TECHNIQUES FOR AUGMENTING WATER QUALITY DATA: APPLICATION TO FLAMING GORGE RESERVOIR AND TO SAMPLING PROTOCOLS

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SUMMARY

ORGANIZATION OF THE REPORT

Section 1

Introduction

In this section we briefly comment on the geology, climate, soils, land cover and hydrology of the Green River watershed. This is followed by a description of Flaming Gorge and a discussion of how the process of eutrophication differs in lakes and reservoirs.

Section 2

Predicting export of water quality parameters from the Green River basin to Flaming Gorge Reservoir; Multiple regression using basin characteristics

Here we develop multiple regression models describing the export of total phosphorus (TP), nitrate-nitrogen (NO_3), total dissolved solids (TDS), total alkalinity, and turbidity (JTU) as functions of basin attributes. Models are verified both by a sequential split-plot analysis and by application to an adjacent but separate drainage. The models are developed from an initial set of over sixty independent variables, or basin attributes. Because data on water quality are sparse, the analyses are based on only sixteen stations or subbasins.

Section 3

Use of Data Augmentation Techniques and Time Series Analysis for Estimating Loading to Flaming Gorge Reservoir

Infrequent and intermittent sampling may have biased results of the multiple regressions in Section 2, so we next develop an augmented data set for the Green River basin -- daily loads of TP and TDS for the years 1965-1979. And, by resampling these daily data, we determine the mean annual load and yearly loads of TP based upon three different sampling intervals and two sampling strategies. Then we derive an optimum scheme for sampling TP and TDS.

Secondly, we explore temporal features of phosphorus loads in the augmented data set. Time series models are developed and analyzed for phosphorus loading. For example we identify years with loading significantly different from each other, and different from the mean annual load, and we indicate which estimates of loading we judge to be the best.

Section 4

Potential effects of loading on eutrophication in Flaming Gorge Reservoir; Analysis with a Vollenweider model

We begin this section by describing the derivation and assumptions of Vollenweider models, which relate phosphorus loading to the trophic state of lakes. Then we use all our loading estimates to evaluate whether excessive loading is predicted to occur for Flaming Gorge reservoir, and whether elimination of point source input might alter the trophic status. Unfortunately, we cannot associate an estimate of uncertainty with our analyses.

SECTION 1:

INTRODUCTION

Watershed Description

Flaming Gorge Reservoir lies in the upper Green River Basin of southwestern Wyoming and northeastern Utah (Figure 1). This drainage, the most upstream portion of the Upper Colorado River Basin, is physiographically, geologically, and climatologically diverse.

The superficial physiography of the upper Green River basin (Figure 1) has not changed since it was described 92 years ago (Powell 1961):

> Green River has its source in Fremont's Peak, high up in the Wind River mountains among glacial lakes and mountain cascades. This is the real source of the Colorado River....
>
> To the north and west of Fremont's Peak are mountain ranges that give birth to rivers flowing into the great Columbia. Conspicuous among these from this point of view is the great Teton Range, with its towering facade of storm-carved rocks; then the Gros Ventre Mountains, the Snake River Range, the Wyoming Range, and, still beyond the latter, the Bear River Range, are seen. Far in the distant south, scarcely to be distinguished from the blue clouds on the horizon, stand the Unita Mountains. On every hand are deep mountain gorges where snows accumulate to form glaciers. Below the glaciers throughout the entire Wind River Range great numbers of morainal lakes are found.... From these lakes creeks and rivers flow, by cataracts and rapids, to form the Green. The mountain slopes below are covered with dense forests of pines and firs. The creeks descend from the mountains in wild rocky gorges, until they flow out into the valley. On the west side of the valley stand the Gros Ventre and the Wyoming mountains, low ranges of peaks, but picturesque in form and forest stretch. Leaving the mountain, the river meanders through the Green River Plains, a cold elevated district much like that of northern Norway, except that the humidity of Norway is replaced by the aridity of Wyoming. South of the plains the Big Sandy joins the Green from the east. South of the Big Sandy a long zone of sanddunes stretches eastward.... Here the northern boundary of the Plateau Province is found, for mesas and high tablelands are found on either side of the river.
>
> On the east side of the Green, mesas and plateaus have irregular escarpments with points extending into the valleys, and between these points canyons come down that head in the highlands. Everywhere the escarpments are fringed with outlying buttes. Many portions of the region are characterized by bad lands. These are hills carved out of sandstone, shales, and easily disintegrated rocks, which present many fantastic forms and are highly colored in a great variety of tint and tone, and everywhere they are naked of vegetation. Now and then low mountains crown the plateaus.... On the west side of the river the mesas rise by grassy slopes to the westward into high plateaus that are forest-clad, first with juniper and pinon, and still higher with pines and firs. Some of the streams

> run in canyons and others have elevated valleys along their courses. On the south border of this mesa and plateau country are the Bridger Bad Lands, lying at the foot of the Unita Mountains. These bad lands are of gray, green and brown shales that are carved in picturesque forms--domes, towers, pinnacles, and minarets, and bold cliffs with deep alcoves; and all are naked rock, the sediments of an ancient lake.

The flats and hills in the southern portion of the drainage, as well as the Bridger Badlands, are remnants of the bed of Lake Gosiute, a prehistoric waterbody present during the Eocene epoch. Mean elevation of the upper Green River basin is 7416 feet (2260m). The maximum elevation is in the Wind River Mountains, at the summit not of "Fremont's Peak", but of Gannet Peak, 13,804 feet (4207m) above sea level.

Paleozoic marine sediments are buried deeply in the basin, but they do crop out on or near the surface as Permian phosphoria deposits in the headwaters of Hams Fork, LaBarge Creek, and Fontenelle Creek in the Wyoming Range on the western border of the Green River drainage. The formation is mined for phosphate rock and contributes phosphate to streams which contact it (Miller 1977). Cretaceous marine shales interact extensively with streams in the basin; names such as Bitter Creek, Killpecker Creek, Salt Wells Creek, and Muddy Creek are typical of those streams which do contact the soft, saline, Createaceous shales.

By the Paleocene epoch of the Tertiary period, the primeval sea had receded from the Green River basin and uplifting of the Unita Mountains began. Lake Gosiute formed during the Eocene epoch; Eocene formations associated with the ancient lake are the source of most salinity in the streams and groundwaters of the upper Green River basin today (Miller 1977). Sixty percent of the drainage is underlain with Tertiary formations including extensive areas of saline Green River shales.

Several types of minerals associated with various geological strata are mined in the Green River drainage. Coal is taken from strip mines near Kemmerer, and older underground mines east of Rock Springs near Superior, South Superior, and Reliance. Extensive oil and gas fields lie five miles (8 km) northwest of Fontenelle Reservoir and along the Overthrust Belt around Kemmerer. Tertiary deposits, in addition to their high salinity, also contain petroleum in oil shales, and such shales are extensive throughout the lower portion of the Green River basin of Wyoming. No commercial oil shale enterprises operate there presently, however. Although there are no uranium mines in the drainage, shallow deposits of lowgrade ore have been mapped in the upper reaches of the Big Sandy River drainage.

West of the Green River below Fontenelle Dam, several companies mine trona deposits. Trona ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$) is a material commonly used in manufacturing glass and other products.

The climate within the Green River basin varies widely, depending on location, elevation and topography. Winds can blow very hard; sandstorms and ground blizzards are not uncommon in susceptible areas of the watershed. Mean winter minimum and mean summer maximum temperatures in the drainage range from -6°F (-21°C) to 86°F (30°C) respectively; a maximum summer temperature of 107°F (41.7°C) and minimum winter temperature of -55°F (-48.3°C) have also been recorded (Lowham et al. 1976). Average yearly precipitation varies from 11" (28 cm) to 41" (104 cm), with the latter figure more typical for the surrounding mountains. Snow accumulates in the mountains during the winter and accounts for most of the precipitation in the drainage; summer thunderstorms are the other typical form of precipitation.

The diverse geology and climate of the basin have molded an assorted set of soil types. The general soil associations (Young and Singleton 1977) range from cold, montane and mountain valley combinations (basic forest Cryoboralfs, deep Cryoborolls, and recently formed Cryorthents) to cool montane sedimentary associations (cool, rich Haploborolls and Argiborolls) to cool intermountain basin and foothill soils (warm Torrifluvents and wet Fluvaquents on stream floodplains, alkaline Torriorthents, and arid, shallow Haplargid and saline Nartargid soils). An extensive dunes area south of the Big Sandy River is composed of young, warm, windblown soils of Torripsamment associations.

Vegetative cover classes predominant in the drainage (Figure 2) are various types of rangeland and coniferous forests; such areas are used chiefly for livestock grazing and lumbering. In addition, farming alluvial haymeadows and two major tracts of irrigated cropland (Bridger Valley of the Blacks Fork and the Eden Irrigation Project near Farson and Eden on the Big Sandy) also supports livestock, since almost two-thirds of the irrigated land is in pasture and hay production (Lowham et al. 1976).

