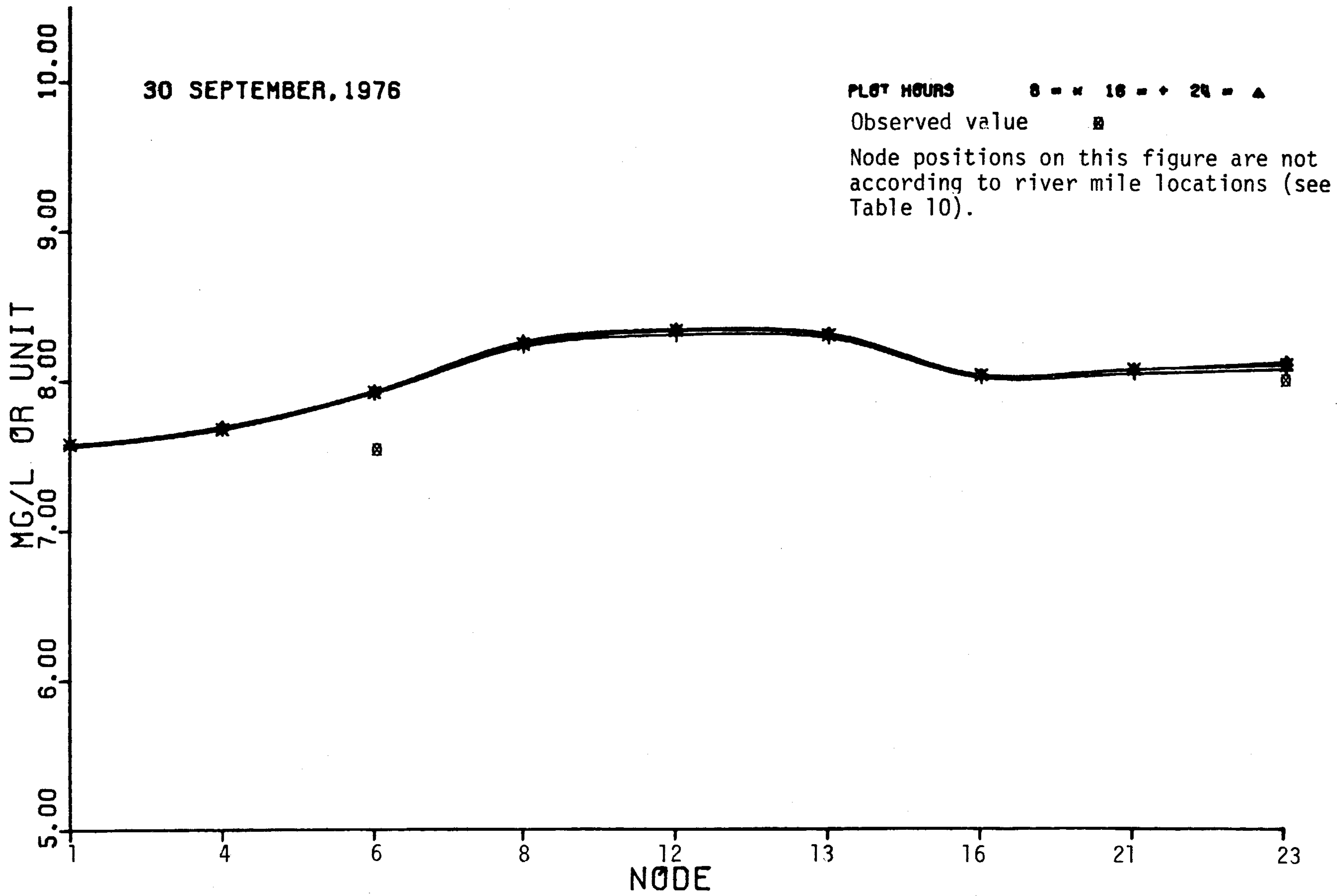

FIGURE C13-LONGITUDINAL PLOT OF PH, UPPER BLACKFOOT RIVER BASIN

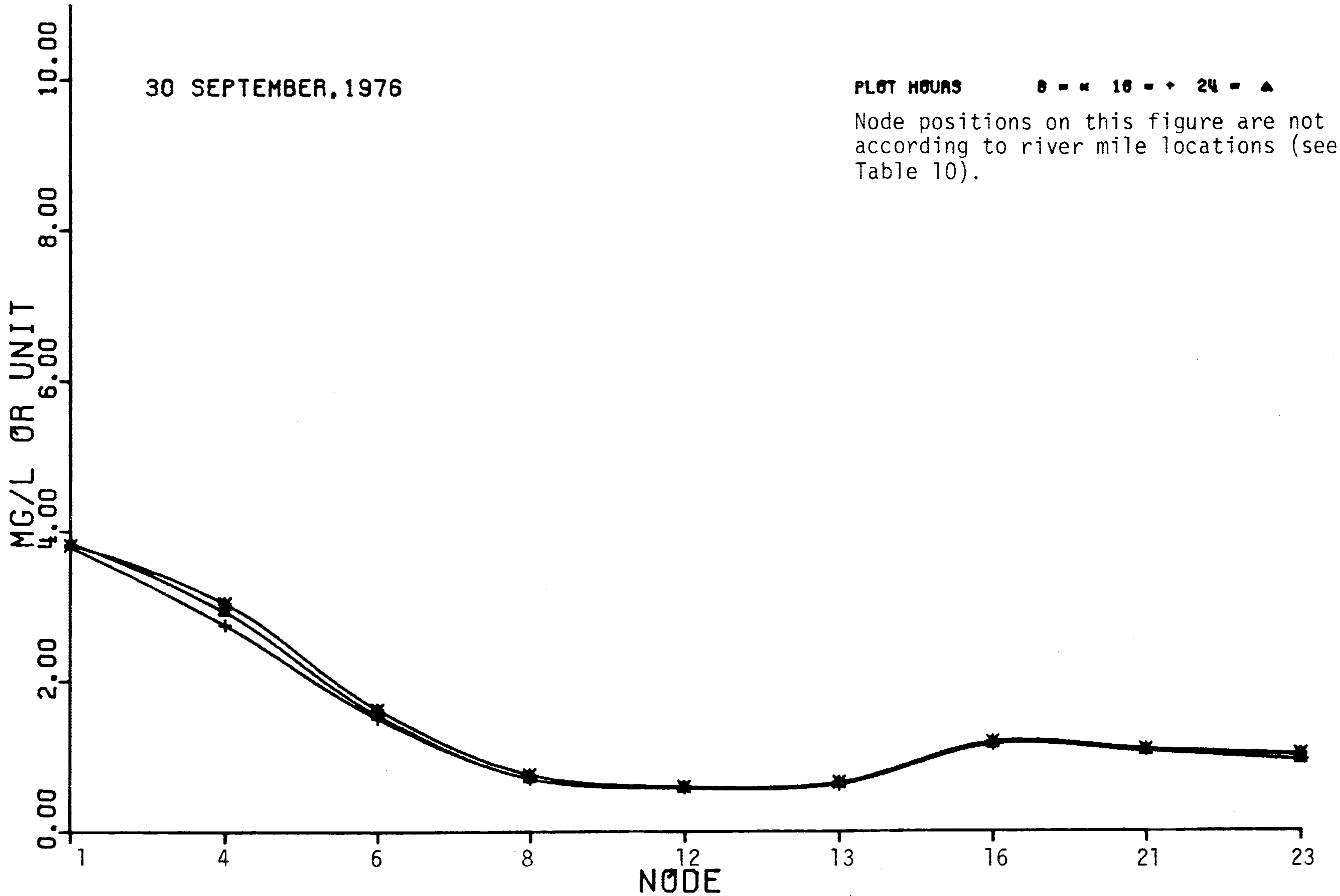

FIGURE C14-LONGITUDINAL PLOT OF CO2 (MG/L), UPPER BLACKFOOT RIVER BASIN

APPENDIX D

Computer Output from Water Quality Model Simulation for Upper Blackfoot River System for May, 1976 Resulting in Model Verification

Water Quality Study of Phosphate Mining Impacts,
Upper Blackfoot River Basin, Souteastern Idaho

General Data for Model

Beginning day of simulation	148
Ending day of simulation	152
Computations per day	24
Method of solution of partial differential equations	multiple x-step, single t-step
Weather tape number	11
Days of simulations before printout begins	4
Printout frequency (hour interval)	12
Number of weather zones	1
Printout option	2
Segments	1 to 23
Latitude	42.8^{o} N
Longitude	111.3^{o} W

TABLE D1 - WEATHER DATA FOR STUDY BASIN - MAY, 1976

PERIOD	DAY OF YEAR	ATMOSPHERE PRESSURE MB	CLOUD COVER TENTHS	WIND SPEED M/SEC	DRY BULB TEMPERATURE C	DEW POINT TEMPERATURE C
1-3	150	799.2	0.2	3.1	3.9	-2.2
4-6	150	799.5	0.2	2.6	0.6	-3.3
7-9	150	801.6	0.2	2.4	3.3	-2.2
10-12	150	802.2	0.2	3.3	12.2	0.0
13-15	150	801.9	0.2	4.3	17.2	0.0
16-18	150	800.9	0.2	3.7	15.0	0.0
19-21	150	799.9	0.2	3.5	11.7	-0.6
22-24	150	799.5	0.2	3.4	5.6	-1.7

TABLE D2 - OUTFLOW DATA OF UPPER BLACKFOOT RIVER BASIN - 27-31 MAY,1976

FROM	TO	OUTFLOW CFS	NAME
1	0	3.1	LOSS TO GW
2	0	5.1	LOSS TO GW
3	0	5.1	LOSS TO GW
4	0	5.1	LOSS TO GW
5	0	6.2	LOSS TO GW
6	0	6.1	LOSS TO GW
6	9	10.0	DIAMOND CR EAST BRANCH
7	0	10.0	LOSS TO GW
8	0	8.6	LOSS TO GW
9	0	3.4	LOSS TO GW
10	0	3.0	LOSS TO GW
11	0	1.6	LOSS TO GW
12	0	4.5	LOSS TO GW

TABLE D3 - INITIAL WATER QUALITY CONDITIONS FOR STUDY BASIN - 27 MAY,1976

NODE	TEMP C	TSS MG/L	COLIF MPN/00	BOD MG/L	DO MG/L	ALKA MG/L	PH	CO2 MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	TDS MG/L	TBTY FTU	HARD MG/L	CHRM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	7.2	70.	3.	0.7	9.0	160.	7.5	3.77	0.05	0.07	0.10	200.	10.0	150.	.003	.007	.005	.001	.000	.003	0.0
2	7.2	70.	3.	0.7	9.0	160.	7.5	3.77	0.05	0.07	0.10	200.	10.0	150.	.003	.007	.005	.001	.000	.003	0.0
3	7.2	70.	3.	0.7	9.0	160.	7.5	3.77	0.05	0.07	0.10	200.	10.0	150.	.003	.007	.005	.001	.000	.003	0.0
4	7.2	70.	3.	0.7	9.0	160.	7.5	3.77	0.05	0.07	0.10	200.	10.0	150.	.003	.007	.005	.001	.000	.003	0.0
5	7.2	70.	3.	0.7	9.0	160.	7.5	3.77	0.05	0.07	0.10	200.	10.0	150.	.003	.007	.005	.001	.000	.003	0.0
6	7.2	70.	3.	0.7	9.0	160.	7.5	3.77	0.05	0.07	0.10	200.	10.0	150.	.003	.007	.005	.001	.000	.003	0.0
7	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
8	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
9	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
10	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
11	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
12	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
13	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
14	8.9	140.	3.	1.0	9.0	165.	8.0	1.18	0.03	0.10	0.12	210.	15.0	160.	.010	.005	.010	.001	.001	.001	0.90
15	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
16	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
17	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
18	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
19	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
20	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
21	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
22	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43
23	8.9	20.	4.	2.0	9.0	165.	8.0	1.18	0.06	0.07	0.11	230.	5.0	160.	.005	.008	.005	.001	.001	.005	1.43

TABLE D4 - INFLOW QUALITY DATA OF UPPER BLACKFOOT RIVER BASIN - 27-31 MAY,1976

SEG	NAME	INFLOW CFS	TEMP C	TSS MG/L	COLIF MPN/100	BOD MG/L	DO MG/L	ALKA MG/L	PH	TIC MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	TDS MG/L	TBTY FTU	HARD MG/L	CHRM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	DIAMOND CR	49.6	8.1	109.	2.	0.5	9.0	129.	7.0	40.4	0.09	0.10	0.20	207.	20.5	130.	.001	.021	.002	.001	.001	.001	1.42
1	STEWART CR	9.8	6.9	72.	2.	0.5	9.0	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
1	TIMBER CR	19.4	6.9	72.	2.	0.5	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
1	UNNAMED	1.0	7.8	100.	3.	0.5	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
2	UNNAMED	3.0	7.8	100.	3.	0.8	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
3	BEAR CANYON	5.0	7.2	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
3	UNNAMED	2.0	7.8	100.	3.	0.8	9.5	163.	7.0	51.4	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
4	HORNET CR	11.0	6.9	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
4	UNNAMED	0.2	8.1	100.	3.	0.8	9.5	163.	7.0	51.0	0.03	0.10	0.15	220.	15.0	165.	.001	.011	.003	.001	.001	.001	1.13
5	COYOTE CR	7.0	6.9	72.	3.	0.8	9.5	163.	7.0	51.4	0.05	0.10	0.15	205.	13.5	157.	.001	.011	.003	.001	.001	.001	1.13
5	UNNAMED 1	0.2	7.5	35.	3.	0.8	9.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
5	TERRACE CR	1.5	6.9	25.	3.	0.8	9.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
5	CAMPBELL CR	20.0	6.1	15.	3.	0.8	9.5	159.	7.7	40.5	0.03	0.05	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.75
5	UNNAMED 2	1.5	6.9	20.	3.	0.8	9.5	136.	7.7	34.6	0.04	0.05	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.75
6	YELLOWJACKET	3.0	6.9	25.	2.	0.8	10.5	136.	8.0	33.6	0.04	0.07	0.10	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.16
6	UNNAMED	0.2	7.9	30.	4.	1.0	10.5	136.	8.0	33.6	0.04	0.07	0.10	220.	15.0	165.	.001	.005	.010	.001	.001	.001	1.16
7	UNNAMED	3.0	7.2	35.	4.	1.0	9.0	159.	7.7	40.5	0.03	0.04	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.76
9	CABIN CR	1.5	6.9	12.	2.	0.5	9.5	191.	8.3	46.3	0.02	0.20	0.32	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.03
9	UNNAMED	0.4	7.5	50.	3.	0.8	9.5	191.	8.3	46.3	0.02	0.20	0.32	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.03
10	UNNAMED	0.3	7.5	50.	3.	0.8	9.5	191.	8.3	46.3	0.02	0.20	0.32	205.	13.5	157.	.001	.005	.010	.001	.001	.001	1.03
11	UNNAMED	0.2	7.8	71.	4.	1.0	9.7	179.	8.3	43.4	0.02	0.03	0.06	210.	14.5	170.	.001	.005	.010	.001	.001	.001	1.20
12	KENDELL CR	10.0	6.1	13.	2.	0.5	10.5	159.	7.7	40.5	0.03	0.04	0.08	205.	1.9	160.	.002	.005	.010	.0	.0	.0	1.76
12	MOSQUITO CR	0.5	7.5	15.	2.	0.5	10.5	171.	8.0	42.2	0.02	0.07	0.12	190.	1.7	163.	.002	.005	.010	.0	.0	.0	1.13
12	UNNAMED	0.1	9.4	30.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.03	0.06	210.	14.5	170.	.001	.005	.010	.001	.001	.001	1.20
13	TIMOTHY CR	6.2	8.3	33.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.10	0.16	170.	10.0	120.	.001	.005	.010	.001	.001	.001	0.55
13	GW GAIN	35.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
14	LANES CR	160.6	12.8	25.	26.	2.0	8.0	136.	8.0	33.4	0.04	0.10	0.16	188.	11.0	133.	.008	.020	.008	.001	.001	.001	0.62
14	UNNAMED 1	1.6	8.3	30.	2.	0.5	9.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
14	UNNAMED 2	1.4	8.3	30.	2.	0.5	9.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
14	BACON CR	9.2	8.9	35.	4.	1.0	9.0	135.	8.3	32.7	0.02	0.10	0.16	170.	10.0	120.	.001	.005	.010	.001	.001	.001	0.55
15	MILL CR	5.1	7.5	17.	2.	0.5	10.5	164.	7.2	46.9	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	UNNAMED 1	11.4	9.4	15.	1.	0.2	10.0	164.	7.2	46.7	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	UNNAMED 2	0.7	9.4	30.	2.	0.5	9.5	164.	7.2	46.7	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
15	GW GAIN	13.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
16	UNNAMED	3.2	10.0	17.	3.	0.5	10.0	164.	7.2	46.6	0.17	0.08	0.13	190.	1.7	163.	.001	.015	.004	.001	.001	.001	1.12
16	GW GAIN	13.0	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
17	ANGUS CR	6.5	11.9	19.	5.	1.0	9.0	139.	6.8	48.1	0.10	0.08	0.13	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.04
17	UNNAMED 1	0.9	11.9	19.	5.	1.0	9.0	139.	6.8	48.1	0.10	0.08	0.13	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.04
18	UNNAMED 1	5.5	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
18	UNNAMED 2	4.0	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
18	UNNAMED 3	3.6	8.4	29.	4.	1.0	9.0	139.	7.0	43.4	0.10	0.09	0.14	189.	8.5	135.	.001	.017	.003	.001	.001	.001	0.82
19	UNNAMED 1	2.3	5.0	38.	4.	1.0	9.0	139.	7.0	44.3	0.10	0.08	0.16	188.	11.0	133.	.001	.015	.005	.001	.001	.001	0.59
20	UNNAMED	2.5	10.3	20.	4.	0.8	10.5	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
20	GW GAIN	5.9	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
21	UNNAMED	3.1	10.3	20.	5.	1.0	9.0	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
21	GW GAIN	5.9	6.7	0.	0.	0.2	10.0	172.	7.8	43.3	0.03	0.08	0.11	196.	0.3	180.	.001	.005	.010	.001	.001	.001	0.15
22	UNNAMED	3.9	10.3	20.	5.	1.0	9.0	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16
23	UNNAMED	5.3	10.3	20.	3.	0.8	9.5	190.	7.0	58.8	0.15	0.12	0.24	220.	10.0	160.	.001	.025	.003	.001	.001	.001	1.16

TABLE D5- FLOW CALCULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 27-31 MAY,1976

SEG	UPPER SEG-1	UPPER SEG-2	SEG-A REC.FLOW	INFLOW SEG-A CFS	OUTFLOW CFS	FLOW FROM SEG-1 CFS	FLOW FROM SEG-2 CFS	TOT INFLOW INTO SEG CFS	FLOW THROUGH CFS
1	0	0	0	0.0	3.1	0.0	0.0	78.8	75.7
2	1	0	0	0.0	5.1	75.7	0.0	3.0	73.6
3	2	0	0	0.0	5.1	73.6	0.0	7.0	75.5
4	3	0	0	0.0	5.1	75.5	0.0	11.2	81.6
5	4	0	0	0.0	6.2	81.6	0.0	30.2	105.6
6	5	0	9	10.0	16.1	105.6	0.0	3.2	92.7
7	6	0	0	0.0	10.0	92.7	0.0	3.0	85.7
8	7	0	0	0.0	8.6	85.7	0.0	0.0	77.1
9	0	0	0	0.0	3.4	0.0	0.0	11.9	8.5
10	9	0	0	0.0	3.0	8.5	0.0	0.3	5.8
11	10	0	0	0.0	1.6	5.8	0.0	0.2	4.4
12	8	11	0	0.0	4.5	77.1	4.4	10.6	87.6
13	12	0	0	0.0	0.0	87.6	0.0	41.2	128.8
14	0	0	0	0.0	0.0	0.0	0.0	172.8	172.9
15	13	14	0	0.0	0.0	128.8	172.8	30.2	331.8
16	15	0	0	0.0	0.0	331.8	0.0	16.2	348.0
17	0	0	0	0.0	0.0	0.0	0.0	7.5	7.5
18	17	0	0	0.0	0.0	7.5	0.0	13.1	20.6
19	18	0	0	0.0	0.0	20.6	0.0	2.3	22.9
20	16	19	0	0.0	0.0	348.0	22.9	8.4	379.3
21	20	0	0	0.0	0.0	379.3	0.0	9.0	388.3
22	21	0	0	0.0	0.0	388.3	0.0	3.9	392.2
23	22	0	0	0.0	0.0	392.2	0.0	5.3	397.5

TABLE D6 - HYDRAULIC CONDITIONS OF UPPER BLACKFOOT RIVER BASIN - 27-31 MAY,1976

SEG	INFLOW	OUTFLOW	FLOW THROUGH	VELOCITY	LENGTH	DEPTH	WIDTH	SAREA	VOLUME	REA02	RETENTION TIME
	CFS	CFS	CFS	FPS	FT	FT	FT	SQ FT	CU FT	1/DAY	HRS
1	78.8	3.1	75.7	2.63	6.917E 03	2.3	13.7	9.454E 04	2.173E 05	2.900	0.80
2	3.0	5.1	73.6	2.62	7.339E 03	2.3	13.6	9.961E 04	2.254E 05	2.942	0.85
3	7.0	5.1	75.5	2.63	6.230E 03	2.3	13.7	8.511E 04	1.953E 05	2.904	0.72
4	11.2	5.1	81.6	2.68	4.699E 03	2.4	13.9	6.545E 04	1.568E 05	2.790	0.53
5	30.2	6.2	105.6	2.83	5.174E 03	2.8	14.9	7.687E 04	2.123E 05	2.442	0.56
6	3.2	16.1	92.7	2.75	7.075E 03	2.6	14.4	1.017E 05	2.615E 05	2.612	0.78
7	3.0	10.0	85.7	3.19	7.498E 03	0.8	31.9	2.395E 05	2.006E 05	13.436	0.65
8	0.0	8.6	77.1	3.05	7.498E 03	0.8	30.4	2.281E 05	1.886E 05	13.092	0.68
9	11.9	3.4	8.5	1.22	4.330E 03	0.8	6.9	2.991E 04	2.393E 04	5.488	0.78
10	0.3	3.0	5.8	1.05	5.491E 03	0.8	5.5	3.032E 04	2.426E 04	4.685	1.16
11	0.2	1.6	4.4	0.93	5.914E 03	0.8	4.7	2.777E 04	2.222E 04	4.178	1.40
12	10.6	4.5	87.6	3.22	5.650E 03	0.8	32.3	1.823E 05	1.531E 05	13.508	0.49
13	41.2	0.0	128.8	3.77	1.315E 04	0.9	38.5	5.063E 05	4.466E 05	14.847	0.96
14	172.8	0.0	172.8	4.26	8.448E 03	0.9	44.1	3.723E 05	3.409E 05	15.956	0.55
15	30.2	0.0	331.8	4.11	7.128E 03	2.1	38.2	2.721E 05	5.757E 05	5.047	0.48
16	16.2	0.0	348.0	4.17	6.494E 03	2.1	38.9	2.525E 05	5.424E 05	5.021	0.43
17	7.5	0.0	7.5	1.32	6.072E 03	0.8	5.7	3.456E 04	2.764E 04	5.905	1.02
18	13.1	0.0	20.6	1.78	7.392E 03	0.9	12.9	9.544E 04	8.533E 04	6.896	1.15
19	2.3	0.0	22.9	1.84	1.014E 04	0.9	13.5	1.364E 05	1.260E 05	6.815	1.53
20	8.4	0.0	379.3	4.28	7.445E 03	2.2	40.2	2.994E 05	6.604E 05	4.972	0.48
21	9.0	0.0	388.3	4.31	8.395E 03	2.2	40.6	3.407E 05	7.570E 05	4.959	0.54
22	3.9	0.0	392.2	4.32	6.600E 03	2.2	40.7	2.689E 05	5.993E 05	4.954	0.42
23	5.3	0.0	397.5	4.34	6.864E 03	2.2	41.0	2.811E 05	6.291E 05	4.946	0.44

TABLE D7-WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 31 MAY, 1976 12.0 HOUR

SEG	TEMP C	TSS MG/L	COLIF MPN/00	BOD MG/L	D O MG/L	D O 0/0	P H	CO2 MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	ALKA MG/L	TDS MG/L	TBTY MG/L	HARD MG/L	CHRM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	8.4	94.	2.	0.5	9.3	87.	7.0	9.44	0.07	0.11	0.18	142.	206.	17.9	140.	.001	.017	.002	.001	.001	.001	1.30
2	8.9	93.	2.	0.5	9.5	90.	7.1	8.65	0.07	0.11	0.18	142.	207.	17.8	141.	.001	.017	.002	.001	.001	.001	1.29
3	9.0	91.	2.	0.5	9.7	92.	7.1	8.18	0.07	0.12	0.18	144.	207.	17.5	143.	.001	.017	.002	.001	.001	.001	1.27
4	8.7	88.	2.	0.6	9.8	92.	7.1	7.96	0.07	0.12	0.17	147.	207.	17.0	145.	.001	.016	.003	.001	.001	.001	1.24
5	8.1	72.	2.	0.5	9.8	91.	7.2	6.59	0.06	0.11	0.15	150.	206.	13.8	148.	.001	.013	.004	.001	.001	.001	1.33
6	8.1	70.	2.	0.6	10.0	93.	7.2	5.99	0.06	0.12	0.15	149.	206.	13.8	149.	.001	.013	.004	.001	.001	.001	1.31
7	9.1	69.	2.	0.6	10.2	97.	7.4	4.25	0.06	0.12	0.15	149.	206.	13.4	149.	.001	.013	.004	.001	.001	.001	1.32
8	9.9	68.	2.	0.5	10.3	101.	7.5	3.18	0.06	0.13	0.14	149.	206.	13.4	149.	.001	.013	.004	.001	.001	.001	1.31
9	9.1	61.	2.	0.6	10.0	96.	7.4	4.47	0.05	0.14	0.18	156.	206.	13.7	150.	.001	.012	.005	.001	.001	.001	1.26
10	10.2	57.	2.	0.6	10.1	100.	7.5	3.75	0.05	0.14	0.18	157.	206.	13.7	150.	.001	.012	.005	.001	.001	.001	1.25
11	11.2	54.	2.	0.6	10.3	103.	7.5	3.26	0.05	0.15	0.17	158.	206.	13.8	151.	.001	.011	.006	.001	.001	.001	1.23
12	9.8	62.	2.	0.6	10.5	102.	7.6	2.38	0.05	0.12	0.14	151.	206.	12.1	150.	.001	.012	.005	.001	.001	.001	1.35
13	10.1	44.	2.	0.5	10.4	102.	7.8	1.66	0.05	0.12	0.13	156.	202.	8.8	157.	.001	.010	.007	.001	.001	.001	0.98
14	13.6	28.	24.	1.9	8.7	92.	8.0	0.84	0.04	0.10	0.16	136.	187.	10.8	133.	.008	.019	.008	.001	.001	.001	0.62
15	11.6	34.	13.	1.2	9.6	98.	7.8	1.40	0.05	0.11	0.14	147.	193.	9.1	146.	.004	.015	.007	.001	.001	.001	0.76
16	11.1	33.	12.	1.2	9.8	98.	7.8	1.38	0.05	0.11	0.14	148.	193.	8.7	147.	.004	.014	.007	.001	.001	.001	0.74
17	14.0	19.	5.	1.0	9.1	98.	6.9	11.12	0.10	0.09	0.13	139.	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.03
18	10.9	29.	4.	1.0	9.4	94.	7.1	8.18	0.10	0.09	0.15	139.	189.	8.7	135.	.001	.017	.004	.001	.001	.001	0.78
19	11.8	29.	4.	1.0	9.7	99.	7.2	6.34	0.10	0.09	0.15	139.	189.	9.0	135.	.001	.017	.004	.001	.001	.001	0.76
20	10.7	33.	11.	1.1	9.9	99.	7.8	1.65	0.05	0.11	0.14	148.	193.	8.6	147.	.004	.014	.007	.001	.001	.001	0.73
21	10.3	34.	11.	1.1	10.0	99.	7.8	1.58	0.05	0.12	0.14	149.	194.	8.5	148.	.004	.014	.007	.001	.001	.001	0.72
22	10.1	35.	11.	1.1	10.1	99.	7.8	1.59	0.05	0.12	0.14	149.	194.	8.5	148.	.004	.014	.007	.001	.001	.001	0.72
23	10.0	35.	10.	1.1	10.2	99.	7.8	1.59	0.06	0.12	0.14	150.	194.	8.5	148.	.004	.015	.007	.001	.001	.001	0.72

TABLE D8 -WATER QUALITY SIMULATIONS FOR UPPER BLACKFOOT RIVER BASIN - 31 MAY,1976 24.0 HOUR

SEG	TEMP C	TSS MG/L	COLIF MPN/00	BOD MG/L	D O MG/L	D O 0/0	P H	CO2 MG/L	PO4P MG/L	NH3N MG/L	NO3N MG/L	ALKA MG/L	TDS MG/L	TBTY MG/L	HARD MG/L	CHPM MG/L	ZINC MG/L	COPR MG/L	VNDM MG/L	CDM MG/L	ARSC MG/L	ORGN MG/L
1	7.5	94.	2.	0.5	9.3	86.	7.0	9.44	0.07	0.11	0.18	142.	206.	17.9	140.	.001	.017	.002	.001	.001	.001	1.30
2	7.4	93.	2.	0.5	9.5	87.	7.1	8.65	0.07	0.11	0.18	142.	207.	17.8	141.	.001	.017	.002	.001	.001	.001	1.29
3	7.3	91.	2.	0.5	9.7	88.	7.1	8.18	0.07	0.12	0.18	144.	207.	17.5	143.	.001	.017	.002	.001	.001	.001	1.27
4	7.4	88.	2.	0.6	9.8	89.	7.1	8.11	0.07	0.12	0.17	147.	207.	17.0	145.	.001	.016	.003	.001	.001	.001	1.24
5	7.3	72.	2.	0.6	9.8	89.	7.2	6.58	0.06	0.11	0.15	150.	206.	13.8	148.	.001	.013	.004	.001	.001	.001	1.32
6	7.5	70.	2.	0.6	9.9	91.	7.3	5.97	0.06	0.12	0.15	149.	206.	13.8	149.	.001	.013	.004	.001	.001	.001	1.31
7	7.4	69.	2.	0.6	10.2	93.	7.4	4.24	0.06	0.12	0.15	149.	206.	13.4	149.	.001	.013	.004	.001	.001	.001	1.32
8	7.5	68.	2.	0.6	10.4	95.	7.5	3.14	0.06	0.13	0.14	149.	206.	13.4	149.	.001	.013	.004	.001	.001	.001	1.31
9	7.3	61.	2.	0.6	10.0	91.	7.4	4.42	0.05	0.14	0.18	156.	206.	13.7	150.	.001	.012	.005	.001	.001	.001	1.26
10	7.2	57.	2.	0.6	10.1	92.	7.5	3.70	0.05	0.15	0.18	157.	206.	13.7	150.	.001	.012	.005	.001	.001	.001	1.24
11	7.2	54.	2.	0.6	10.2	93.	7.6	3.16	0.05	0.15	0.17	158.	206.	13.8	151.	.001	.011	.006	.001	.001	.001	1.23
12	7.4	62.	2.	0.6	10.5	96.	7.7	2.35	0.05	0.13	0.14	151.	206.	12.1	150.	.001	.012	.005	.001	.001	.001	1.35
13	7.2	44.	2.	0.5	10.5	96.	7.8	1.64	0.05	0.12	0.13	156.	202.	8.8	157.	.001	.010	.007	.001	.001	.001	0.98
14	11.9	28.	24.	1.9	8.8	90.	8.0	0.85	0.04	0.10	0.16	136.	187.	10.8	133.	.008	.019	.008	.001	.001	.001	0.62
15	9.8	34.	13.	1.2	9.6	94.	7.9	1.39	0.05	0.11	0.14	147.	193.	9.1	146.	.004	.015	.007	.001	.001	.001	0.76
16	9.9	33.	12.	1.1	9.7	94.	7.9	1.34	0.05	0.11	0.14	148.	193.	8.7	147.	.004	.014	.007	.001	.001	.001	0.74
17	10.8	19.	5.	1.0	9.3	92.	6.9	11.55	0.10	0.09	0.13	139.	190.	6.0	138.	.001	.019	.002	.001	.001	.001	1.03
18	7.2	29.	4.	1.0	9.6	87.	7.1	8.51	0.10	0.09	0.15	139.	189.	8.7	135.	.001	.017	.004	.001	.001	.001	0.78
19	6.8	29.	4.	1.0	9.9	89.	7.2	6.59	0.10	0.09	0.15	139.	189.	9.0	135.	.001	.017	.004	.001	.001	.001	0.76
20	10.0	33.	11.	1.1	9.7	95.	7.8	1.57	0.05	0.11	0.14	148.	193.	8.6	147.	.004	.014	.007	.001	.001	.001	0.73
21	10.3	34.	11.	1.1	9.7	96.	7.8	1.47	0.05	0.12	0.14	149.	194.	8.5	148.	.004	.014	.007	.001	.001	.001	0.72
22	10.8	35.	10.	1.1	9.7	96.	7.8	1.44	0.05	0.12	0.14	149.	194.	8.5	148.	.004	.014	.007	.001	.001	.001	0.72
23	11.2	35.	10.	1.1	9.7	97.	7.8	1.44	0.06	0.12	0.14	150.	194.	8.5	148.	.004	.015	.007	.001	.001	.001	0.72