The basin is sparsely inhabited with 52,300 people, most of whom live in the cities of Rock Springs, Green River, or Kemmerer (U.S. Bureau of the Census 1981). Rock Springs and Green River city lie in the most downstream portion of the upper Green River drainage; Kemmerer is situated on the Hams Fork of the Blacks Fork in the northwest part of the basin. The economic bases of Rock Springs and Kemmerer are extractive and support industries for coal, oil, and gas mining. Green River city's economy is driven primarily by trona mining, but oil and gas industries and associated support enterprises are also significant.

Hydrology of the mainstem Green River is determined most by the input of vernal snowmelt; its yearly hydrograph (Figure 3) exhibits relatively low base flow in winter, a vernal rising limb, a peak in late spring, and a falling limb to base flow in early fall. Smaller tributaries, especially the ephemeral and intermittent streams which begin in lower elevations of the basin, display in addition the effects of intense summer thunderstorms. In small and headwater streams, the natural yearly hydrograph (Figure 4) again shows a sharply rising vernal limb, repeated because of freeze-thaw cycles, and a falling limb to baseflow in early summer. Summer hydrographs are generally at base flow or no flow, except for short-duration, high-intensity incidents caused by localized storms. In intermittent and ephemeral streams, water may not flow again until snowmelt; in perennial streams, base flow is maintained by ground water inputs until spring.

The upper Green River basin is that portion of the Green River drainage lying upstream of Ashley Dam, which impounds the Green River to form Flaming Gorge Reservoir. Major perennial streams tributary to the Green are the New Fork and Big Sandy Rivers in the eastern part of the basin, and the Blacks Fork in the west. The Green and Blacks Fork Rivers are the two principal tributaries to Flaming Gorge Reservoir, located in the southern most part of the upper Green River basin. Unless specifically stated otherwise, the terms Green River drainage, upper

Green River drainage, Green River Basin, etc., include both the Green River section and the Blacks Fork sections of the watershed (Figure 1).

Flaming Gorge Reservoir

Ashley Dam was completed in 1962, and impounded the Green River to form Flaming Gorge Reservoir. The reservoir takes its name from a strikingly beautiful but now inundated canyon first described by Major John Wesley Powell (1834-1902) on his 1869 expedition down the Colorado River:

> "The river is running to the south; the [Unita] mountains have an easterly and westerly trend directly athwart its course, yet it glides on in a quiet way as if it thought a mountain range no formidable obstruction. It enters the range by a flaring, brilliant red gorge, that may be seen from the north a score of miles away. The great mass of the mountain ridge through which the gorge is cut is composed of bright vermillion rocks; but they are surmounted by broad bands of mottled buff and gray, and these bands come down with a gentle curve to the water's edge on the nearer slope of the mountain. ...We name it Flaming Gorge." (Powell 1961)

Except for the much smaller Fontenelle Reservoir, Flaming Gorge Reservoir is the most upstream of the Colorado River Storage Project reservoirs. The ninety-one mile (146 km) long reservoir has a potential storage of 3.75 million acre-feet (4.63 billion m^3) of water; this full pool storage has been achieved only once since its initial full pool in 1973. At full pool, the reservoir covers 42,000 surface acres (17000 hectares).

Based on initial topographical, limnological, and biological features, the reservoir was categorized into three sections (Figure 5). The canyon area is the 24 miles (38.6 km) of the impoundment immediately upstream of Ashley Dam. This area contains historic Flaming Gorge, and is characterized by steep canyon walls and a mean depth of 200 feet (61 m). The canyon area exhibits seasonal stratification, and is generally considered oligotrophic.

The section of the reservoir next upstream is the open hills area, named for the adjacent physiographic feature. Large expanses of open water and extensive littoral area identify this section of the reservoir. Frequent and often strong winds, combined with the expanses of relatively shallow, open water, ensure that strong seasonal stratification occurs only occasionally. The open hills area is about 30 miles (48.3 km) long, and has typically been classified as mesotrophic.

The inflow area, the twenty miles (32.2 km) of the reservoir most upstream from Ashley Dam, is most influenced by the Green River and Blacks Fork. The inflow area is often turbid, as a result of wind- driven mixing and muddy influent streams. Mean depth is 50 feet (15.2 m), but varies markedly with lake elevation.

An alternate method to categorize Flaming Gorge Reservoir, based only on limnological criteria, has recently been proposed by U.S. Bureau of Reclamation scientists (c.f. Miller 1984 and Verdin et al. 1984). This method is founded on a model of reservoir hydrodynamics, and recognizes that reservoirs may have three intergrading zones (Thornton et al. 1981): 1) The upstream riverine (inflow) zone is shallow and well mixed due to the turbulent inflow of the main tributary. 2) The most downstream lacustrine zone is deep and typically clearer and more "lake-like" than the riverine zone. 3) Between the riverine and lacustrine zones is the transition zone, which encompasses the plunge point where turbulent river water sinks underneath reservoir water of lesser density.

Flaming Gorge Reservoir exhibits such "structure". The lacustrine zone encompasses the lower half of the reservoir, that quarter of the reservoir next upstream is the transition zone, and the quarter most upstream is the riverine zone. However, the proportions of the reservoir comprising the riverine or transition zone are defined by their limnological attributes, not by an arbitrary length of reservoir. Because of the higher flows in the main tributaries during spring runoff (May to July), the riverine zone is larger than during the remainder of the year. Conversely, the portion of the reservoir comprising the transition zone is larger during low-flow periods.

Until 1983, a highly saline wedge of water created meromixis at the base of Ashley Dam (Madison and Waddell 1973, Miller 1984). Although the saline monimolimnion became anoxic, since the chemocline was below the penstock outlet structure for the dam, and since by definition the monimolimnion did not mix with overlying waters, its impact on water quality either in the reservoir or downstream was not significant. After impoundment, the reservoir also exhibited the nutrient enrichment typical of newly formed artificial lakes (Ostrofsky 1978). This enrichment may have caused better than average growth of gamefish (Varley et al. 1971, Wiley and Varley 1978) and algal blooms throughout the reservoir. These general blooms had ceased by the early 1970's.

Several studies (USEPA 1977, SWWQPA 1978, Fannin 1983, Parker, et al. 1984) have described the sporadic, but increasingly serious, effects of summer eutrophication in Flaming Gorge. During recent years upper sections of the reservoir have exhibited severe water quality problems, including dense late summer blue-green algal blooms, high summertime water temperatures, and late summer hypolimnetic anoxia (USEPA 1977, SWWQPA 1978, Fannin 1983, Verdin et al. 1984, Miller 1984). The algal blooms have lessened the quality of body-contact recreation and the combination of low oxygen and high temperatures has all but eliminated the summertime salmonid fishery in both riverine arms of Flaming Gorge Reservoir. The public's perception of the severity of the water quality problems in upper Flaming Gorge Reservoir is perhaps intensified because they expect to encounter clear, cold waters similar to those of the lower reservoir and of lakes in the surrounding mountains. Oster, et al. (1987) presented an analysis of the economic impacts of reduced recreation in the upper reservoir.

Water Quality Problems in Flaming Gorge

In general, water quality problems in Flaming Gorge Reservoir result from processes occurring both in the water body and in its drainage basin (c.f., Wegner 1982). Important processes in the basin are those causing export of nutrients, especially phosphorus. Such export is the ultimate source of nutrient loading to the reservoir. When these nutrients reach the reservoir, internal processes control how the nutrients are used by algae, the extent of oxygen depletion, etc.

While summertime water quality in the upper end of Flaming Gorge may be poor, the deep, downstream portion of the impoundment is uniformly oligotrophic. This longitudinal gradient of water quality is typical of many reservoirs, but normally is not found in lakes (Thornton et al. 1981). This gradient occurs in part as a result of the three intergrading limnological regions found in impoundments but not in natural lakes; a shallow, narrow, upstream riverine zone; an intermediate transition zone; and a deep lacustrine zone downstream .

In natural lakes anoxia normally occurs first in the deepest waters, but in artificial impoundments oxygen depletion commonly begins in the transition zone. Hannan and Cole (1983) suggest this occurs because the flowing waters of the tributary rivers are able to carry more suspended material than the calmer waters typical of lakes. Therefore, when water, especially turbid water, moves from the riverine zone to the lacustrine zone of reservoirs it loses energy and its ability to maintain particles in suspension is reduced. Particles settle to the bottom of the transition zone. If the transition zone is deep enough to stratify thermally, and if the settling particles contain organic matter, then bacterial decomposition of these organics depletes oxygen in the bottom of the transition zone. The thermal stratification of the transition zone ensures that this anoxic water cannot mix with overlying oxygenated waters, or be exposed to the atmosphere.

The tendency toward oxygen depletion and anoxia in the transition zone can drive or influence other internal processes exacerbating eutrophication in Flaming Gorge Reservoir. First, the transition zone is the area where problems presently occur. (Recollect that during the periods of most intense algal blooms--late summer--the transition zone makes up most of the upper end of the reservoir, with little area exhibiting riverine characteristics.) Hydrodynamics typical of Flaming Gorge Reservoir, including its longitudinal gradation and density differences between influents and stratified reservoir waters may tend to aggravate problems of oxygen depletion. Second, anoxia in the transition zone may provide additional nutrients. Anoxia promotes release of phosphorus from sediments deposited by the river in the year or years previous. Phosphorus derived from sediments is one example of internal loading of nutrients to an impoundment, as contrasted to external loading from the surrounding watershed.