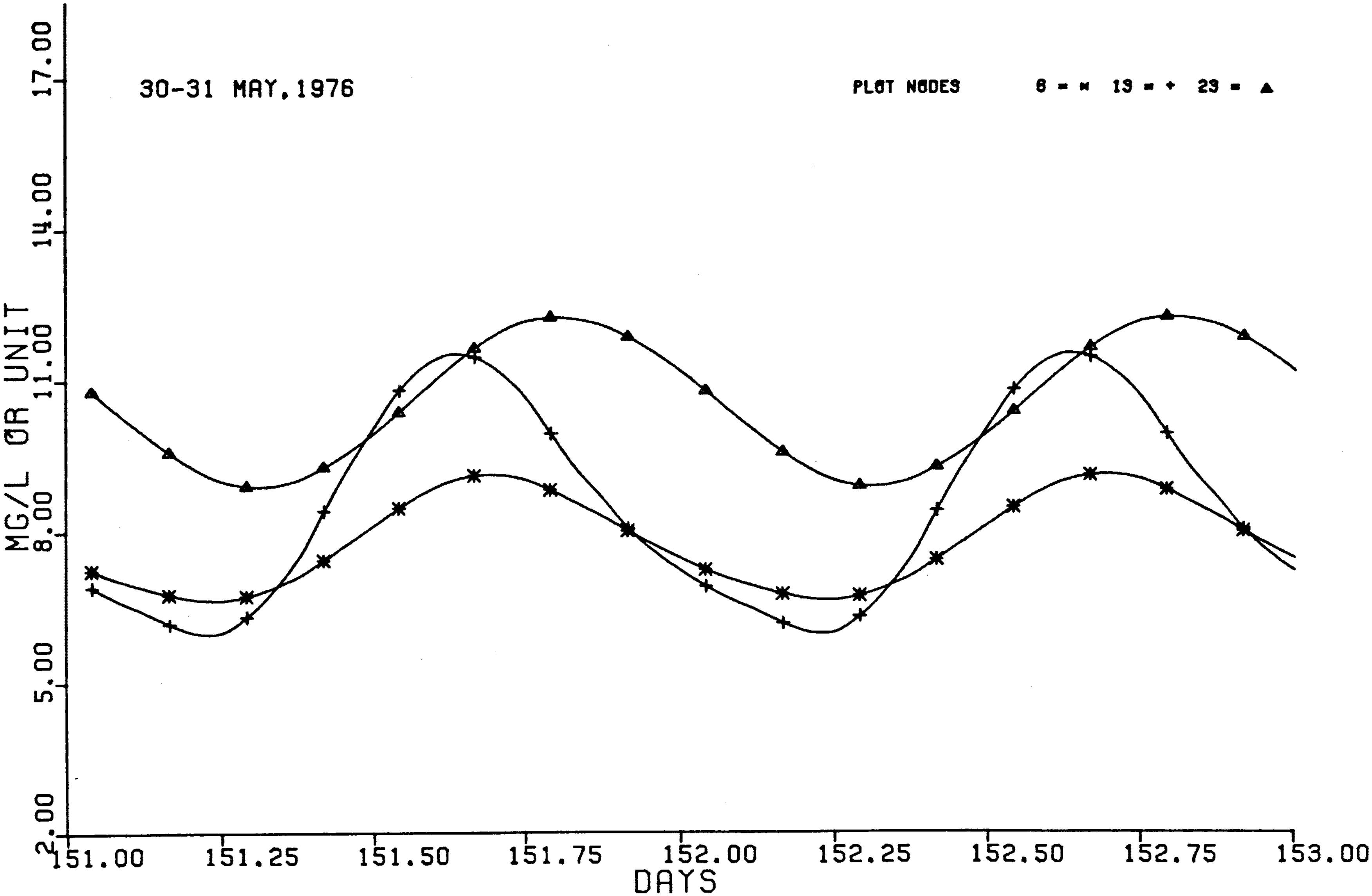

FIGURE D1 -TIME PLOT OF TEMPERATURE (°C), UPPER BLACKFOOT RIVER BASIN

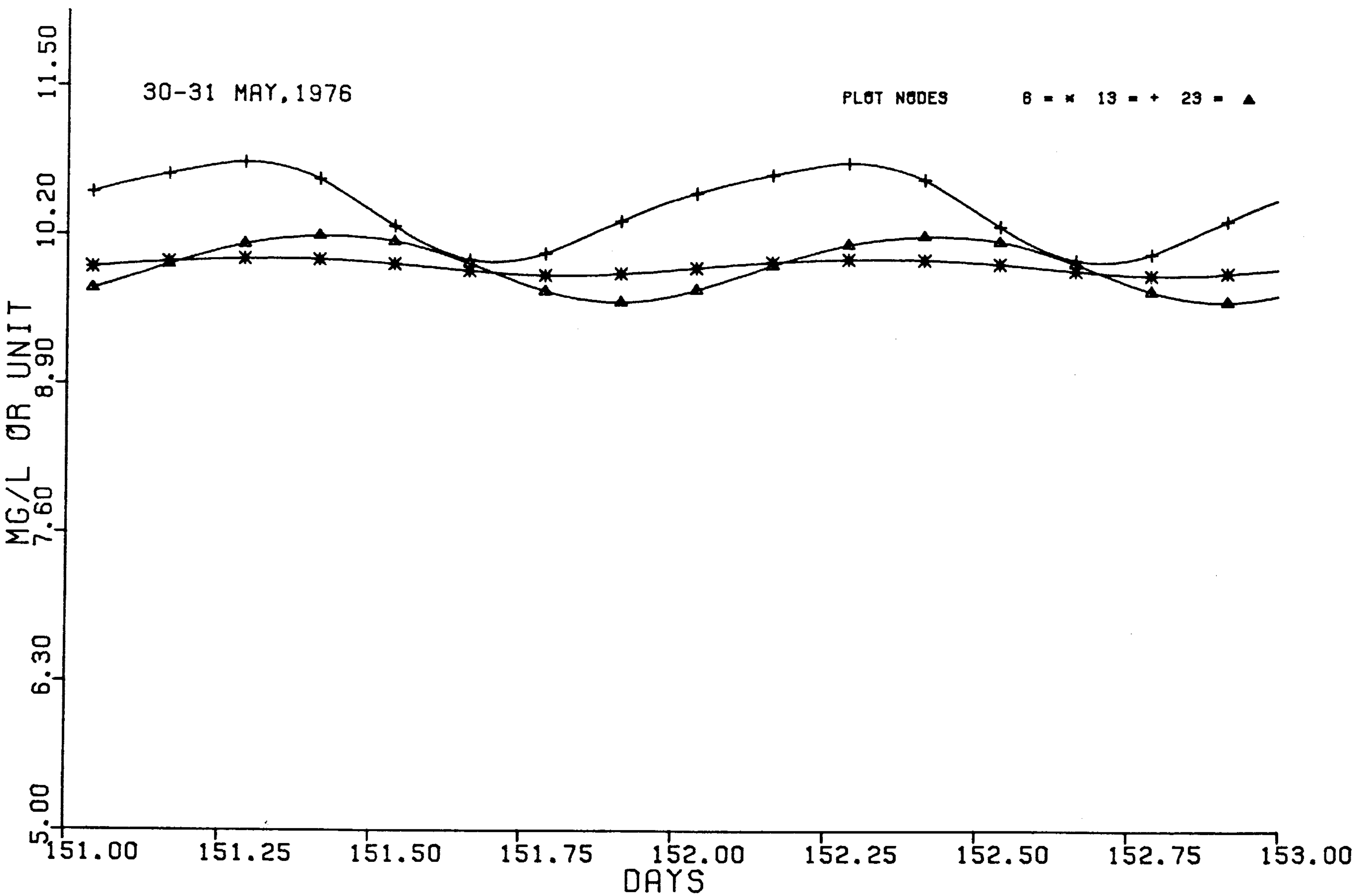

FIGURE D2-TIME PLOT OF DO(MG/L), UPPER BLACKFOOT RIVER BASIN

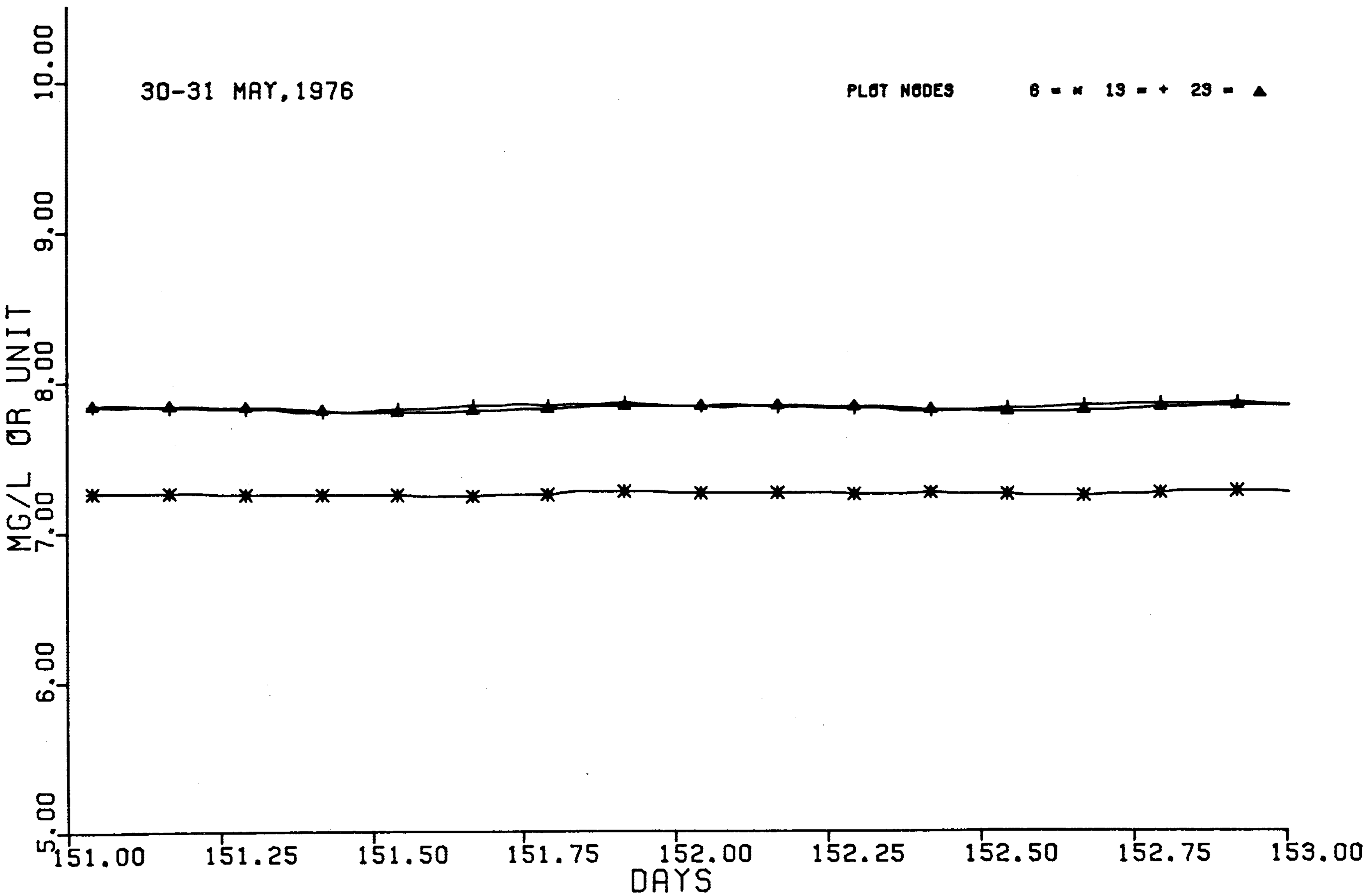

FIGURE D3 -TIME PLOT OF PH, UPPER BLACKFOOT RIVER BASIN

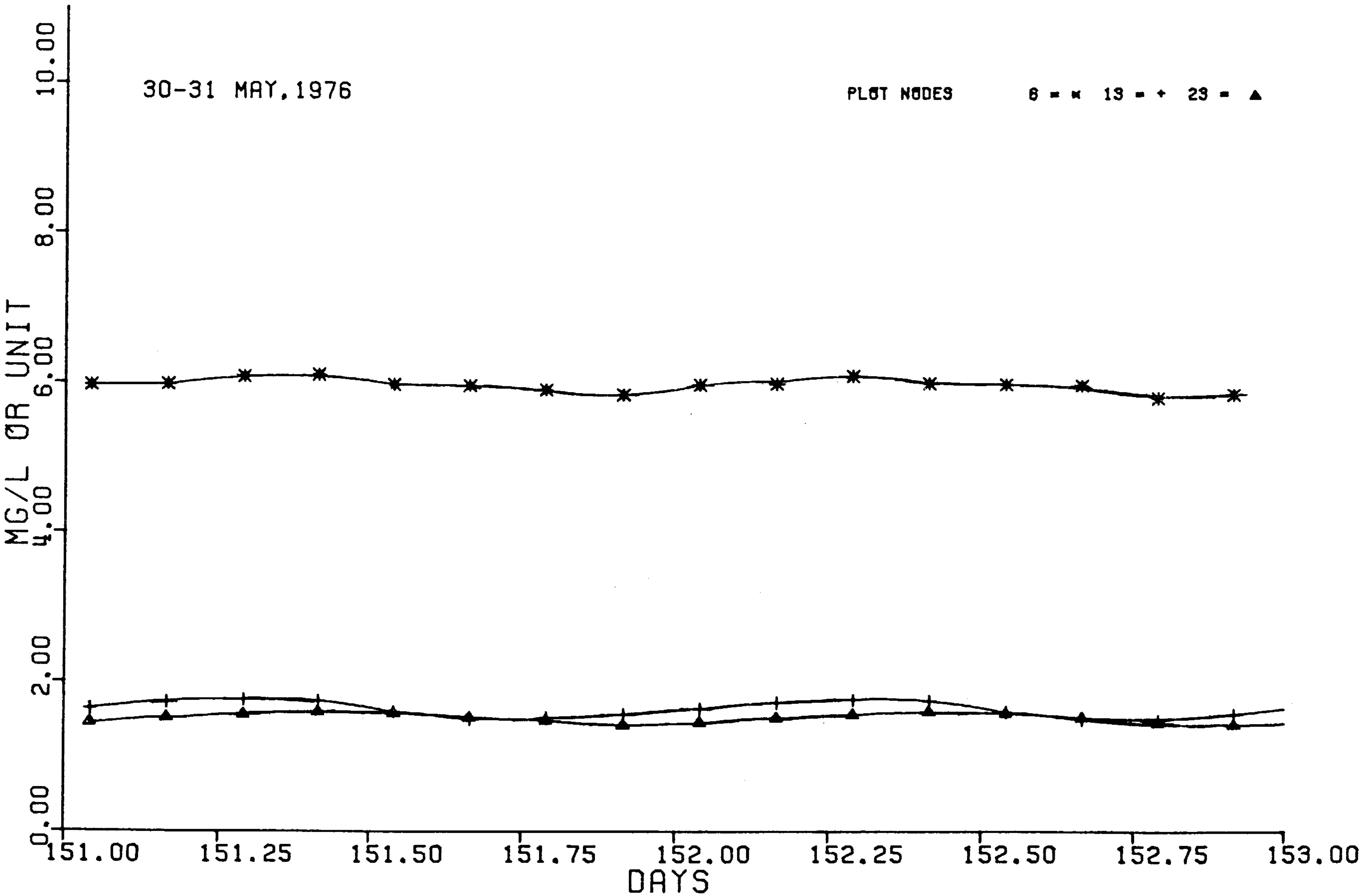

FIGURE D4 -TIME PLOT OF CO2 (MG/L), UPPER BLACKFOOT RIVER BASIN

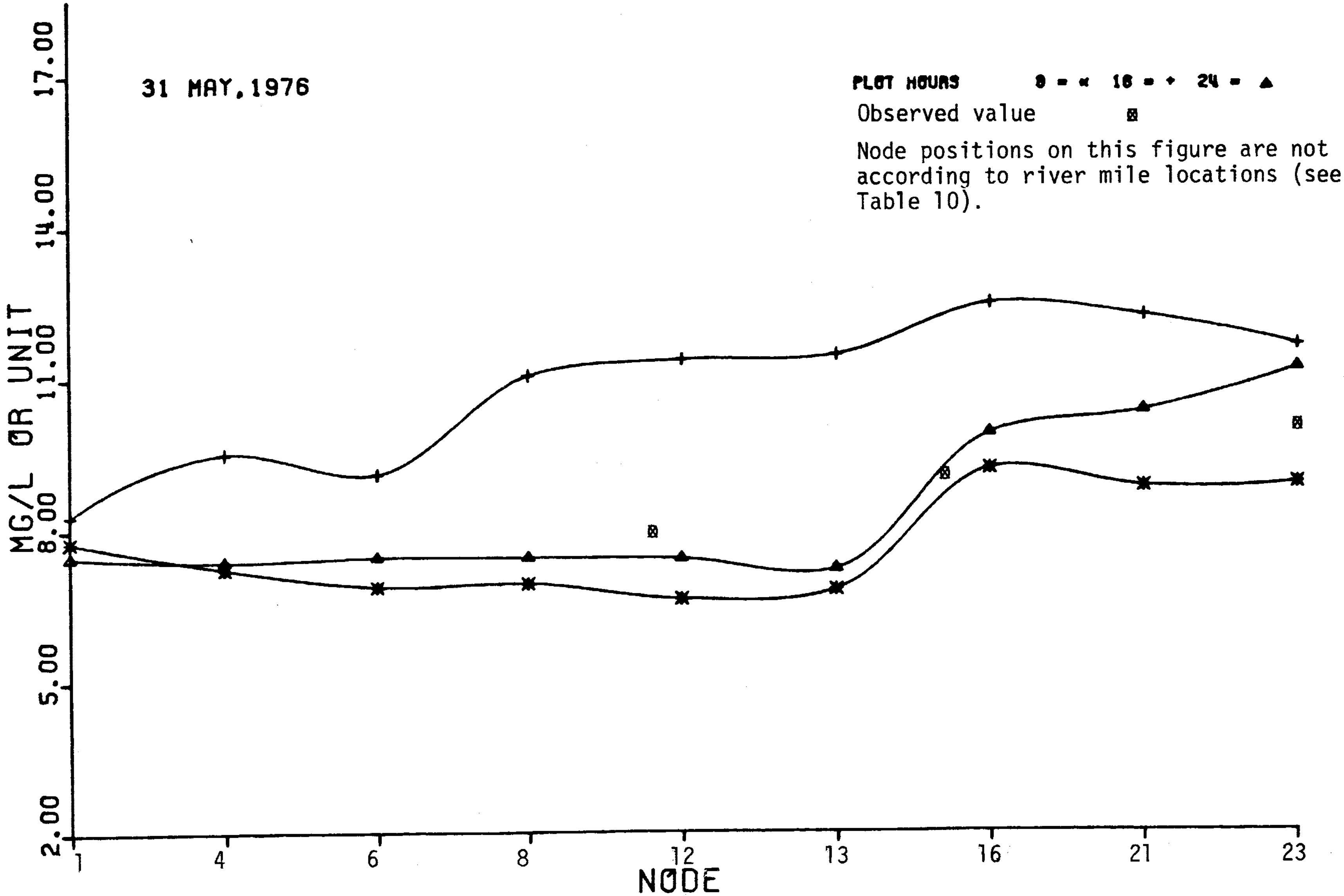

FIGURE D5 -LONGITUDINAL PLOT OF TEMPERATURE (°C), UPPER BLACKFOOT RIVER BASIN

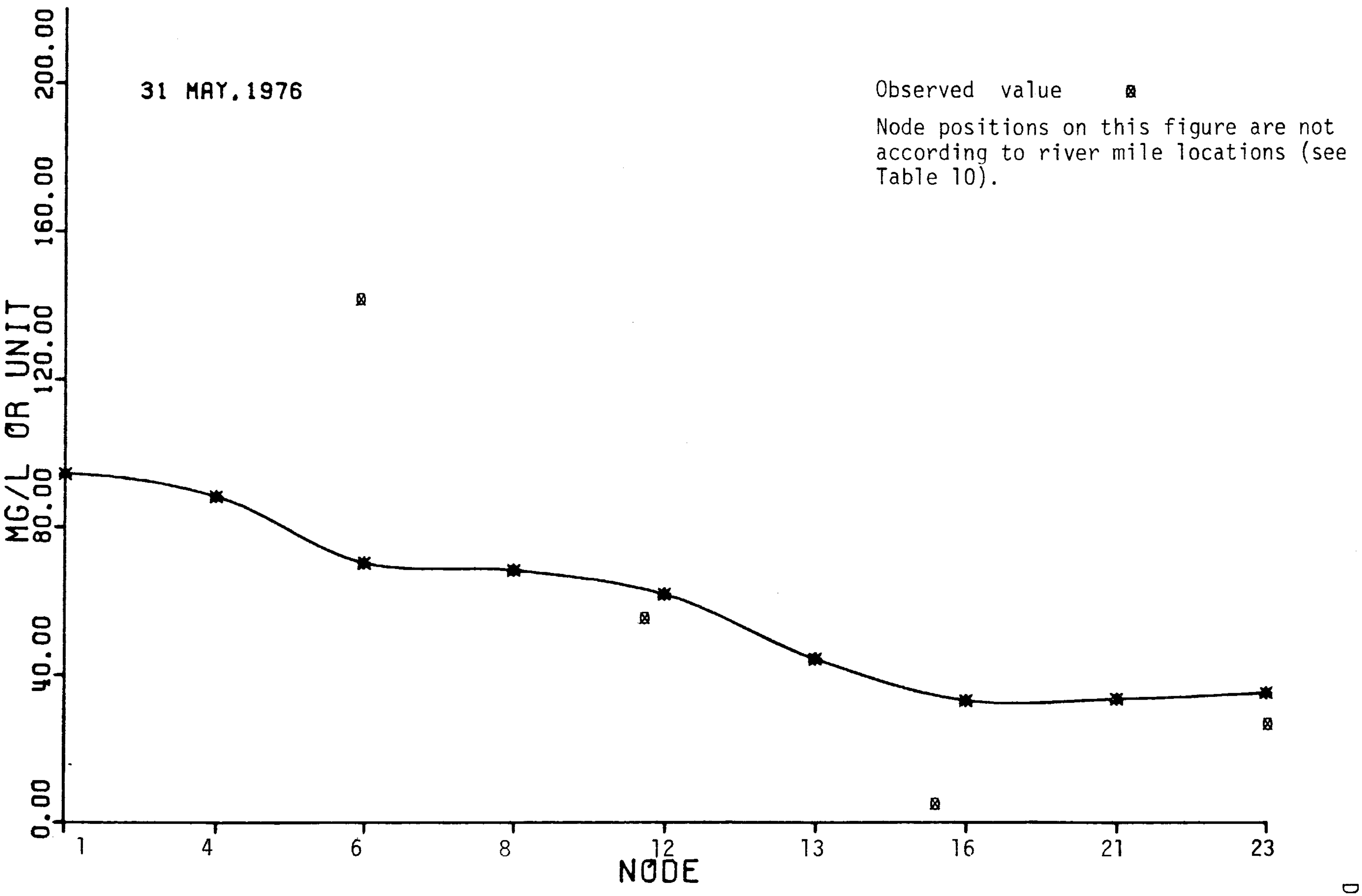

FIGURE D6 -LONGITUDINAL PLOT OF TSS (MG/L), UPPER BLACKFOOT RIVER BASIN

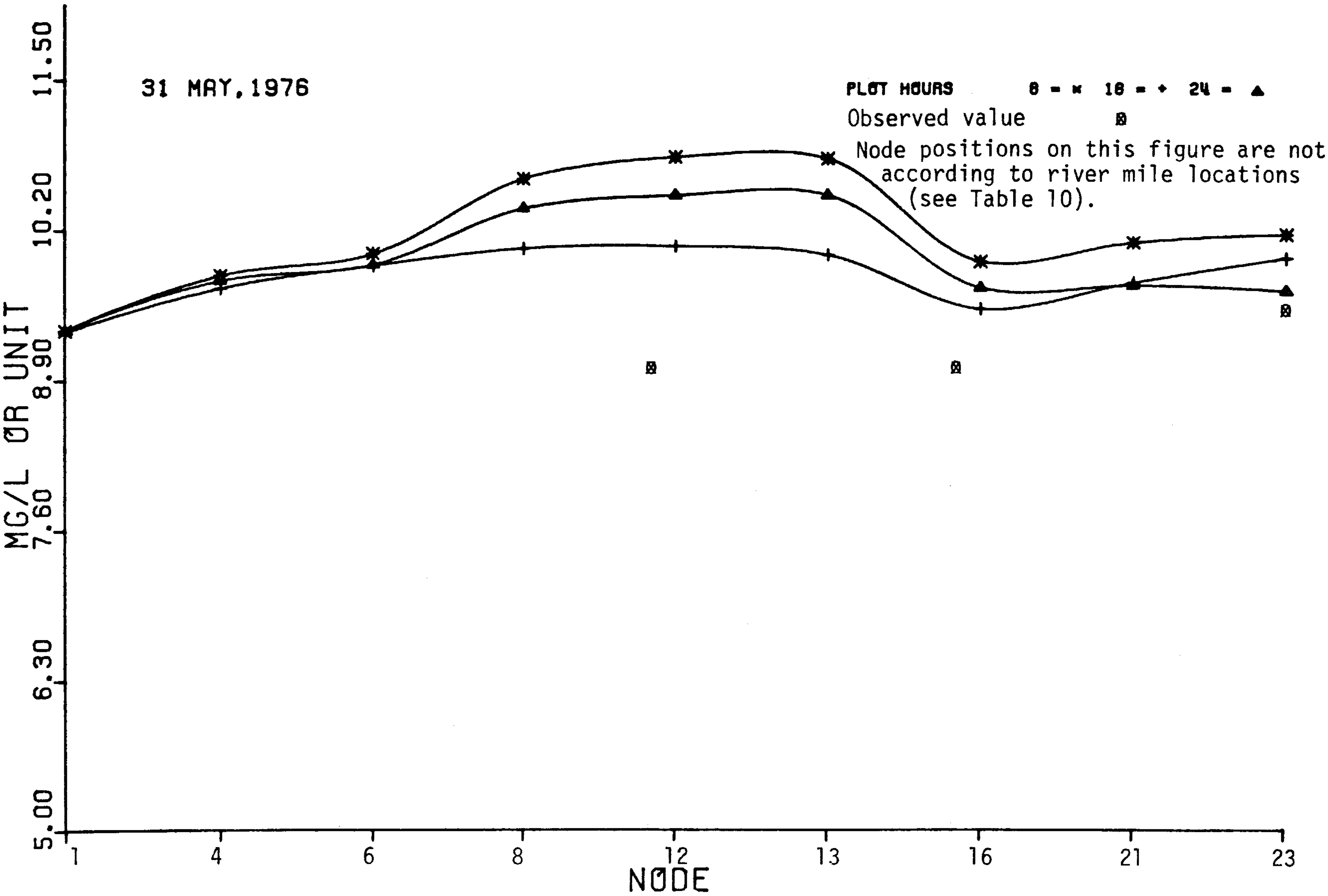

FIGURE D7-LONGITUDINAL PLOT OF DO (MG/L), UPPER BLACKFOOT RIVER BASIN

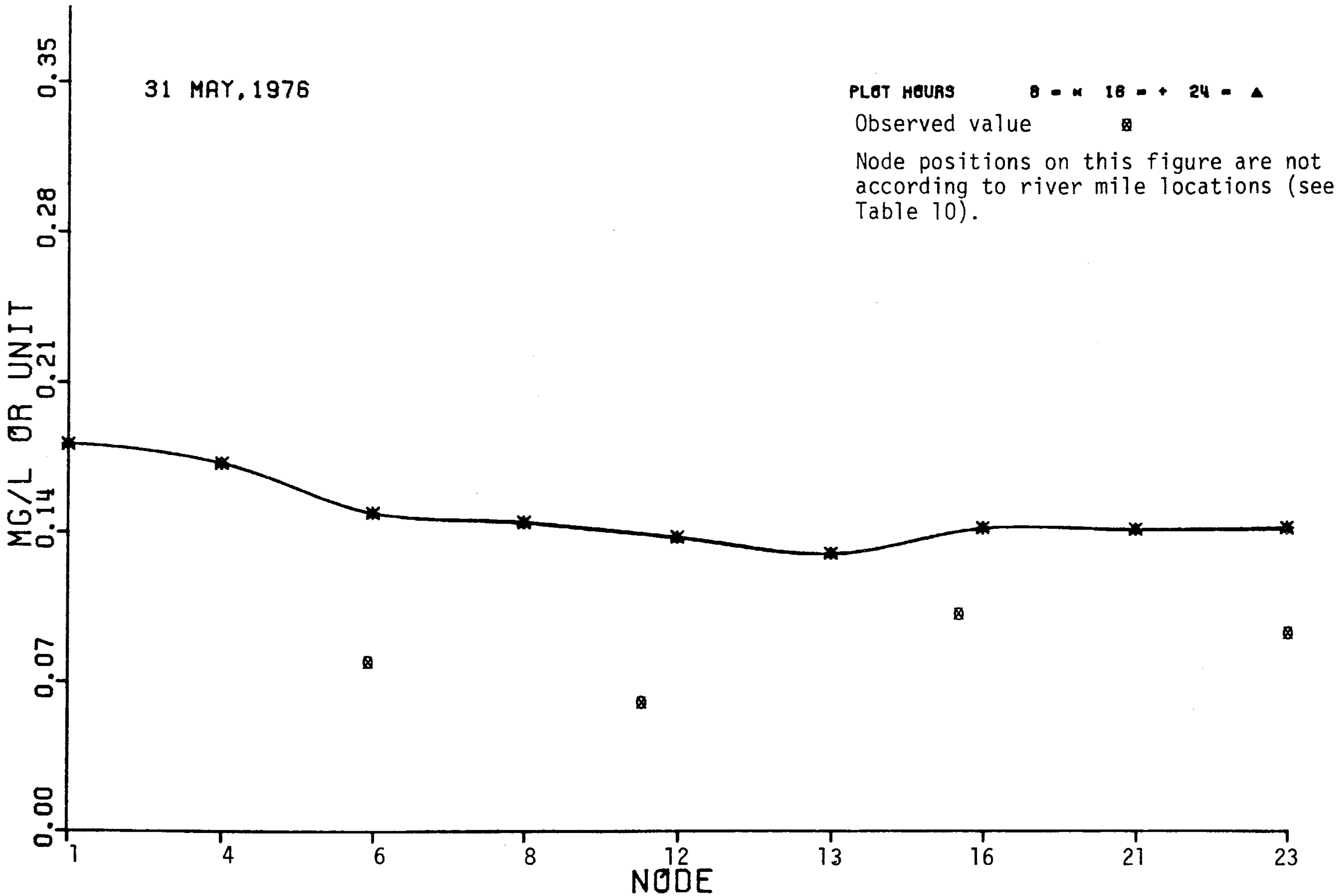

FIGURE D8 -LONGITUDINAL PLOT OF NO3-N (MG/L), UPPER BLACKFOOT RIVER BASIN

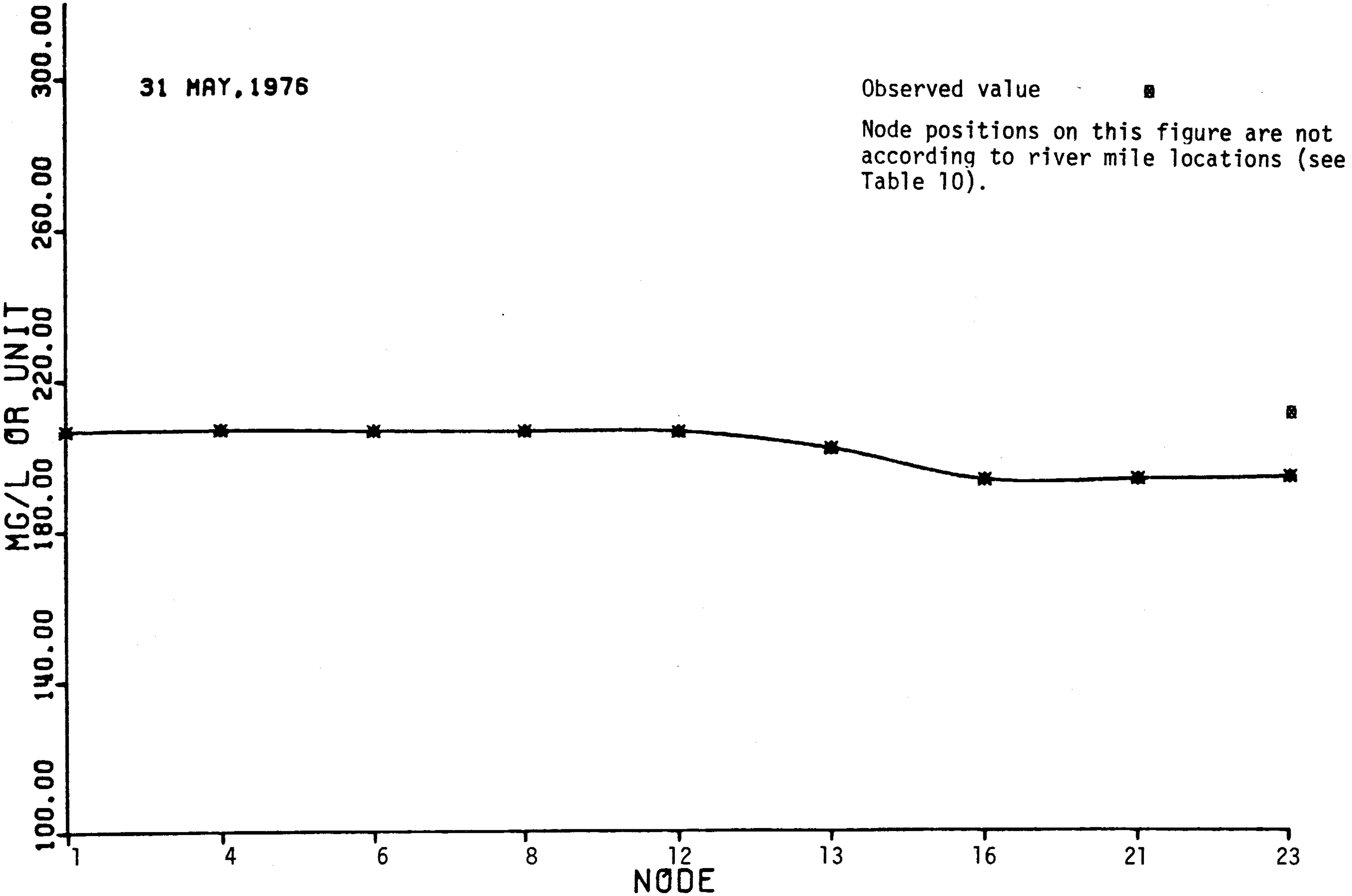

FIGURE D9 -LONGITUDINAL PLOT OF TDS(MG/L), UPPER BLACKFOOT RIVER BASIN

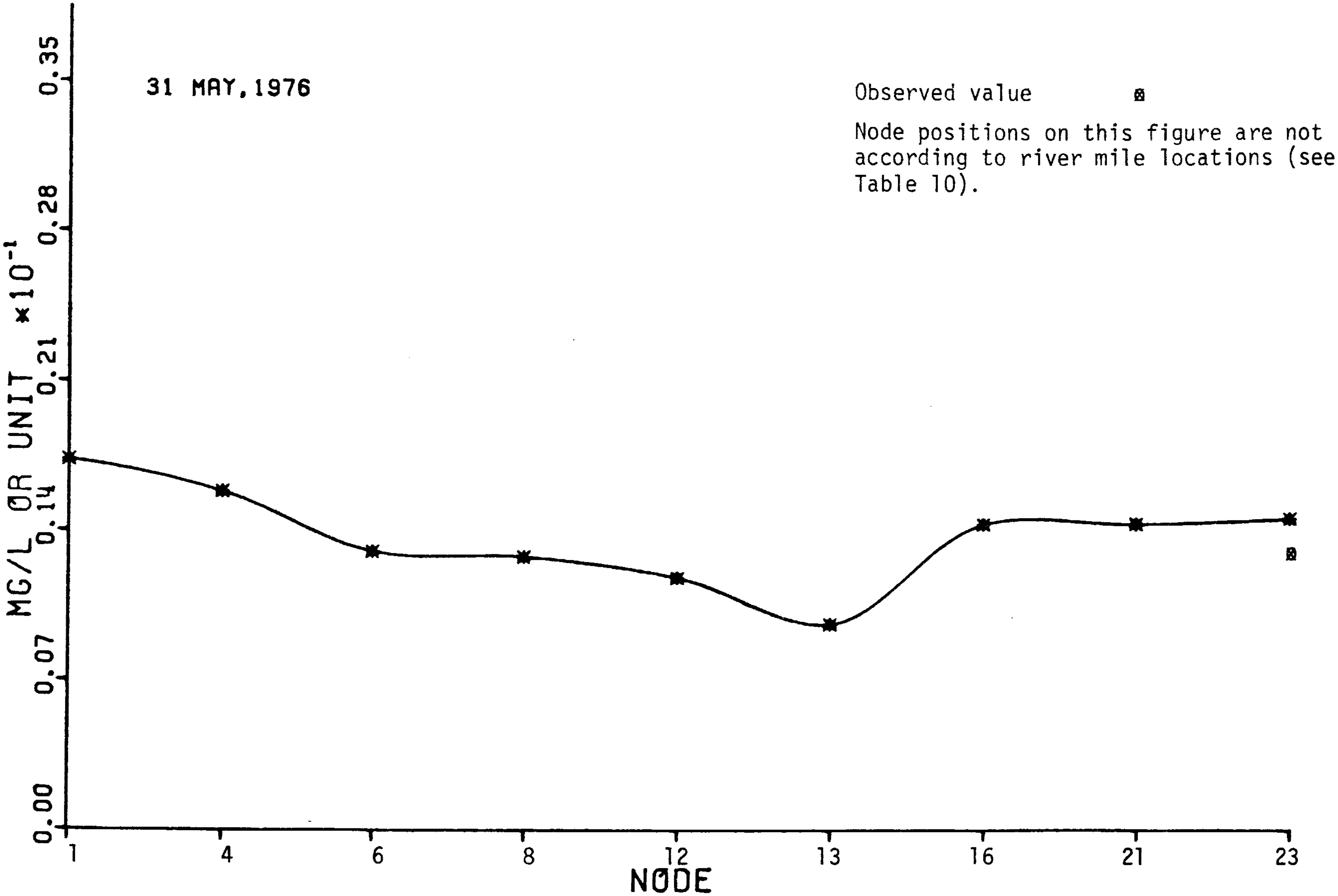

FIGURE D10-LONGITUDINAL PLOT OF ZINC (MG/L), UPPER BLACKFOOT RIVER BASIN