Because the hypolimnion is not deep in the transition zone, transport of dissolved phosphorus from the hypolimnion to the epilimnion occurs more rapidly than in deep water. Any phosphorus transported to the epilimnion is immediately available to support additional algal growth. A comprehensive discussion of phosphorus release from sediments in upper Flaming Gorge Reservoir has been provided by Messer, et al. (1983, 1984). They estimate that under anaerobic conditions, sediments in the upper arms of the reservoir release 12.8 mg P/m^2/day at 25°C (77°F).

In addition to reservoir hydrodynamics (*c.f.*, Thornton et al. 1981), the phenomena described above depend upon both climate and the hydrology of Flaming Gorge Reservoir's tributaries. For example, climate affects the onset and duration of thermal stratification. Stratification and oxygen reduction in the transition zone can appear anytime from early May to late September in hot, dry, fairly calm years, or from mid-July to late August in cool, wet, windy years. In years with a cool spring the duration of stratification in the upper arms of Flaming Gorge Reservoir may be inadequate for much internal loading to occur (Miller et al. 1983). In most years, however, the transition zone develops oxygen sags or anoxia, and correspondent high phosphorus concentrations below the thermocline in the transition zone's hypolimnion. The combination of low oxygen in the relatively cool hypolimnion and high temperatures in the well-oxygenated epilimnion precludes the persistence of salmonid fish in the affected waters.

Blue-green algae blooms occur in late summer or early fall. At fall turnover, which usually occurs in September, the phosphorus in the hypolimnion is distributed to the entire water column, intensifying blooms already present or triggering the early fall blooms. These diminish with declining water temperatures in November.

Climate and tributary hydrology affect the lacustrine zone by altering duration and timing of spring runoff, the movement of river water into, and the mixing of river water with, the reservoir water. This is important for the development of blooms and oxygen depletion because it affects where in the impoundment the river-borne nutrients and organic matter are found (Thornton et al. 1981, and Lind 1984). For example, a high-discharge year will increase the length of the riverine zone and cause sediments and nutrients to precipitate below the euphotic zone in deeper areas of the reservoir. There they are not readily available for algal uptake, and are diluted by larger volumes of water at fall turnover.

Biological availability of nutrients also influences the severity of algal blooms. If a nutrient is abundant but in a form which is unavailable for algal use (e.g., phosphorus strongly bound to particulate material), then that form will affect blooms very little. In Flaming Gorge this may be significant because when fall blooms occur, the available nutrients from some point sources (i.e., sewage) should be a relatively larger component of the total load than during spring runoff. This is because input from point sources is fairly constant, whereas runoff-related input is highly seasonal.

The relative magnitude of loading into Flaming Gorge Reservoir from nonpoint sources versus point sources of nutrients has been estimated in previous studies. Nonpoint sources are responsible for as much as 88% of the phosphorus input to Flaming Gorge Reservoir (SWWQPA 1978). USEPA (1977) attributes over 78% of phosphorus loading into the impoundment to nonpoint sources. The present study found nonpoint sources constitute 48 to 88 percent of the load to Flaming Gorge Reservoir, depending on the year; the mean nonpoint source load found by this study was 71%. Nonpoint sources may be important in algal dynamics because they deliver a far greater bulk of nutrients to the impoundment. A portion of this bulk is delivered in biologically available form indirectly from sediments at fall overturn. Shortly after fall overturn is a typical time that algal blooms occur (Miller et al. 1983).

SECTION 2:

PREDICTING EXPORT OF WATER QUALITY PARAMETERS FROM THE GREEN RIVER WATERSHED TO FLAMING GORGE RESERVOIR; MULTIPLE REGRESSION USING BASIN CHARACTERISTICS

INTRODUCTION

To mitigate water quality problems in the Green River drainage and Flaming Gorge Reservoir via out-of-reservoir techniques, one should know i) which portions of the basin contribute most to the problems, and ii) which characteristics of the basin contribute most to causing the problems (e.g., geology, land use, rainfall, etc.). A description of relations between basin characteristics and water quality could provide such information. In addition it would provide data for comparison with future studies of water quality, perhaps when some of the basin attributes have changed, and might be used to predict what water quality was like in the past if data on previous basin attributes were available. Thus practical applications of such knowledge include i) apportioning chemical loadings to specific areas of the drainage, ii) predicting changes in the water quality of the Green River flowing into Flaming Gorge Reservoir from changes in basin characteristics, and iii) investigating whether associations of water quality with basin characteristics change over time.

The notion of associating characteristics of a drainage basin with water quality of streams, rivers, and lakes within the basin is not new. Loehr (1974) surveyed "controllable" and "uncontrollable" contributions of nutrients from land uses including rangeland, urban, farming, and forestry. He concluded that rangeland and unmanaged forest lands were either uncontrollable and/or low-yield nutrient sources, but that irrigation return flows and cropland runoff were controllable non-point sources of nutrients which possibly would justify controls. Another survey of non-point source nutrient pollution focused specifically on lakes (Uttormark et al. 1974). Dillon and Kirchner (1975) examined the combined effects of land use and geology upon nutrient export to several lakes in Ontario. Omernik (1976) derived regression models relating land use to stream water quality in the eastern United States, and then in the entire country (Omernik 1977). Omernik's "best fit" models for the western U.S. were multiple regression models of the summed percentages of agricultural and urban lands in the drainage, and the percentage of forested lands in the basin, versus total phosphorus, orthophosphorus, total nitrogen, and inorganic nitrogen (all in units of log[mg/l]). The variances (R^2) in concentration of these substances in western streams explained by attributes of the watershed were all less than 0.5. While this does not represent a very good fit of the equations to the data, it is reasonable given the complex interactions of basin attributes and water quality in such a geographically expansive study.

In a study of the Susquehanna River basin, Lystrom et al. (1978a, 1978b) derived multivariate associations between water quality in the Susquehanna River and a multitude of characteristics of its watershed. The R^2 values for Lystrom's equations were universally greater than 0.5 and generally above 0.7, indicating that much variance in water quality was indeed explained by basin characteristics.

The application of this approach to model water quality in the upper Green River drainage is recommended by the fact that both are very large basins. The Susquehanna basin modeled by Lystrom et al. was 27,510 mi^2 (71,250 km^2), and the upper Green River basin investigated in this study is 10,000 mi^2 (26000 km^2). Thus we report here results of an investigation of associations between streamwater quality and attributes of the Green River drainage, and the validation of these associations via split data sets and application to another watershed.

No systematic basin-wide investigation of the origin of dissolved and suspended substances in the Green River has yet been performed. However, much data concerning the Green River basin is available, albeit from diverse sources (c.f., Parker et al. 1984). In trying to study this problem in the most economical way, we derived our associations entirely from previously published or previously available data. We assumed that water quality in the Green River drainage is indeed a function of physical, chemical and biological characteristics of the drainage, and that multiple regression is suited for associating such characteristics with water quality.

The objectives of this analysis of existing data from the Green River basin were:

1) To retrieve and compile available information about surface water quality and discharge;
2) To retrieve and compile available information about characteristics of the basin;
3) To derive regression models associating basin characteristics with basin water quality, using appropriate data from 1) and 2);
4) To compile a list of point sources in the basin, and to estimate their contributed loads;
5) To illustrate the effect of excluding point source loads from appropriate models found in 3);
6) To calculate from the models' predictions the specific areas of the basin which are major contributors of the dissolved and particulate material in the river.

The physical scope of the project includes the Blacks Fork drainage above the USGS gauging station near Little America, Wyoming, and the Green River drainage above the USGS water quality sampling station at Green River City (Figure 6). The Blacks Fork is tributary to the Green River downstream from our basin study area, within Flaming Gorge Reservoir. The Green River section of the upper Green River drainage encloses about 7250 mi^2 (19,000 km^2), the Blacks Fork section about 2900 mi^2 (7500 km^2). We considered three subbasins in the Blacks Fork section, and thirteen subbasins in the Green River section. The subbasins are located upstream from the sampling stations noted on Figure 6, and are named after the respective sampling station (e.g., the subbasin above the sampling station on the Green River at Big Island is referred to as subbasin GRBI).

Water quality variables investigated were loads of dissolved solids (TDS), nitrate (NO_3), total phosphorus (P), total alkalinity (as $CaCO_3$), and turbidity in Jackson turbidity units (JTU). Though we searched for data from all water years from approximately 1900 to 1980, we chose water years 1965 to 1979 as our study period. Most water quality data available at the initiation of this study fell within those years, and 1964 was the year Ashley Dam was closed.

The null hypotheses tested in this study were:

H_{o1}: There are no significant relations between attributes of the Green River basin and water quality in the Green and Blacks Fork Rivers. Rejection of this hypothesis would indicate that some association exists which could be useful in locating areas of the basin contributing greater loads, and for further investigations of cause-effect relations in the drainage.