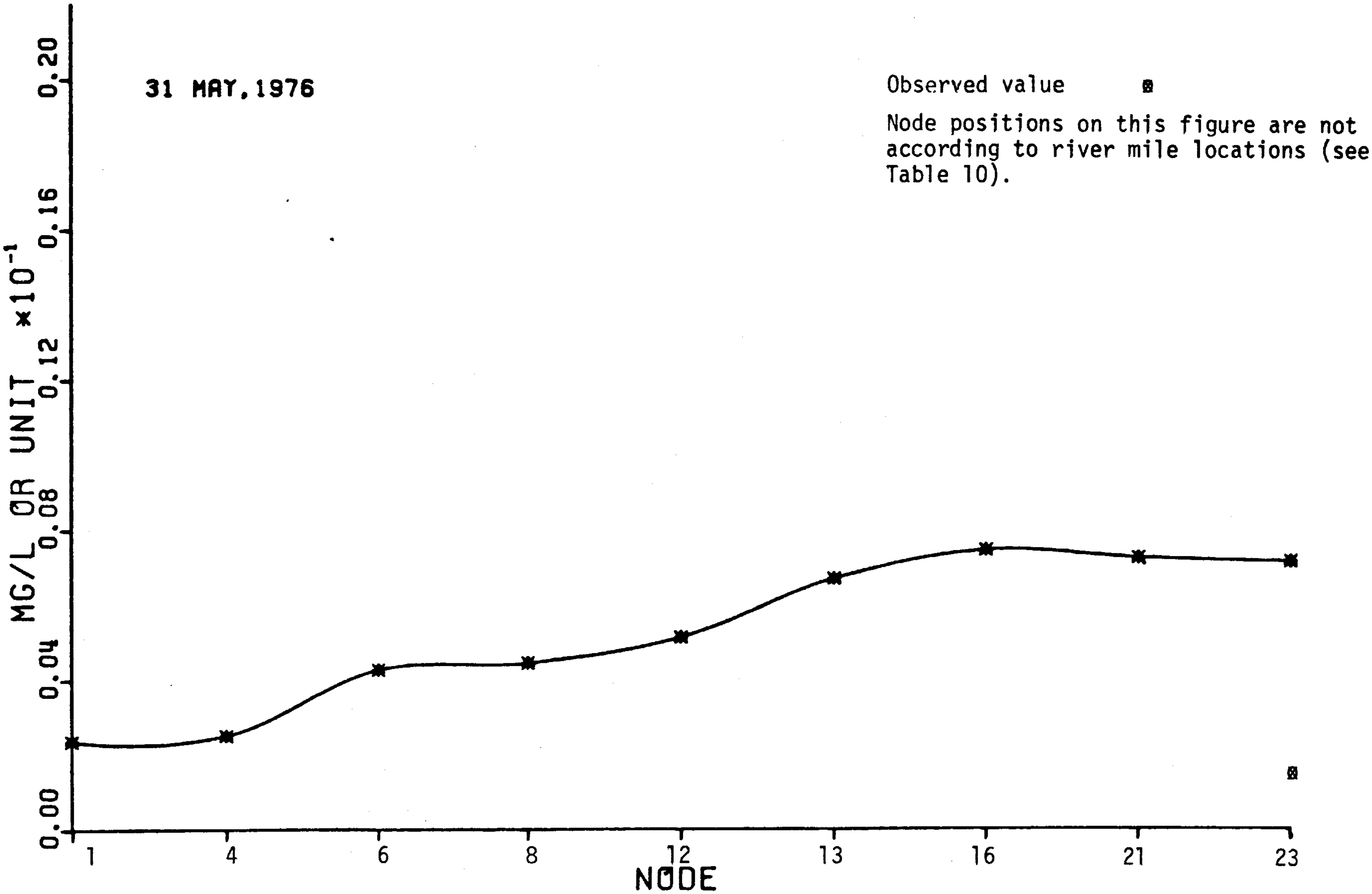

FIGURE D11-LONGITUDINAL PLOT OF COPPER (MG/L), UPPER BLACKFOOT RIVER BASIN

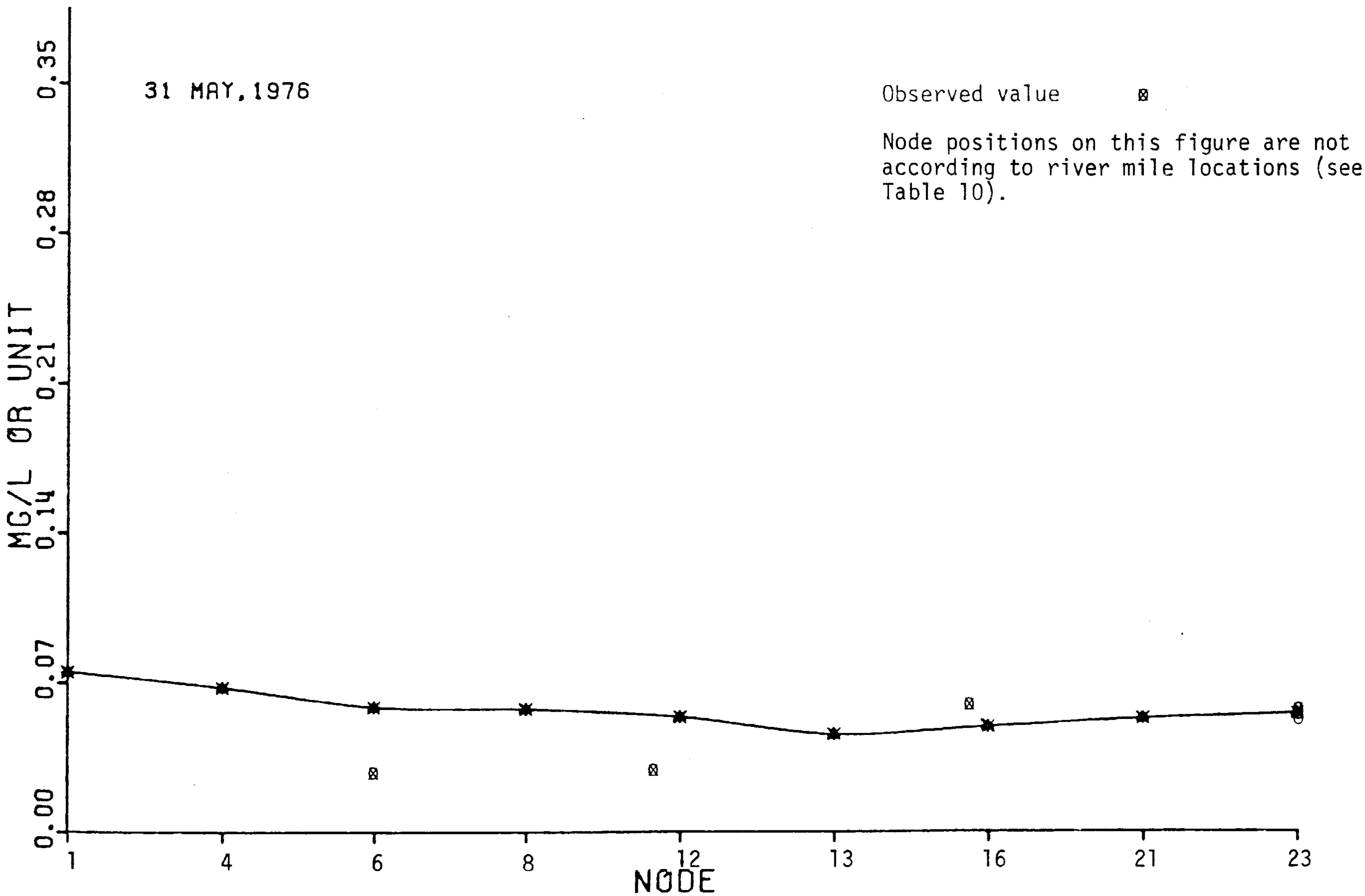

FIGURE D12-LONGITUDINAL PLOT OF PO4-P (MG/L), UPPER BLACKFOOT RIVER BASIN

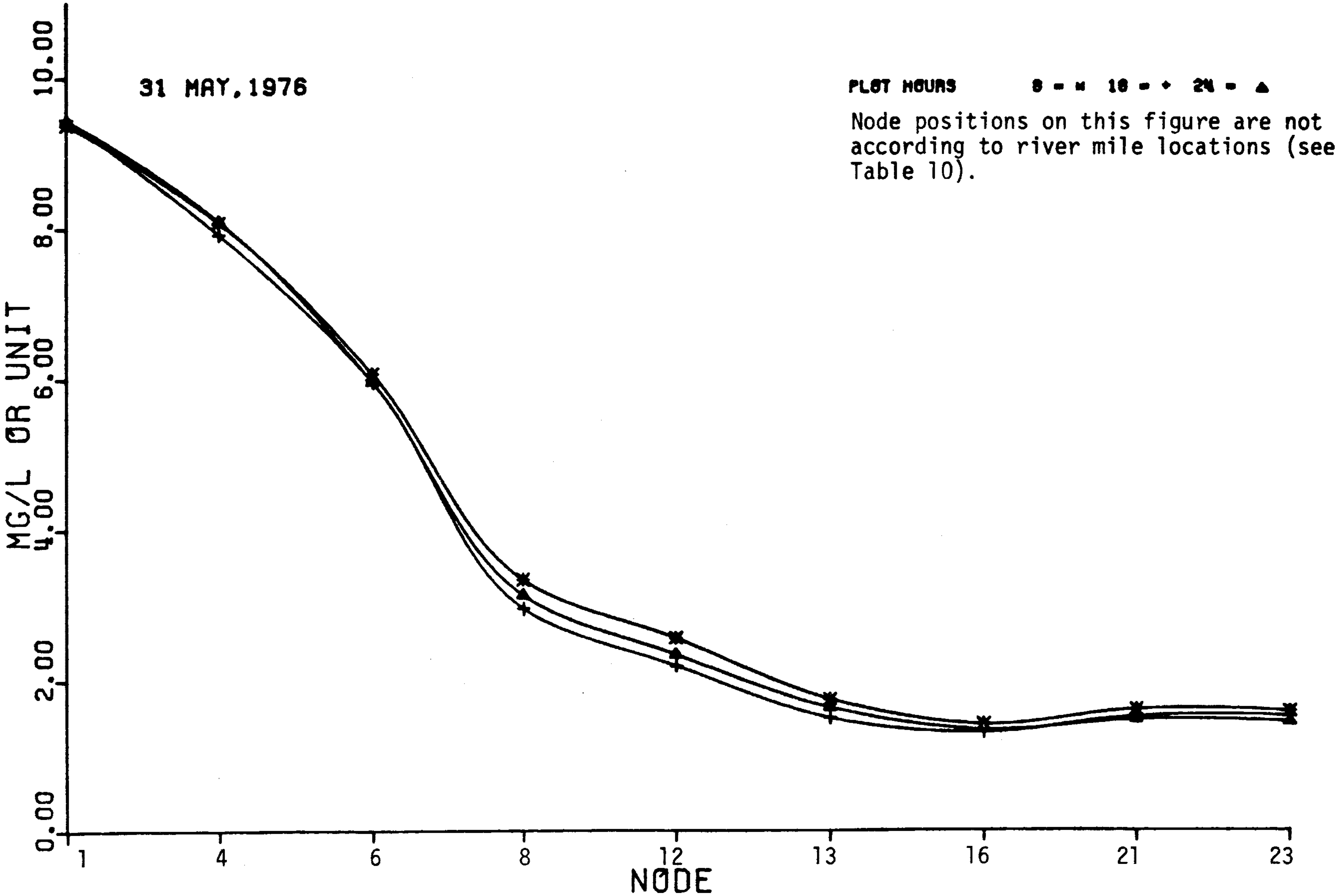

FIGURE D13—LONGITUDINAL PLOT OF CO2 (MG/L), UPPER BLACKFOOT RIVER BASIN

APPENDIX E

Three Hourly Longitudinal Plots of Water Quality Simulations with Arbitrary Waste Inflows and Actual Inflows Combined for 27 and 28 May, 1976, Upper Blackfoot River Basin.