H_{o2}: There is no significant difference between the observed and predicted loads of water quality variables at the most downstream stations of the Green River and the Blacks Fork. To estimate accurate loads for use in the Vollenweider permissible loading model (Section 4), predicted and observed loads at these stations should not be significantly different.

H_{o3}: The models will not appreciably underestimate the variance explained when they are applied to new data. This is an indicator of robustness in the model. Robustness is a desirable trait since such models may be applied to make predictions for future time intervals.

H_{o4}: There is no significant difference between the observed and predicted loads of water quality variables when the models of water quality derived in the Green River basin are applied to the Sweetwater River, an adjacent but separate drainage. This is another measure of robustness, indicating whether predictions are applicable to one drainage basin only.

REGRESSION MODELS

Multiple linear regression describes variation in a single dependent variable as a function of variations in several independent variables. The assumptions of the technique are (Lewis-Beck 1984):

1. The relation between the dependent variable Y and the independent variables $X_1 \ldots X_n$ is linear.
2. No relevant independent variables have been excluded.
3. No irrelevant independent variables have been included.
4. The variables are accurately measured.
5. The errors have zero mean, have constant variance, are not intercorrelated with each other, are not correlated with the independent variable, and are normally distributed.

In this study, a single water quality parameter is the dependent variable, and its variation is accounted for by the variation in two or more independent variables of physical, chemical, or biological basin characteristics. The general equation (from Edwards 1979) is:

$$Y' = a_1 + b_1X_1 + b_2X_2 + \ldots + b_kX_k \qquad \text{Equation 1}$$

where Y' is the dependent variable, X's are the independent variables, k is the number of independent variables in the equation, and a is the regression constant. By choosing appropriate independent variables (basin parameters), we seek to maximize the correlation between the predicted value of our water quality variable and the actual value of the variable. The basis for our choice of independent variables in each model is an interpretation of output from three SPSS (Hull and Nie 1981) multiple regression programs, and one BMDP (Dixon et al. 1985) multiple regression program.

Characteristics of the regression programs

Each of the three SPSS NEW REGRESSION multiple regression techniques is a variation on sequential entry of independent variables into the program. The SPSS STEPWISE method chooses the independent variable best correlated with the water quality variable, according to the entry criteria, then adds the next best correlated variable which is not intercorrelated with the first variable entered. The method is iterative; additional variables are entered, and all variables are subject to removal, based on both the criteria for entry and removal, and the intercorrelation tolerance. Variables removed on one step may be reconsidered and reentered on another step if an intercorrelated variable in the equation is removed. A multiple regression equation output by the STEPWISE method contains basin attributes which are correlated with the dependent water quality variable, but not with each other. The SPSS FORWARD STEPWISE and BACKWARD STEPWISE methods are similar to the STEPWISE method; however, variables entered in one step of the FORWARD STEPWISE method may not be removed. Conversely, a variable removed on a step of the BACKWARD STEPWISE method may not be reentered on another step. Because of this and the tolerance criteria for intercorrelation, both the FORWARD STEPWISE and BACKWARD STEPWISE methods are highly sensitive to the order in which variables are entered. Simply changing the order of variables in the basin attribute data set can yield very different models.

The BMDP ALL SUBSETS method chooses its optimum model from all subsets of variables in the unique set of basin attributes. This all but eliminates sensitivity to order of entry of the basin attributes. A tolerance criterion for minimizing intercorrelation is included.

Because of the high sensitivity to order of entry characteristic of the SPSS FORWARD STEPWISE and BACKWARD STEPWISE, the primary regression method we considered was the SPSS STEPWISE method, with the BMDP ALL SUBSETS method as the secondary method. These latter methods are the most insensitive to order-of-entry of the four methods used. Selection of the same model by SPSS FORWARD STEPWISE and BACKWARD STEPWISE as well would further support the selection made by SPSS STEPWISE and BMDP ALL SUBSETS.

For each of the three SPSS methods employed, an initial equation was derived. Then the independent variable chosen for this initial equation was eliminated from the data set of independent variables, and the program rerun to derive the next-to-optimal model for consideration. This process was repeated until the $R^2_{adjusted}$ showed an appreciable decrease. Alternate models are automatically generated by the BMDP ALLSUBSETS method, which outputs a choice of up to 10 models for each subset size (i.e., one independent variable, two independent variables, etc.).

Selection criteria for regression models

We judged the quality of a regression model by several of the statistics output by the SPSS and BMDP regression programs:

1. A large adjusted R^2 and small standard error of the regression. The multiple regression coefficient (multiple R^2) is a composite measure of how much of the variation about the mean annual load of a water quality variable is explained by the variation about all of the independent variables in the equation. However, the adjusted R^2 is a better measure of this shared variation because the number of independent variables is considered. In other words, the adjusted R^2 can vary for the same equation if, for example, fifteen and then five variables were considered to derive the same three- variable equation. A better model will have a higher multiple and adjusted regression coefficient.

   The standard error of the regression (a.k.a. the standard error of the estimate) can be used to choose among several models generated for a specific water quality variable. A better model should have a lower standard error of the regression. The percent standard error of the estimate ("PSEE") is the mean of the observed dependent variable divided by the standard error of the regression. While the PSEE can be used to choose among models, in addition it shows which models are better across water quality variables. In other words, a Total Dissolved Solids (TDS) model having "good" residuals (see below) and a PSEE = 0.176 is a better model (i.e., fits the dependent and independent data better) than a Nitrate- nitrogen model having "good" residuals and a PSEE = 0.479.

2. Minimum intercorrelation of independent variables. The model should have a minimum amount of intercorrelation among its independent variables. Multicollinearity can seriously violate assumptions of the multiple regression technique, and "...in some situations render the regression model almost useless" (Montgomery and Peck 1982).
3. Well-fitting residuals plots. Fit of the plots of standardized residuals is a subjective judgment based on inspection of several types of residuals plots. Residuals are the variances not explained by the model. These plots indicate which of the assumptions of the regression technique are being met, and therefore which models are most "adequate" (sensu Montgomery and Peck 1982). Models which have poorly fitting residuals on 1:1 normalized probability plots do not meet the assumption of normal distribution of the residuals. In addition to normalized probability plots, we inspected plots of standardized residuals vs. sequence to verify the assumption of independent (uncorrelated) residuals, and plots of standardized residuals versus standardized predicted loads to verify the assumption of constant variance of the errors.
4. A small PRESS. A better regression model should have a lower predicted error sum of squares (PRESS, Montgomery and Peck 1982). In effect, the PRESS is calculated by performing N - 1 split-set analyses (where N is the number of cases or stations), sequentially comparing each station as a set against all other stations taken as a set. The $R^2_{predicted}$, calculated from PRESS, shows how much of the variance in new data, for example succeeding water years, will be predicted by the model derived from the older data. PRESS and the $R^2_{predicted}$ share a relationship similar to the standard error of the regression and the percent standard error of the estimate (PSEE). While the PRESS should only be used to compare models derived for the same dependent water quality variable, the $R^2_{predicted}$ may be used for comparisons of models derived for different dependent variables. The regression model with the lowest PRESS is, for models with similar quality of residuals, the best model.

Given these criteria, we tempered their strict application by the philosophy that "a relationship may be statistically significant without being substantively important" (Milliken and Johnson 1984). Lystrom et al. (1978a) also chose their best models based on other-than-statistical considerations; that is, they applied their "conceptual knowledge of the water-quality processes" as one of their criteria. Similarly, if a regression was good statistically, but we could find no reason for the association of its basin attributes with water quality, we chose a statistically less good but conceptually more sensible model.

METHODS AND MATERIALS

A. General Procedures for Data Extraction and Manipulation

Because all analyses were to be performed with existing information, our first effort was to identify potentially useful data on water chemistry and flow which existed in electronic data bases. Next we developed criteria to choose an ideal subset of data and then actually selected data as a compromise between what ideally was desired and what was available. Once chosen, data then were retrieved from the electronic data base and converted to forms appropriate for our use.

Other required information also had to be converted to an appropriate electronic form. For example, some information on soils was available in tabular or cartographic form by county. However, we needed such information compiled not by county but by drainage or subdrainage basin. An electronic digitizer was used to create and record electronically many such additional data. We attempted to compile data on basin attributes from sources which collected information between 1964 and 1979, as we did for data on water quality and discharge. The general water quality modeling scheme is illustrated in Figure 7.

The major use of the digitized data was to create independent variables (X's) for the multiple regression models. Initially we had 157 independent variables in five major categories with which to work, obtained from both digitized data and other data; the potential set of different models that could be generated was huge. As discussed below, this large initial data set (Appendix A) was reduced before analyses if particular statistical assumptions were not met.

Independent Variables

We define an independent variable as the unique numerical measure of some feature of the drainage basin. The five major types of independent variables or basin attributes are Geology, Hydrology, Soils, Land Cover/Land Use, and Climate. These attributes roughly correspond to those of Lystrom et al. (1978a), but the individual attributes within each of our categories were dictated by the availability of data.

Much of the data from which we derived basin attributes had to be transformed from maps, charts, or lists. We used a COMPAQ microcomputer with a Houston Instruments 11" x 11" digitizing pad to measure areas from maps or charts and LOTUS 123 software (Lotus Development Corporation 1983) and TWIN software (Mosaic Software, Inc.) to store and manipulate collected information. Sources of information and a description of its transformation into independent variables follow. The initial set of 157 independent variables is listed in Appendix A.

Basin attributes may be divided roughly into two classes. The first, which we call "permanent" attributes are those characteristics such as geological formation, maximum and minimum temperature, subbasin area, and basin slope, which cannot easily be altered by man. The second class of "temporal" attributes includes characteristics potentially affected by human activity: land cover and land use; precipitation; erosional tendency of soils; and many hydrological variables. This distinction between permanent and temporal variables is important because if we assume a cause-effect relationship, then temporal variables quantify how management could improve or worsen water quality.

Geology

We calculated areas of all geological formations shown on three hydrologic investigations maps (Welder and McGreevy 1966, Whitcomb and Lowry 1968, and Welder 1968). The area of each formation in each of 18 subbasins (Table 1) were recorded and areas of geologically similar formations summed as independent variables. Percentage transformations also were recorded. All geological attributes are permanent variables.

Hydrology

Hydrological variables, except for flood estimates, were calculated using data taken from current U.S. Geological Survey 1:250,000 scale topographic maps of the basin. Areas were obtained with the digitizer, and linear measures with a map measuring wheel. Total streamlength (SLENG) is the length of all streams in a subbasin, including intermittent streams marked on the map, but not including their extension to the drainage divide. Drainage density (DDEN) is the ratio of (SLENG) divided by subbasin area (AREA1). We determined Strahler order number (ORDR) from the method of Branson et al. (1981). Main channel length (CHANL) is the length of the longest channel, again including any intermittent portions, but not including the extension to the drainage divide. Main channel slope (CHANS) was measured as the $S_{10/85}$ (Lystrom et al. 1978a). Elongation ratio (ELONG; Branson et al. 1981) is the ratio of the diameter of a circle having the same area as the subbasin to the maximum length of the subbasin. Mean basin elevation (MELEV) and mean basin slope (BASINS) we determined according to Lystrom et al. (1978a). The average bifurcation ratio (BIFUR) is the mean of all bifurcation ratios within a subbasin.

We calculated 2-, 10- and 25-year floods (FLOD2, FLOD10, and FLOD25) in two ways. First, where possible, we determined them from a log- Pearson Type III plot generated by the Water Resources Data System (WRDS, Wyoming Water Research Center 1983). There were five stations where lack of data required an alternate method. We chose that of Lowham (1976), with stream width estimates for his equations supplied by personal communications with members of the Wyoming Game & Fish Department. All peak flows (PK6579, PKPOR) were obtained from WRDS output. Flood ratio (FLDRAT) is calculated by dividing the peak 10-year flood discharge (FLOD10) by the peak discharge in the period of study (PK6579).

All Hydrological variables were considered temporal, except for area, elevation, elongation ratio, and basin slope.

Soils

From Young and Singleton (1977) we found those soil series represented in soil associations in the watershed, and by digitizing determined the area of each association in each subbasin. From corresponding Soil Conservation Service soil series data sheets supplied by Munn (1984), we calculated the area-weighted means of the characteristics of all soil series within each association to obtain each subbasin's value.

Missing data or series were not included in weighted averages. Frost-free days, mean annual soil temperature, basin slope and basin elevation were considered permanent attributes.

Land Cover/Land Use

From a map compiled by Anderson et al. (1984), we obtained values of cover, weighted by area, for each subbasin. Since some of the cover classes are subgroups of other categories, we also determined the area of all higher-order classes, as well as percentage transformations. All land cover/land use classes are temporal variables.

Climate

Maps from Lowers (1960) were enlarged xerographically. From the area between adjacent isotherms, we determined minimum and maximum temperatures for each subbasin. Precipitation in the Wyoming portion of the drainage was estimated similarly from a map not yet cleared for public release. Precipitation falling on the Utahn part of the drainage was estimated from an undated precipitation map from the Utah State Engineer's Office. Precipitation was not considered a permanent attribute because of proposals to increase water yield in the basin by seeding clouds.

Reduction of Number of Independent Variables

We reduced the number of independent variables from 157 (Appendix A) by first eliminating those variables which were duplicates, percentages, or sums of other variables (except for Geological variables, where we kept the sums and eliminated their components; see Appendix C). We further pared the number of independent variables by dropping those which were not significantly (p=0.05) related to a water quality variable in a simple bivariate regression. Thus, for every dependent water quality variable, we had a unique set of independent basin attributes with which to begin multiple regression analyses. The number of independent variables in these unique sets was trimmed even further during each regression analysis as explained in the Regressions section, below.

<u>Dependent Variables</u>

Selection of variables and stations

We extracted from WRDS all water quality data on all dates for all sampling stations in the watershed. Since these data reflect the inputs to a waterbody of both non-point sources and point sources combined, these data are termed combined source concentrations and/or loads. Water quality parameters with combined source measurements were selected as dependent variables as described below.

A water quality parameter was defined as acceptable to include in our analyses if it had at least seven years of data between water years 1965 and 1979, with at least one year of data comprised of ten or more samples. Using these criteria, we found acceptable only nine water quality variables (Table 2) at sixteen surface water discharge stations (Table

1). The areas above these sixteen stations defined the subbasins for which we compiled independent variable, or basin attribute values. All of our stations were included in the WRDS database.

Reduction of number of dependent variables

We constructed via SPSS (Nie et al. 1975) a simple Pearson correlation matrix for the eight water quality parameters having units of concentration. Because Total Dissolved Solids (TDS) is highly ($R^2 > 0.97$) and significantly ($p=0.001$) correlated with Dissolved Sodium, Conductivity, and Hardness, TDS is a good surrogate variable for the other three. Consequently, no further analyses were performed with the latter water quality variables.

Calculation of loads from concentration

We wanted mean annual loadings for water quality parameters to be the dependent variables in our regression models, but most information was only available as concentrations. The concentration of many water quality parameters depends upon discharge (Lystrom et al. 1978a). For such parameters, mean annual loads should be calculated as sums of instantaneous loads. For parameters with concentration independent of discharge, mean annual loads may be calculated from average discharges and average concentrations over the study period (Lystrom et al. 1978a):

$$L_n = 0.986\ C_nQ \qquad \text{Equation 2}$$

where L_n is the load in tons/year, C_n the average nutrient concentration in mg/l, Q the mean daily discharge in ft^3/second, and the constant 0.986 has units of ton-liter-seconds/mg-ft^3-year.

To evaluate the dependence of concentration upon discharge, a within-parameter analysis of variance test can be used. For each water quality parameter, this test compares the variances of two groups of data. The variance of the observed concentrations is one group, and the variance about the log-concentration/log-discharge regression (standard error of the mean, or SEE) is the other data group. If there is no significant difference between the group variances, then calculating loads as the product of mean concentrations and mean discharges (Equation 2) is acceptable.

All but six of our stations (GRBP, BSBD, BSAC, GRBI, BCGR, HFAG) had both surface water discharge and water quality records, so we were able to obtain the appropriate SEE from a WRDS LOAD program. Stations BSBD, BSAC, and HFAG have water quality data, but no data on discharge: information on discharge from stations immediately upstream (BSAF,BSGB, and Hams Fork at Kemmerer--USGS #9223500, respectively) was used to calculate SEE's via a log-log regression (SPSS SCATTERGRAM). We used a similar approach for station GRBI, adding same-day discharges from upstream stations on two tributaries (GRBF and BSAC) to obtain discharge estimates. Unfortunately, for station BSAC, water quality samples were taken after the period of record for discharge, and regressions could not be executed.

Of the five water quality parameters tested by analysis of variance, only TDS concentration had a significant difference between SEE versus the variance in observed concentrations (Table 3). Therefore, mean annual loads for Nitrate-nitrogen, Total phosphorus and Alkalinity were calculated from average concentration and average discharge using data from the 15-year period of study (Equation 2). TURBIDITY was analyzed as Jackson turbidity units.

One of our original nine water quality parameters had units as load (TDS load, tons/day). These data were used directly in regression analyses, rather than converting TDS concentrations to daily loads and averaging.

To summarize, dependent variables in multiple regression analyses were mean annual combined source loads of nitrate, phosphorus, alkalinity, and dissolved solids. Turbidity is measured in Jackson turbidity units of opacity.

Regressions

Further reduction of independent variables

We used a four step process to i) reduce the number of independent variables to include only those meeting the assumptions of the multiple regression technique, and ii) ensure that each water quality variable had a unique set of associated basin attributes prior to regression modeling.