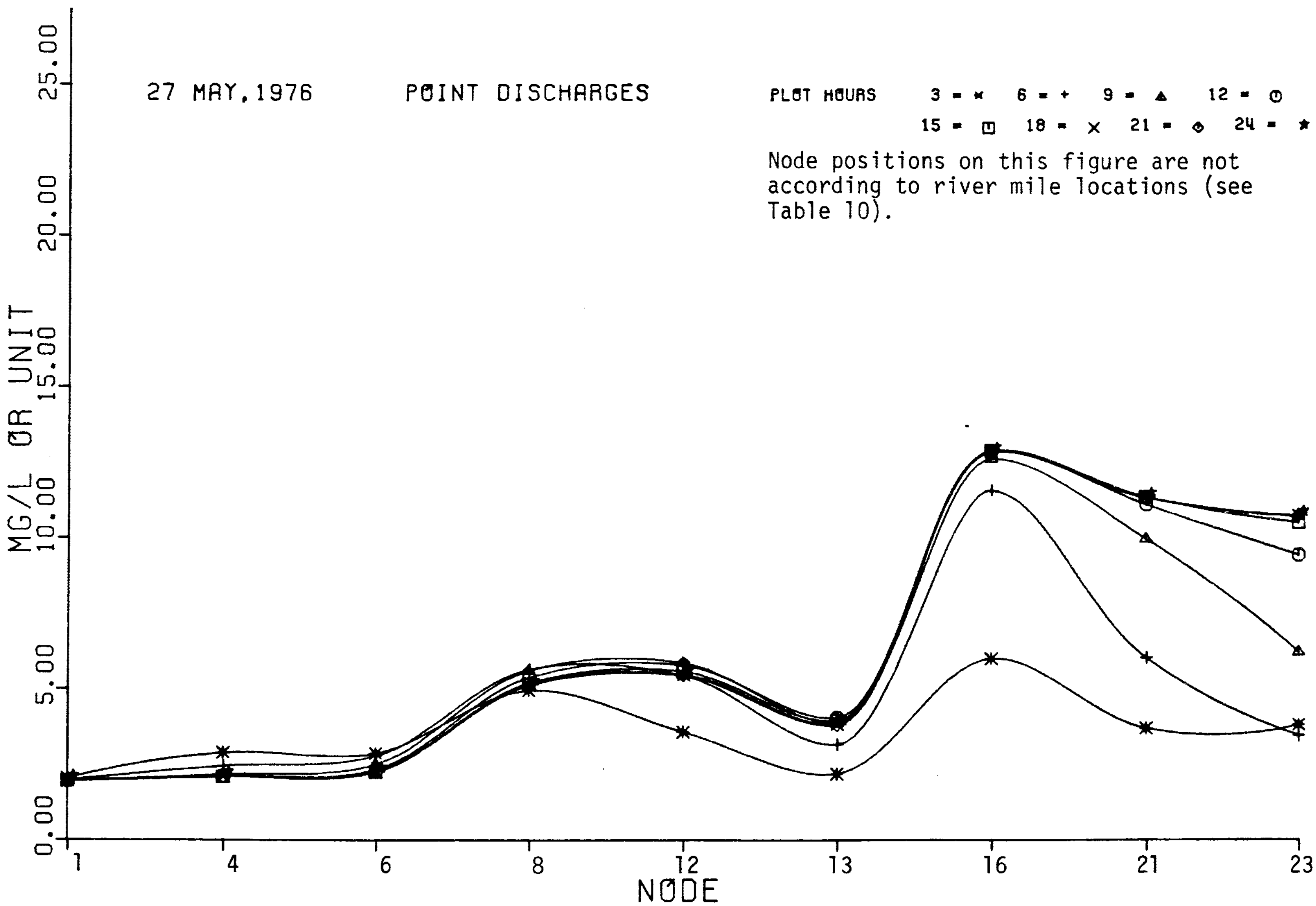

FIGURE E1 -LONGITUDINAL PLOT OF COLIF(MPN/OO), UPPER BLACKFOOT RIVER BASIN

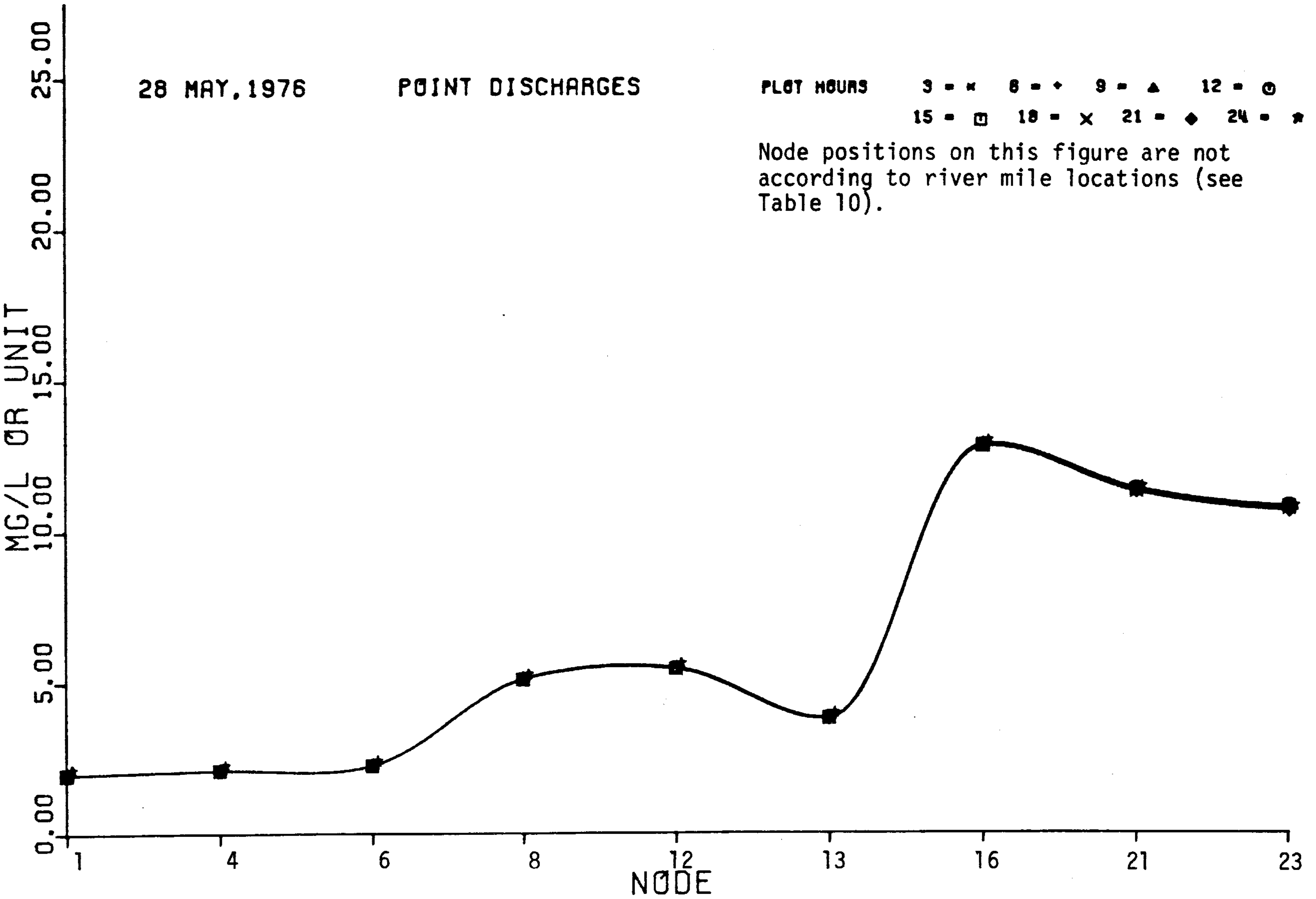

FIGURE E2 -LONGITUDINAL PLOT OF COLIF (MPN/OO), UPPER BLACKFOOT RIVER BASIN

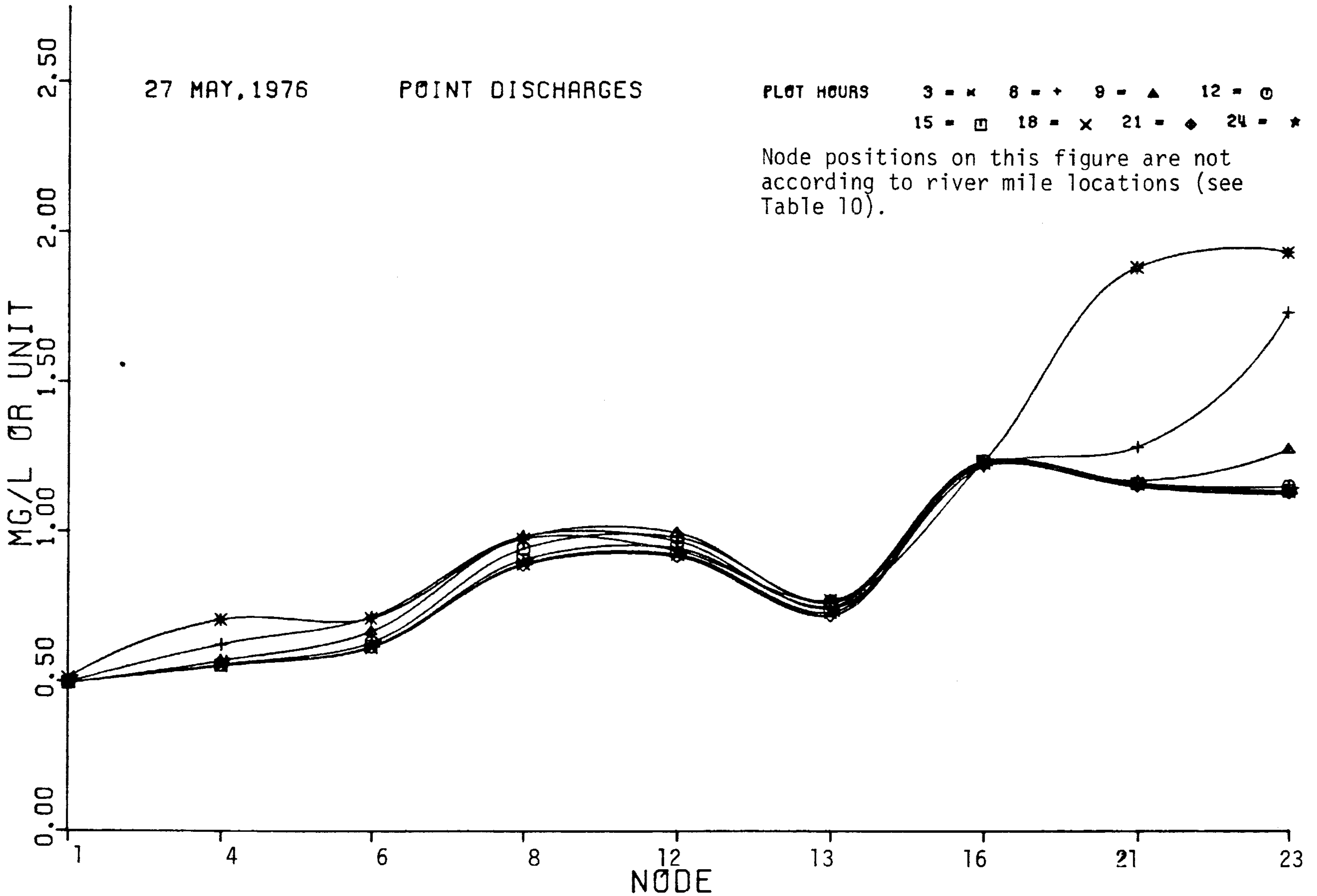

FIGURE E3 - LONGITUDINAL PLOT OF BOD (MG/L), UPPER BLACKFOOT RIVER BASIN

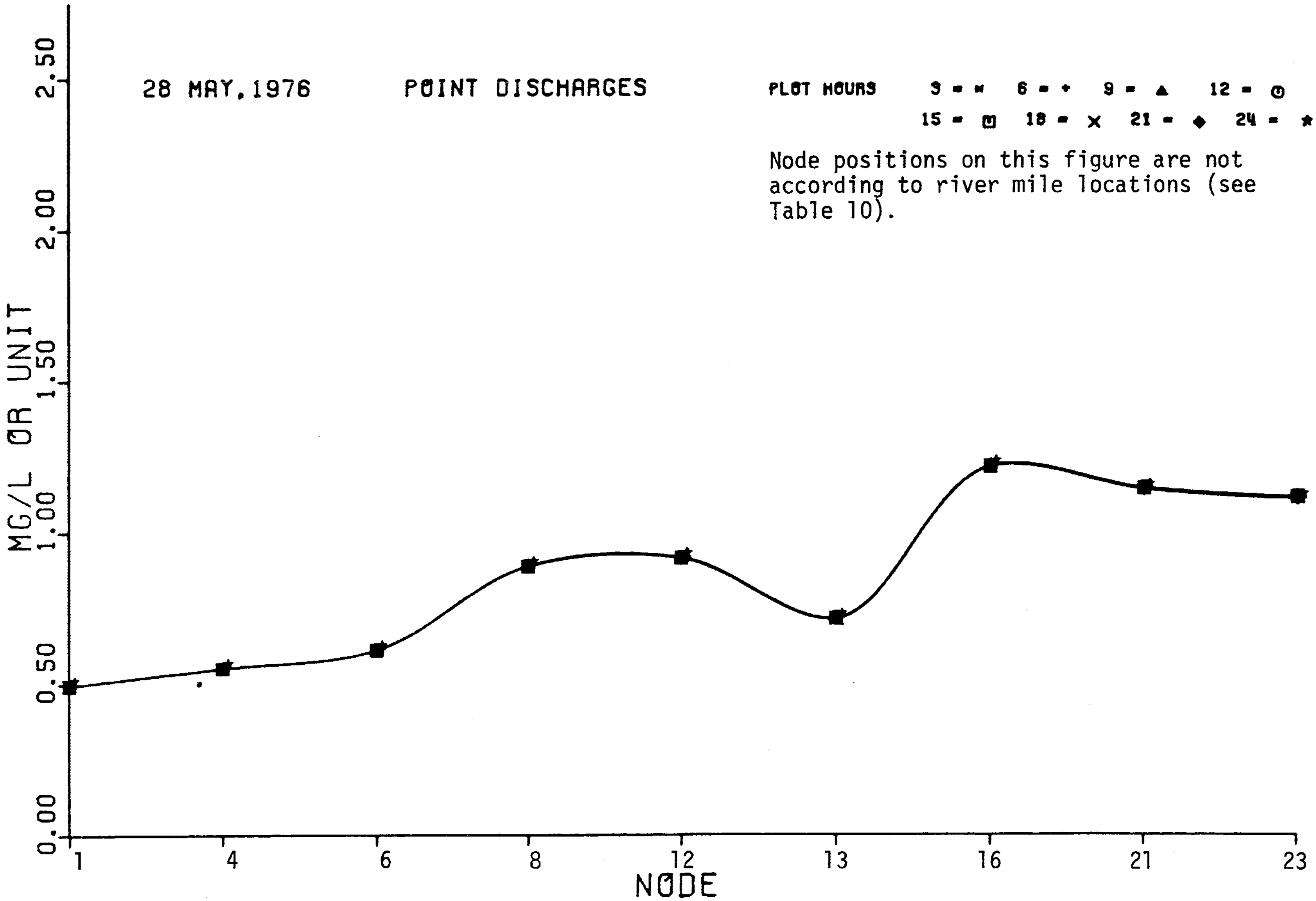

FIGURE E4 - LONGITUDINAL PLOT OF BOD (MG/L), UPPER BLACKFOOT RIVER BASIN

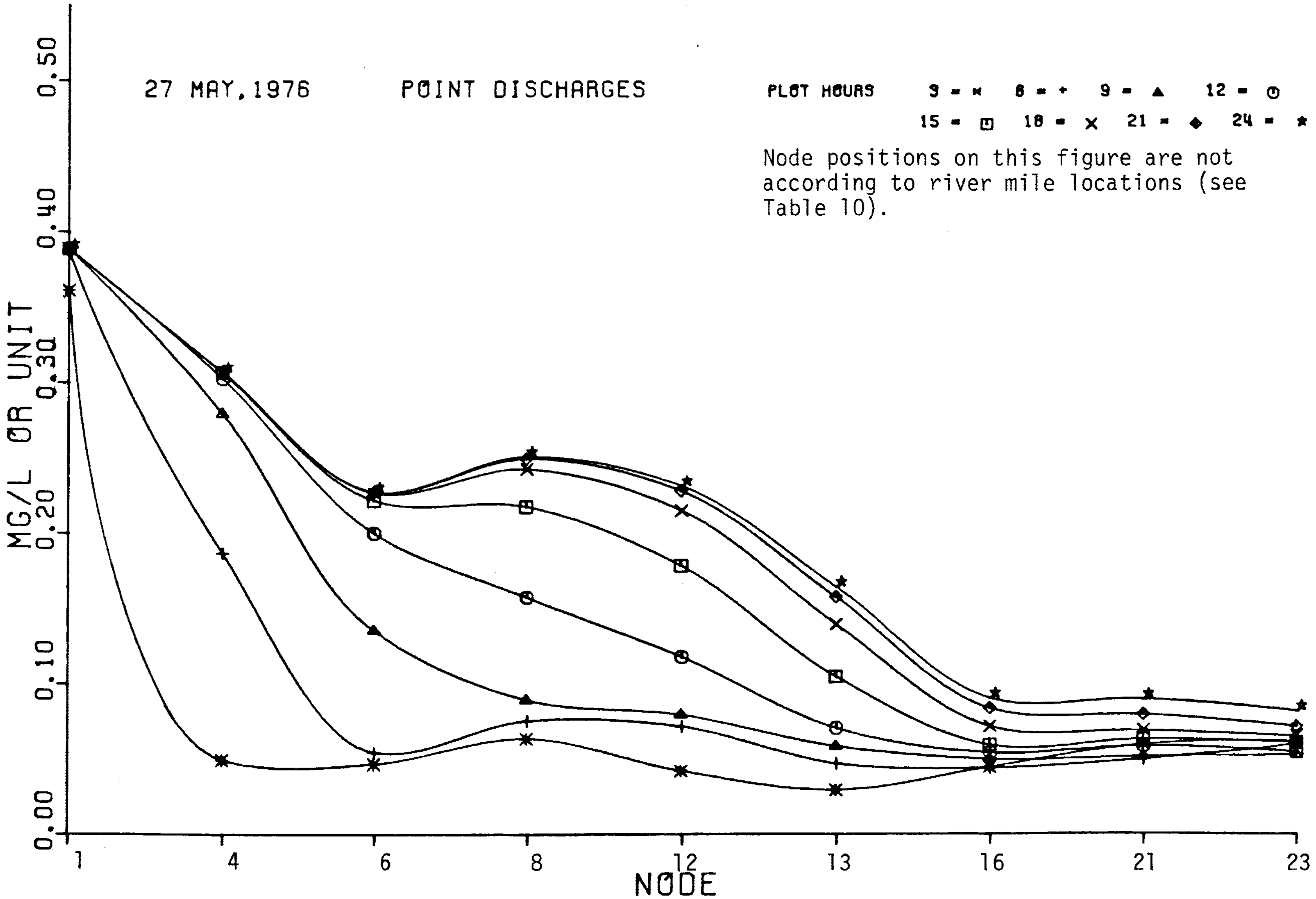

FIGURE E5-LONGITUDINAL PLOT OF PO4-P (MG/L), UPPER BLACKFOOT RIVER BASIN

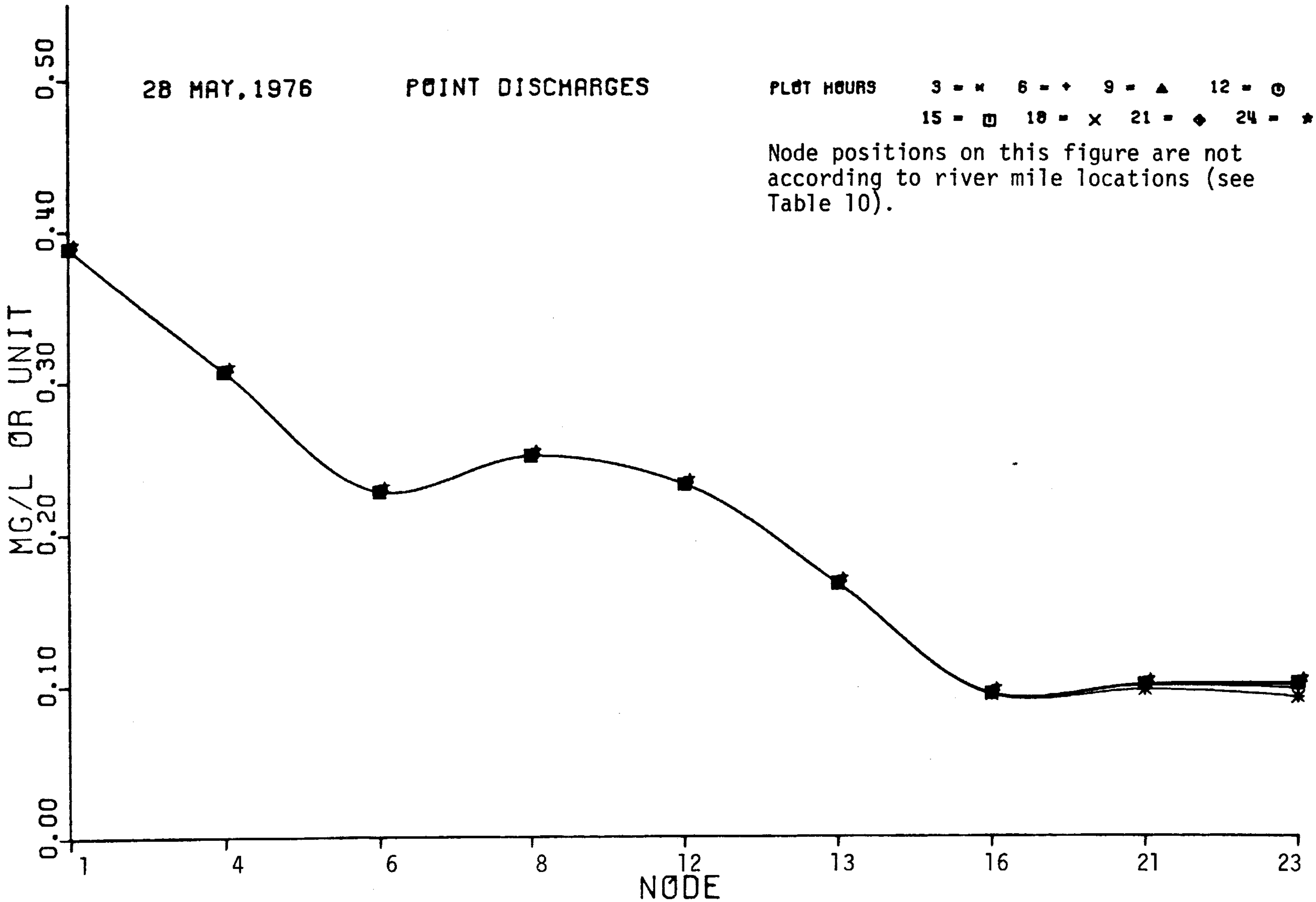

FIGURE E6-LONGITUDINAL PLOT OF PO4-P (MG/L), UPPER BLACKFOOT RIVER BASIN

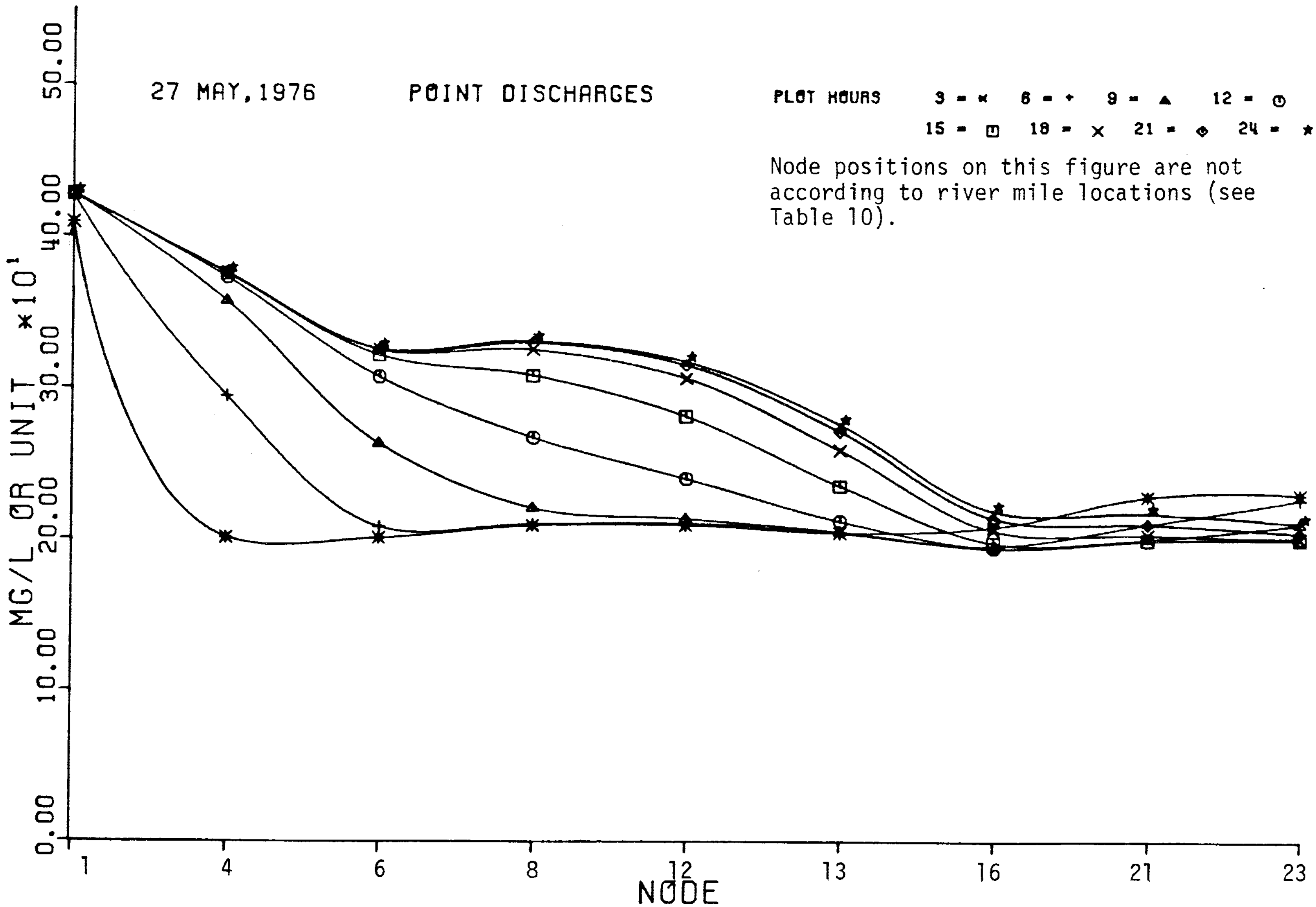

FIGURE E7-LONGITUDINAL PLOT OF TDS (MG/L), UPPER BLACKFOOT RIVER BASIN

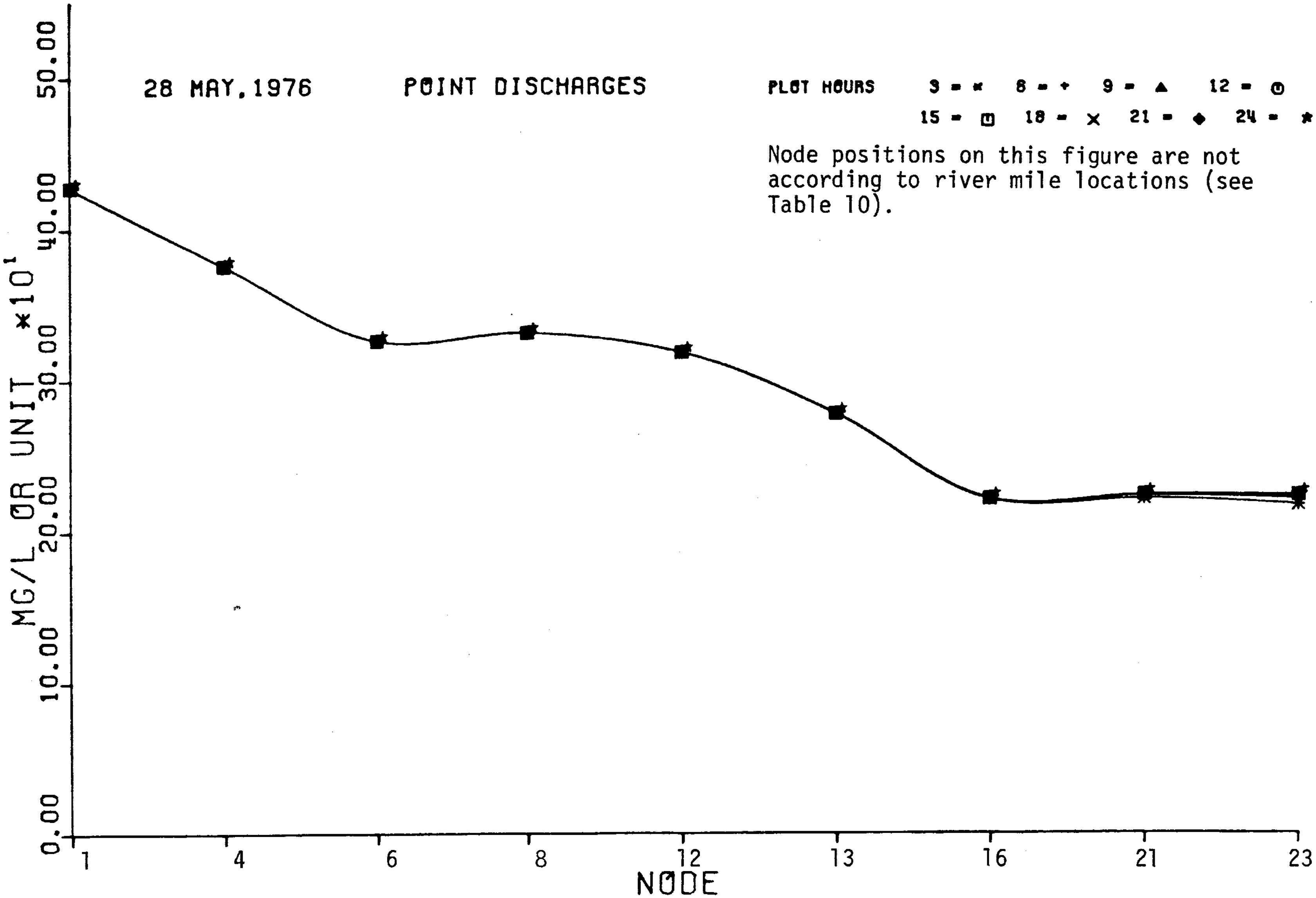