1) We examined scatterplots of each independent variable (Appendix C) with each dependent variable to determine if transformations were necessary to establish a linear relation between the variables. The most frequently required transformations were $\log_e$ (i.e., ln-normal and ln-ln) and hyperbolic functions.
2) After inspecting scatterplots, we eliminated independent variables whose distributions were effectively discrete. For example, the alpine vegetation cover class (ALPV) had several cases (subbasins) with no alpine vegetation, and six subbasins with 15 mi^2 each of alpine vegetation. This independent variable was not a continuous variable, as required by multiple regression analysis. Such discrete and quasi- discrete independent variables were eliminated from further consideration in the modeling effort.
3) Independent variables not significantly ($p < 0.05$) correlated with the dependent variable in a simple bivariate relation were eliminated (Pearson correlation analyses, Nie et al. 1975).
4) To not overfit the regression equation, a rule of thumb is that the number of independent variables considered should not exceed the number of cases (number of stations--16). As a result of the previous manipulations, no unique set of independent variables for any water quality parameter had over twenty members.

At this point, then, each water quality variable had a unique set of associated basin attributes eligible for further analyses. During regression modeling, three more steps were taken to reduce the number of independent variables to meet the assumptions of multiple regression and to define the better models.

1) Many basin attributes in each unique set were highly intercorrelated (multicollinear). Since this seriously violates an assumption of regression, we structured the regression analyses to exclude variables with high intercorrelations. Hull and Nie's (1981) NEW REGRESSION and BMDP P9R (Dixon et al. 1985) include a tolerance

value which we set at 0.4. This tolerance ensured that once a variable was entered, another variable intercorrelated with it at $R^2 > 0.6$ would not be considered; conversely, if a variable was removed on a step, its highly intercorrelated variables would then be eligible for inclusion in the succeeding step.

2) For the dependent water quality variables NO_3, TP, and Alkalinity, which are loads calculated from mean annual discharge and mean annual concentration, models incorporating discharge-derived basin attributes were not considered because loads include discharge in the dependent variable (e.g., the 15-year mean discharge (DIS15), the peak discharge measured during the period of record (PKPOR), etc.). If such models were considered, the $R^2_{adjusted}$ would be artificially high because a portion of the correlation would be acquired from the correlation of the discharge component of the independent variable with the discharge component of the load.
3) After the initial regression of a unique set of independent variables with its associated water quality variable, the basin attribute chosen by the analysis was eliminated from the independent variable set and the data reanalyzed. This procedure was iterated until the $R^2_{adjusted}$ for an iteration fell substantially below the $R^2_{adjusted}$ of the initial regression. For the SPSS programs, this allowed several models to be generated for each water quality variable. BMDP ALLSUBSETS automatically generates several such models.

Interpretation of regression results

To find the "best" association of a water quality parameter with basin attributes we used four objective criteria and a philosophical principle:

1. A large adjusted R^2 and small standard error of the regression.
2. Minimum intercorrelation of independent variables.
3. Well-fitting residuals plots.
4. A small PRESS.

The philosophical principle was that if a regression was good statistically but had no reasonable basis for the association of its basin attributes with water quality, we chose a statistically less good but conceptually more sensible model (see "Selection criteria for regression models").

B. Validation of regression models

First, the PRESS statistic can be interpreted as a measure of temporal validity of the regression models. A common practice to validate models, called cross-validation, is to split the original data set into the estimation data and the prediction data. The investigator then builds a model with the estimation data, and tests how well the model so derived fits the prediction data. The PRESS technique in effect does this N - 1 times (N = number of cases), sequentially dropping a case out of the full data set to serve as the prediction data set for the model built from the data of the other N - 1 cases.

The PRESS statistic can also be used to calculate how much variance ($R^2_{prediction}$) in new data from the same stations would be explained by the model (Montgomery and Peck 1982):

$$R^2_{prediction} = 1 - [PRESS / TOTAL\ REGRESSION\ SUM\ OF\ SQUARES]$$
Equation 3

An $R^2_{prediction}$ value close to the $R^2_{adjusted}$ value derived from the original data signifies that the model is valid independent of the time period to which it is applied.

A second validation method is a cross-basin validation. We applied all of the models derived from the Green River basin to an adjacent basin--the Sweetwater River, Wyoming. The U.S. Geological Survey maintains a water quality sampling station (USGS #663900) on the Sweetwater River twenty-five miles south of Alcova, Wyoming. We determined the observed mean annual load (tons/year) and 95% confidence intervals for NO_3, TP, Alkalinity, TDS, and Turbidity (as JTU) from data in USGS water year books (U.S. Geological Survey 1965-1979), and compared them to means and confidence intervals predicted by the models.

C. Miscellaneous methods

All analyses using SPSS (Nie et al. 1975), BMDP (Dixon et al. 1985), and MINITAB (The Pennsylvania State University 1982) were conducted on the University of Wyoming's Control Data Corporation Cyber 760 and 840 mainframe computers. We used MINITAB to perform matrix algebra necessary to calculate PRESS statistics and confidence intervals for multivariate regression equations (Montgomery and Peck 1982). Confidence intervals for bivariate models were calculated according to Mendenhall and Reinmuth (1982) using TWIN (Mosaic Software, Inc. 1983).

RESULTS AND DISCUSSION

A. Combined Source Regression Models

We begin with a short summary of the process of choosing the most appropriate regression models. First, from the large list of independent variables in Appendix A, we deleted variables which were components of other variables (for geological variables) or supersets of variables (for all other variable classes). This constituted the set of common independent variables (Appendix C). Next, for each water quality variable, we deleted those independent variables which were not significantly linearly correlated, either normally or transformed, with the dependent water quality variable. Obviously this led to a unique set of basin attribute variables for each dependent water quality variable.

We next ran, for each water quality variable, multiple regression analyses by each of four different methods. For three of the methods, after an initial run we deleted the chosen independent variable from the unique data set and reran the analysis. This process was repeated several times, and generated several models for each dependent water quality variable (Table 4 through Table 8).

From analyses of residuals plots and whether or not discharge- related variables were chosen, we reduced the number of models generated by the SPSS methods to that shown in Table 9.

After applying the four criteria to the models in Table 9, we found the regression model(s) which best associates attributes of the Green River watershed with each water quality variable investigated in the Green River drainage (Table 10).

The models--choosing the optimal models for a parameter

Nitrate-nitrogen

Eliminating the discharge-related models from the initial models (Table 4 Nitrate-nitrogen) left only the models in Table 9, Section A. The final Nitrate-nitrogen models (Table 10) could have been chosen based on $R^2_{predicted}$ alone. However, the CROPI model was chosen because of the potentially causal relation between irrigated cropland and the amount of nitrogen in surface waters, while the two-variable model was selected since it possessed the highest $R^2_{predicted}$ and $R^2_{adjusted}$, the lowest PSEE, and good fit of the residuals.

Total phosphorus

The two best models of total phosphorus by the criteria of $R^2_{adjusted}$ possess length of the stream channel (CHANL) and subbasin area (AREA1) as independent variables (Table 9, Section B). The AREA1 model was eliminated since it has a substantially lower $R^2_{predicted}$. The model with a slightly lower PRESS than the CHANL model was the HBASINS model, which included as the independent variable a hyperbolic transform of the basin slope. But since this model had a poorer fit of residuals, we chose the CHANL model as best (Table 10).

Alkalinity

For alkalinity load, when models with poorly fitting residuals were deleted from the initial set of regressions (Table 7), seven models remained (Table 9, Section D). Of these, the three with an $R^2_{adjusted} > 0.8$ and excellent fit of the residuals were considered when choosing the two final regression models. The final model including AREA1 and HMINT (a hyperbolic transform of the January minimum air temperature) was chosen over the model with HMINT and SLENG (total streamlength) because the $R^2_{adjusted}$ was slightly better. As a more parsimonious model, we chose that model incorporating only CHANL. It had excellent fit of residuals, and an $R^2_{adjusted} > 0.8$; also, with $R^2_{predicted} = 0.72$, the CHANL model should adequately reflect the relations between mean annual alkalinity load and main channel length using new data.

Total dissolved solids

After disregarding the models with poor residuals in Table 7 (Total Dissolved Solids (TDS)), seven models remained (Table 9, Section D). Of these, the model incorporating AREA1 was clearly best by all criteria, and was therefore chosen.

Turbidity

Of all the models listed in Table 8 (Turbidity), only two had sufficiently adequate residual plots to be considered further (Table 9, Section E). The residuals plots are only "fair", and some assumptions of the multiple regression technique may be violated by one or both of the models. The higher $R^2_{predicted}$ and $R^2_{adjusted}$, and lower PSEE, of the model containing MINT (minimum January air temperature) recommends it over the alternative model including LALPA (natural log transform of the area covered by alpine vegetation) and HDDEN (hyperbolic transform of the drainage density).

All final models (Table 10) had relations between basin attributes and water quality parameters which were highly significant ($p < 0.01$). We therefore reject the first null hypothesis of this study that there are no significant relations between attributes of the Green River basin and water quality in the Green and Blacks Fork Rivers. Such associations do exist and might be useful in further investigations of such relationships in the drainage.

Obviously, the final models (Table 10 and Figures 8-14) are not the only associations of basin attributes with water quality. First, between the initial regressions and the final regressions many models were evaluated but rejected using the previously outlined criteria. Second, even though the initial set of basin attributes was extensive, some important basin attributes associated with water quality in the watershed may have been overlooked. Finally, it should be apparent that choosing regression models is both quantitative (calculation of metrics) and qualitative (interpretation of both residual plots and relative importance of the plots and metrics). Consequently, the final regressions represent our judgment of the best models of water quality in the Green River basin.

The models--comparison across different dependent variables

The adequacy of models can be compared using the same four quantitative criteria exercised to select the final regression models for each water quality variable:

1. A large $R^2_{adjusted}$, and small standard error of the regression and correspondent PSEE.
2. Minimum intercorrelation of independent variables.
3. Well-fitting residuals plots.
4. A small PRESS and larger $R^2_{predicted}$.

More accurate models have higher values for $R^2_{adjusted}$ and lower values for PSEE (percent standard error of the estimate). All final models (Table 10) explain over seventy percent of the variance ($R^2_{adjusted}$) in the water quality parameters, which is considered good.

As measured by the percent standard error of the estimate (PSEE) descriptor (Table 11), Nitrate-nitrogen Model B is marginally better than Model A, and Alkalinity Model A is the better of the two Alkalinity models. The Total Phosphorus and Turbidity models have PSEE values greater than 50%, rather poor in comparison to all the others.

Based upon PSEE the best model generated is that for TDS; this possibly is related to the number of samples available for calculating loads. According to the number of years sampled during the 15 year period of record and the number of years sampled more often than 10 times, the ranking of the water quality parameters is TDS > Alkalinity > Nitrate-nitrogen >> Turbidity > Total phosphorus. Because TDS loads were derived from more stations, more years of data, and more years of data with greater than ten samples, a more accurate model resulted. This phenomenon probably has a similar effect upon values of $R^2_{adjusted}$ and $R^2_{predicted}$ (Table 11).

A higher $R^2_{predicted}$ signifies a more robust model, because variance explained by the model when using new data should not be appreciably less than with the data used to create the regression originally. While in this case we cannot test for statistically significant differences between $R^2_{adjusted}$ and $R^2_{predicted}$, we can suggest what R^2 value is acceptable for application to new data. In other words, we can use judgment rather than statistics to evaluate the third null hypothesis in this study--that the models will not appreciably underestimate the variance explained when they are applied to new data. It seems apparent that the model for Total phosphorus definitely should not be used as a predictive model for new data because of its abysmally poor $R^2_{predicted}$, but that both the models for Nitrate- nitrogen are marginally acceptable as predictive models (Table 11).

Accuracy of the regression models

Accuracy relative to observed data

One type of model accuracy reflects how well a model mimics or explains the data used to build it. General measures of such accuracy are the $R^2_{adjusted}$ and percent standard error of the estimate (PSEE) of the regression equation, while the accuracy of individual predicted values are evaluated by comparison to the regression's 95% confidence interval at the predicted value. If confidence limits are small, most of the actual data will plot close to the regression line, and therefore the equation fits the data well at that predicted value.

Examining the loads and confidence limits predicted by the water quality models at each station yields information concerning 1) the general fit of the model to the predicted and observed data, 2) relative fit of different models of the same water quality parameter, 3) outlying or unusual predicted or observed values, 4) tests of hypotheses of significant difference between stations or between observed and predicted loads, and 5) overprediction or underprediction (bias) at specific stations.

The general accuracy of the models may be judged by examining the predicted loads and confidence limits (Table 12 and Table 13, and Figures 15-21). The absolute confidence intervals about the estimate for the stations are relatively constant (e.g., for nitrate-nitrogen models, Figures 15 and 16, the interval is about + 50 tons/yr). Confidence intervals as a percentage of the predicted load are not constant, however, and can vary markedly. The Nitrate-nitrogen Model A (Figure 15) has a maximum confidence interval of + 121%, while the Alkalinity Model A (Figure 18) shows an interval of + over 1800%. The marked variations can be accounted for by the smaller headwater drainages such as NFAB, BSLS, BFAL, and HFAG. Elimination of these subbasins from consideration reduces the maximum confidence intervals from 121% and 1800% in the Nitrate-nitrogen and Alkalinity Models A to 68% and 75% respectively. The model estimates are therefore more accurate for larger subbasins.

If 95% confidence intervals overlap between stations, the respective predicted values cannot be considered different from each other ($p = 0.05$). This applies to predictions for stations within a single model, as well as for comparisons between Nitrate-nitrogen Models A and B (Figures 15 and 16) and between Alkalinity Models A and B (Figures 18 and 19). There is no significant difference in the predicted loads for each station between Nitrate-nitrogen Models A and B. Neither model is preferred based upon differences in loads.

For Alkalinity, neither model accurately predicts the load at station HFAG, and there is no difference in loads at any other station, so a model should be chosen based upon criteria other than relative accuracy (ease of measurement of the basin attributes, for example).

For the stations at GRGR and BFLA, the 95% confidence limits can be used to test the second null hypothesis in this study--that there is no significant difference between observed and predicted loads at the most downstream stations of the Green River and the Blacks Fork. Obviously, those models having significant differences between observed and predicted values should not be used to estimate loadings to Flaming Gorge Reservoir. At station GRGR observed and predicted values for all models but those of Nitrate-nitrogen are not significantly different (Appendix A and Tables 12 and 13). We reject H_{02} for both Nitrate- nitrogen models, and fail to reject it for the other models.

Nitrate Models A and B will overpredict or underpredict more than 99% of the time. All models but Nitrate-nitrogen are suitable for predicting loadings to the Green River Arm of Flaming Gorge Reservoir. Specifically note that the TP model is a good predictor of TP in the Green River above its confluence with Bitter Creek.

We reject H_{02} for more models at station BFLA on the Blacks Fork. Only for the models Nitrate-nitrogen Model B, Alkalinity Model B, and Turbidity Model A does no significant difference occur between observed and predicted loads. We reject H_{02} for all the other water quality models. There is no total phosphorus data for station BFLA, so its model cannot be evaluated.

The lack of observed data for TP at BFLA illustrates an advantage of regression analysis: it is possible to evaluate accuracy of TP loads at BFLA, in spite of the fact that TP is not monitored there. Also, predictions from the TP model will encompass an actual mean of yearly loads collected at the station 95% of the time.

Accuracy relative to independent estimates

The measures of accuracy of a model (e.g., standard error of the regression, PSEE) tell how well the model fits the data used to generate it. The second type of a model's accuracy reflects how well its predictions agree with predictions or estimates calculated by independent investigators. We were able to make such comparisons for TP and TDS load, since independent estimates for the Green River basin are available.

Total phosphorus

Measures of phosphorus loading into Flaming Gorge Reservoir have been made by the USEPA (1977), SWWQPA (1978), and Wyoming Water Resources Research Institute (WRRI 1977). First, during the National Eutrophication Survey of Flaming Gorge Reservoir, the USEPA estimated a TP load in 1975 (less municipal waste treatment plants) of 48,325 kg/yr (53 tons/yr), and a total load to the Green River Arm of 87,715 kg/yr (97 tons/yr). The SWWQPA calculated a combined load of 123 tons/yr in 1975 and 326 tons/yr in 1976, as it entered Flaming Gorge Reservoir. Their 1975 figure is only 38% of the 1976 loading and gives some indication of the year to year variation in TP loading to the reservoir. WRRI computed a combined source phosphorus load of 84 tons/yr to the Green River Arm using data from 1975 in computer simulations.

The TP load from all sources predicted by Total phosphorus Model A for station GRGR is 79 tons/yr (Table 12). By adding to this estimate the point source load from along Bitter Creek and the Green River downstream of GRGR but upstream of the Green River Arm of Flaming Gorge Reservoir (33.3 tons/yr, Appendix B), we predict an mean annual total phosphorus load to the Green River Arm of 112 tons/yr. Adding the point source load (33.3 tons/yr) to the 95% confidence limits about the predicted load at GRGR yields a range of total loads to the Green River Arm of 95 tons/yr to 130 tons/yr.

Our estimates are not significantly different ($p = 0.05$) from the figures of USEPA (97 tons/yr) and the SWWQPA estimate for water year 1975 (123 tons/yr). The upper and lower range of our estimates are significantly different, but still within the same order of magnitude, as loads determined by WRRI for water year 1975 and SWWQPA for water year 1976 (84 and 326 tons/yr, respectively). Total phosphorus Model A accurately predicts mean annual loading to the Green River Arm of Flaming Gorge Reservoir, compared to independent estimates.

Total dissolved solids (TDS)

For TDS, we may compare loads predicted by Total dissolved solids

Model A (Table 12) to estimates from WRRI (1977) and DeLong (1977). First, from computer simulations using 1975 data, WRRI estimated TDS load of 826926 tons/yr at River Mile 85, just before the inflow of Bitter Creek to the Green River; the WRRI sampling point is approximated by station GRGR in this report. The 95% confidence limit about our predicted load, based upon 15 years of information, is from 566000 tons/yr to 652000 tons/yr. The WRRI estimate is 32% to 21% greater than our prediction, though within the same order of magnitude.