FIGURE E8-LONGITUDINAL PLOT OF TDS (MG/L), UPPER BLACKFOOT RIVER BASIN

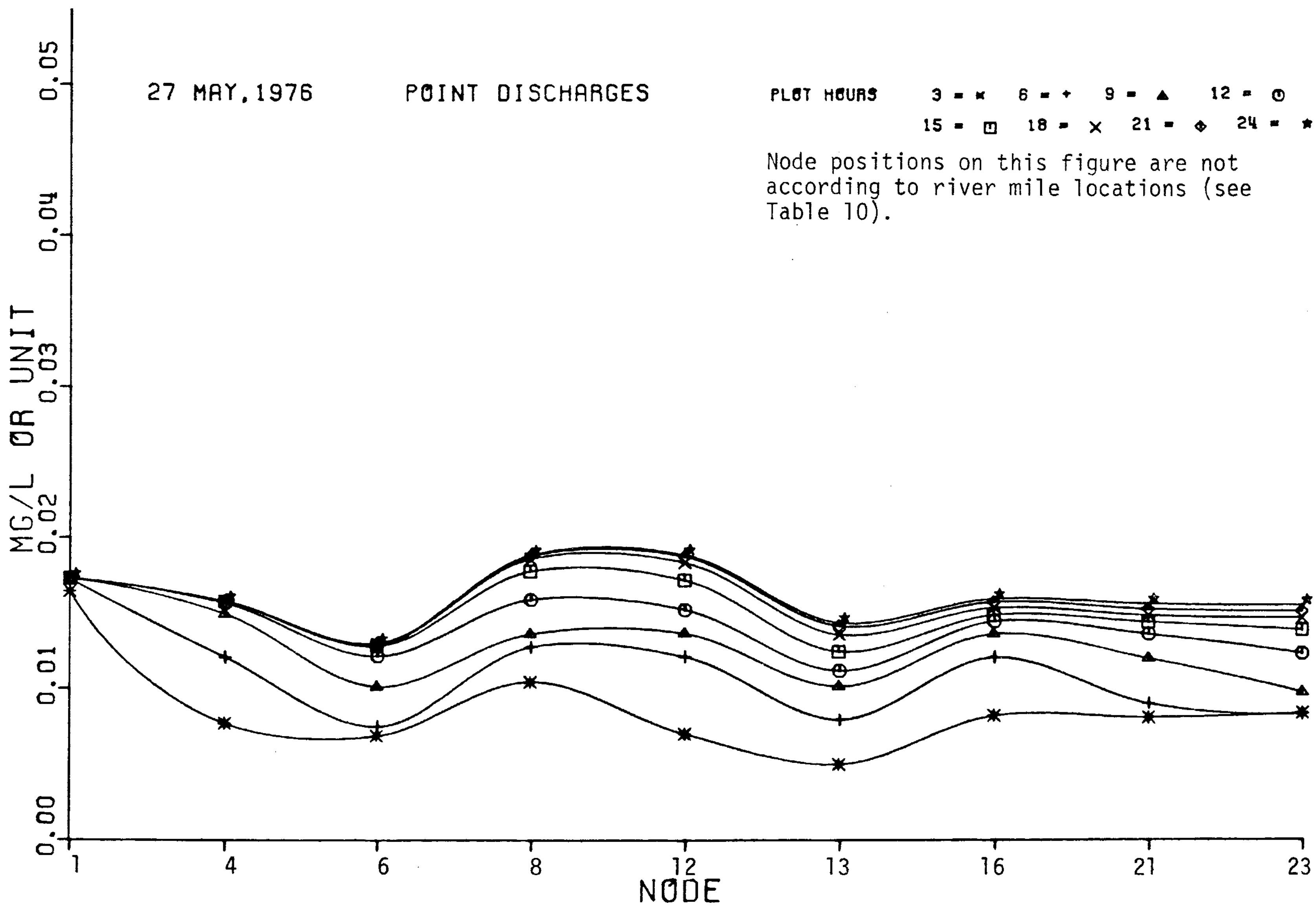

FIGURE E9-LONGITUDINAL PLOT OF ZINC (MG/L), UPPER BLACKFOOT RIVER BASIN

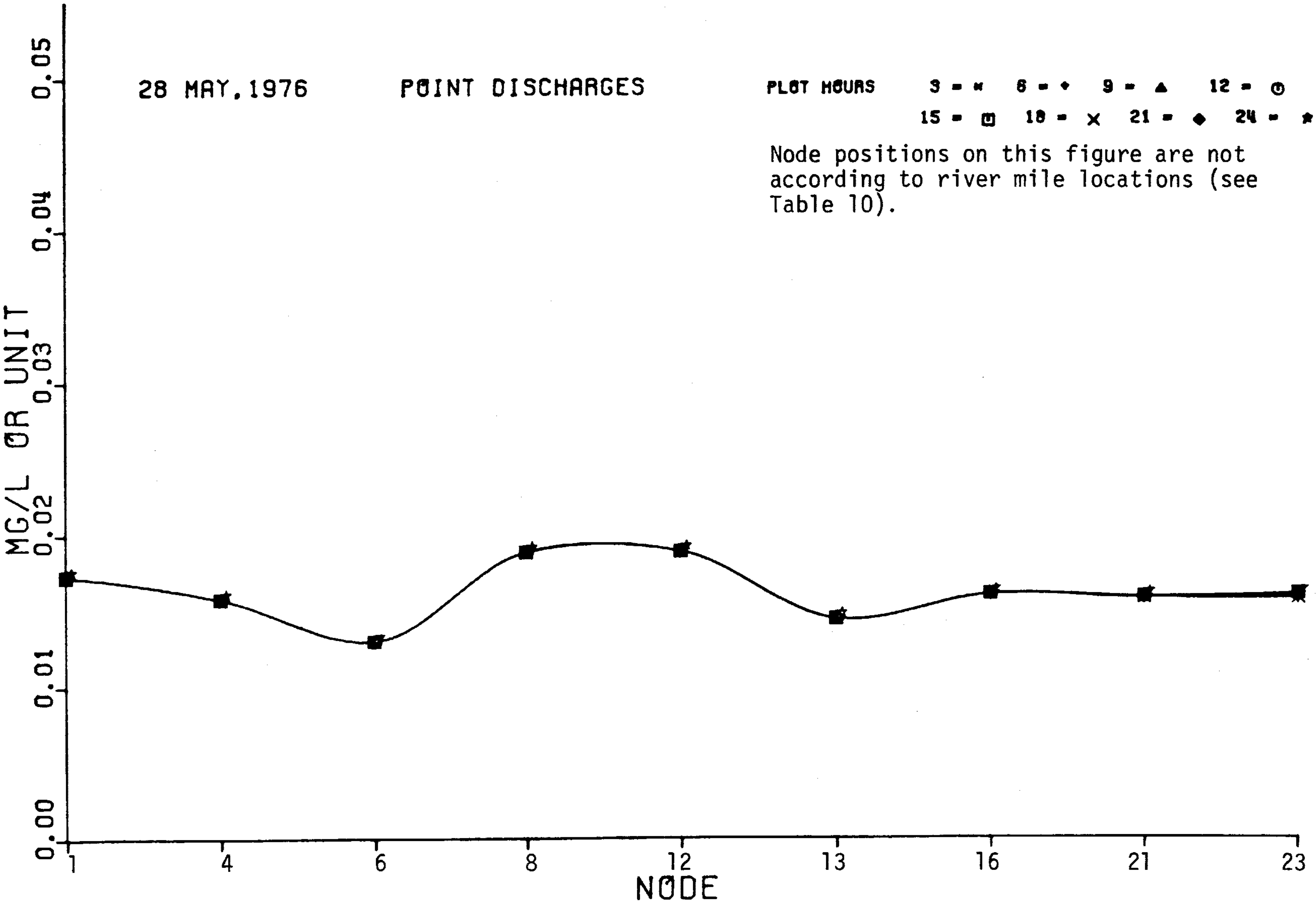

FIGURE E10-LONGITUDINAL PLOT OF ZINC (MG/L), UPPER BLACKFOOT RIVER BASIN

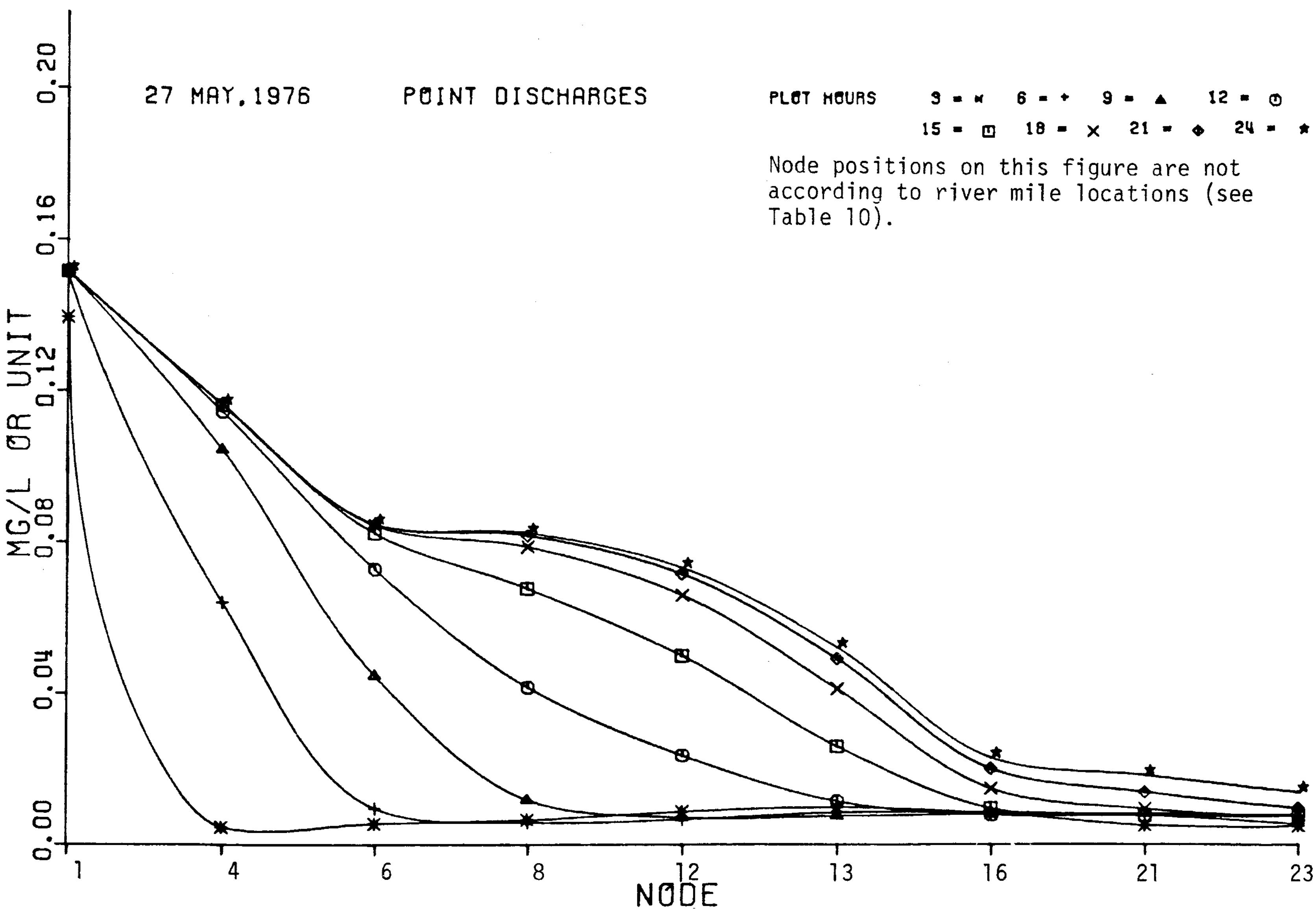

FIGURE E11-LONGITUDINAL PLOT OF COPPER (MG/L), UPPER BLACKFOOT RIVER BASIN

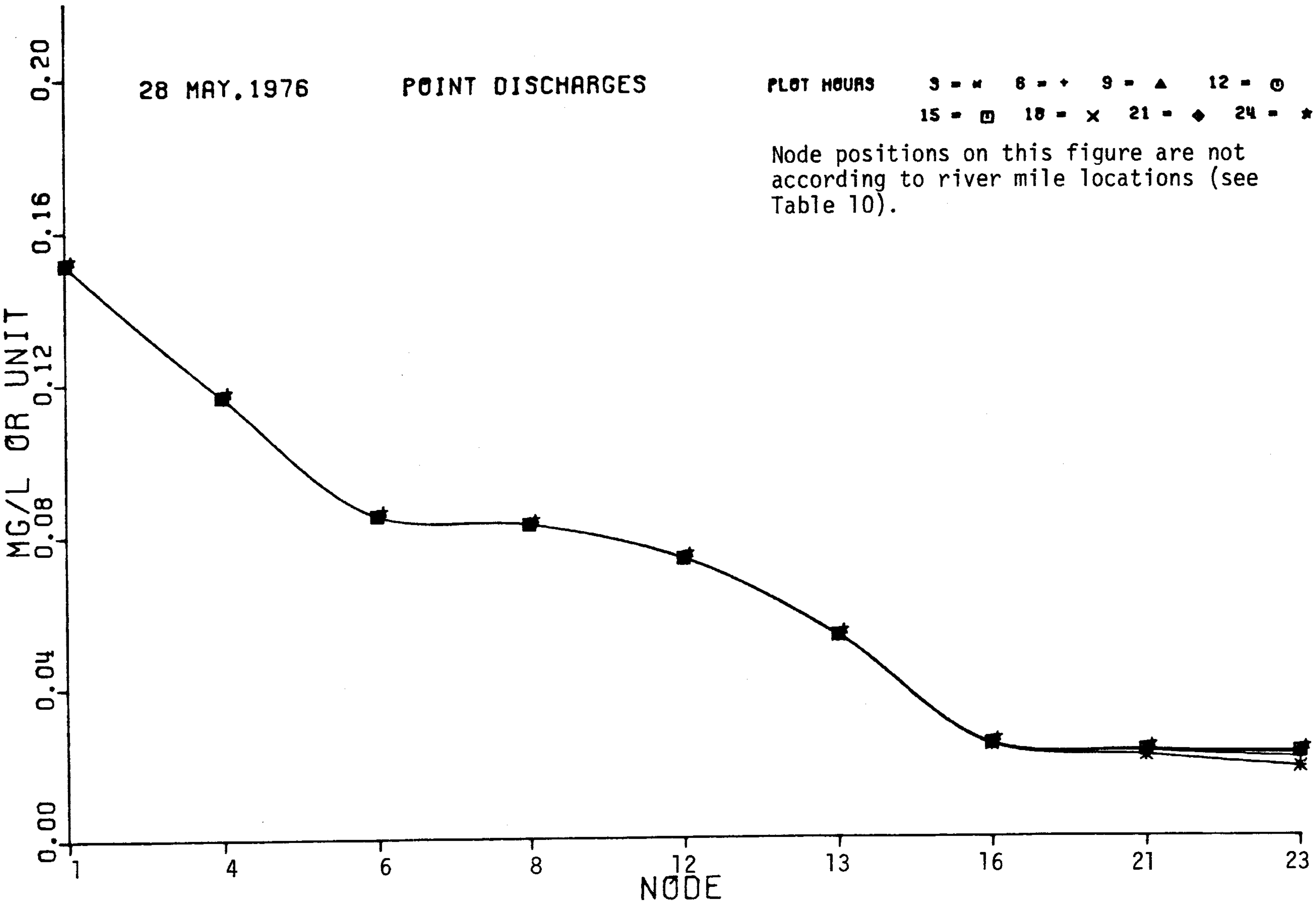

FIGURE E12-LONGITUDINAL PLOT OF COPPER(MG/L), UPPER BLACKFOOT RIVER BASIN

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15. Supplementary Notes

16. Abstract

This study relates to the construction and application of a water quality model for the Upper Blackfoot River basin in southeastern Idaho to serve as a management tool for future phosphate mining and processing operations in the area. The model was developed by making suitable modifications to an existing model which had been used for the Boise River study. The Blackfoot River model is steady state, deterministic and one-dimensional. It has been calibrated and verified and has been found satisfactory under the limitations of the observed data and the complexity of the ecosystem. The technique of model application has been illustrated with the help of arbitrary waste discharges at selected points in the basin.

The model can be useful in deciding the management policies for phosphate mining and processing operations in order to mitigate or avoid their adverse impacts on water quality of the streams. The model can be adapted to the planning of these operations as well as to the planning and management of other human activities in the area with regard to their water quality impacts.

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