Second, DeLong (1977) estimated the difference in TDS load between the Green River stations below Fontenelle Reservoir (GRBF) and at Green River city (GRGR). The difference in our mean predicted TDS loads between these two stations is 255749 tons/yr. (From Table 12, 608785 tons/yr - 353036 tons/yr = 255749 tons/yr.) The range of mean annual TDS loads estimated from the 95% confidence limits about the model's prediction is 190055 tons/yr to 321443 tons/yr. DeLong estimated an increase in loading between the two stations of 202000 tons/yr. His figure is not significantly different ($p = 0.05$) from our prediction.

The close agreement of loads predicted by the Total phosphorus and Total dissolved solids Models A with independently computed loads argues for the accuracy of these models and for the value of the multiple regression approach to predicting water quality in the Green River drainage.

B. Validation

Temporal

The temporal validity of the various models is determined by examining the $R^2_{predicted}$ (Table 11). The role of the $R^2_{predicted}$ in choosing valid models has been previously discussed ("The models-- comparison across different dependent variables"). Small differences between the $R^2_{adjusted}$ and the $R^2_{predicted}$ signifies a temporally valid model, because variance explained by the model when using new data is not appreciably less than with the data used to create the regression originally. Total phosphorus Model A and both the models for Nitrate- nitrogen are not temporally valid because of the greater than 20% difference between their respective $R^2_{adjusted}$ and $R^2_{predicted}$ values (Table 11). If new phosphorus or nitrate-nitrogen data are to be interpreted, a new model should be built including the new data. Alkalinity Model B and Total dissolved solids Model A, with less than 10% difference between their $R^2_{adjusted}$ and $R^2_{predicted}$ values are temporally valid for analysis of new data.

Alkalinity Model A and Turbidity Model A are marginally valid models; their $R^2_{adjusted}$ and $R^2_{predicted}$ values differ only between 10% and 20%. Whether or not new models should be built for new data depends upon whether the potential gain of explained variance justifies the effort involved building the new model.

Spatial

Our final validation step was a cross-basin validation. We applied all of the models derived from the Green River basin to an adjacent basin-- the Sweetwater River of Wyoming, which is located in the Missouri River drainage. For USGS station #663900 on the Sweetwater, we determined the observed mean annual loads (tons/year) and 95% confidence intervals (Table 14) for nitrate-nitrogen, TP, alkalinity, TDS, and turbidity (as JTU) from data in USGS water year books (U.S. Geological Survey 1965-1979). We compared these results to means and confidence intervals predicted by the Green River basin models incorporating Sweetwater River basin data (Figure 22).

If there is no significant difference between the load predicted by a model when it is applied to data from another basin and the observed data from that basin, the model is spatially valid. Nitrate Model A and Alkalinity Model B show no significant differences between their predicted loads and the observed loads from Sweetwater River drainage data; their predictions are spatially valid for at least one basin other than the drainage in which they were developed. By a less stringent, non-statistical comparison, the Nitrate Model B, TP model, and TDS model had confidence limits of observed and predicted loads in the same order of magnitude. For some purposes these models may be adequately valid for application to the Sweetwater River drainage.

Alkalinity Model B and the Turbidity model are obviously not valid for application to at least this one other drainage, because of the statistically significant and large differences between their respective predicted and observed values.

C. Impact of point sources on modeled predictions

Point source loads as proportions of the observed combined loads

Point sources for the period investigated in this report (water years 1965 to 1979) are listed in Appendix B (Wagner 1984). The entire point source phosphorus load (5.4 tons TP/year) in the Green River section of the drainage, upstream of station GRGR, is only 5% of the observed TP load from all sources (95 tons TP/year, Appendix A). These point sources are a small proportion of combined loading, and most are remote from the Green River arm of Flaming Gorge Reservoir. Therefore, combined source TP inputs in the Green River section are practically equivalent to non-point source TP inputs. Total phosphorus was not measured at station BFLA on the Blacks Fork, so no proportion can be calculated; the load of TP from all point sources in the Blacks Fork is about 11 tons TP/year, mostly from the waste treatment plant at Kemmerer (7 tons TP/year).

Nitrate-nitrogen point sources in the Green River section and the Blacks Fork section (8.9 tons/yr and 13.8 tons/yr; Appendix B) contribute, respectively, 3% and 11% of the nitrate-nitrogen load observed in the Green River section (297 tons/yr; Appendix A) and the Blacks Fork section (124 tons/yr; Appendix A). Because of its small contribution and distance to the Green River arm of Flaming Gorge Reservoir, we consider the nitrate-nitrogen combined source load in the Green River section practically equivalent to the non-point source load. In the Blacks Fork section, however, point sources are a large proportion of the total nitrate-nitrogen load in the river at BFLA, and may have a significant effect upon processes in the reservoir.

The total nutrient load to the Green River Arm of Flaming Gorge Reservoir may be found by adding the point source inputs from Green

River city and Bitter Creek (33.3 tons TP/yr and 45 tons NO_3/yr; Appendix B) to the load observed at station GRGR, upstream of their inflows (95 tons TP/yr and 297 tons NO_3/yr; Appendix A). Since these point source inputs are only about five miles upstream of Flaming Gorge Reservoir, there is not a long reach of the Green River in which riverine processes can assimilate the inputs. The phosphorus and nitrate loads from these more proximate point sources, which constitute 26% of the entire phosphorus load and 13% of the entire nitrate-nitrogen load to the Green River arm, may have potentially great impact upon water quality in the reservoir.

The total load to the Blacks Fork Arm of Flaming Gorge Reservoir is the combined source load at the most downstream station on the Blacks Fork (BFLA, Blacks Fork at Little America), since there are no point sources to the Blacks Fork between that station and Flaming Gorge Reservoir.

Point sources as proportions of the predicted combined loads

We applied Nitrate-nitrogen Models A & B and Total phosphorus Model A to stations GRGR and BFLA to examine the impact of point sources in the Green River basin. Point source loads for both the Blacks Fork and Green River sections (Appendix B) were subtracted from the predicted combined source loadings (total export) at BFLA and GRGR and the resulting difference examined to see if it fell outside the 95% confidence limits of the predicted combined source load (Tables 12 and 13). If so, the nonpoint source load is significantly different from the combined source load; point sources may considerably influence processes in the river and Flaming Gorge Reservoir. Non-significant differences indicate that the effects of point sources are probably negligible.

Nitrate-nitrogen

Point source loads of nitrate-nitrogen contributed upstream of station GRGR (8.9 tons/yr as NO_3, Appendix B) are not a significant proportion of the combined source load predicted by either Nitrate Model A or B (525 tons/yr and 531 tons/yr, respectively, Tables 12 and 13). The addition of nitrate point sources downstream of station GRGR (45 tons/yr as NO_3, Appendix B) yields a total nitrate load to the reservoir of 570 to 576 tons/yr. Since these loads are within the 95% confidence intervals of the combined source load of nitrate-nitrogen, they are not significantly different from the predicted load from all sources combined. Nitrate-nitrogen point sources loads to the Green River Arm of Flaming Gorge Reservoir cannot distinguishably affect eutrophication processes in the reservoir.

At station BFLA on the Blacks Fork, upstream point sources contribute 14 tons/yr of nitrogen as nitrate (Appendix B). Again, the elimination of the load from these point sources yields a nonpoint source load not significantly different from the combined source load predicted by either Nitrate Model A or B (232 tons/yr and 153 tons/yr, respectively, Tables 12 and 13). Nitrate-nitrogen point sources loads to the Blacks Fork Arm of Flaming Gorge Reservoir cannot distinguishably affect eutrophication processes in the reservoir.

Total Phosphorus

The predicted combined source total phosphorus load at BFLA (Table 12) is 30.63 tons/yr. Point sources upstream of this station contribute 10.6 tons/yr of this amount (Appendix B); there are no point sources downstream. Assuming that riverine processes sequester none of the point source load, 10.6 tons/yr of point source TP inputs is a significant proportion of the combined source load. The potential effect of these significant phosphorus point sources on downstream water quality suggests a worthwhile prospect for future investigation.

The point sources above station GRGR export 5.34 tons of phosphorus per year (from Labarge, Marbleton, Big Piney, and Pinedale waste treatment plants, Appendix B). The predicted combined source load at station GRGR is 78.95 tons/yr. By subtraction, and assuming again that riverine processes sequester or immobilize none of the point source input, the nonpoint source load is 74.51 tons/yr. This is not significantly different from the combined source load (Table 12); point sources of phosphorus above Green River city do not significantly increase phosphorus in the Green River.

By contrast, addition of phosphorus from point sources below station GRGR (33.34 tons/yr, Appendix B) to the combined source load at GRGR (78.95 tons/yr) yields a total load to the Green River Arm of Flaming Gorge Reservoir of 112 tons/yr, a significant increase over the combined source load at GRGR. Also, considering the proximity to the Green River Arm of the point sources downstream of this station, their constant, non-seasonal discharge, and their high proportion of bioavailable phosphorus, these point sources may affect water quality in the reservoir more than the simple proportions of their contributions suggests.

From these calculations alone we cannot say that reduction of point sources of phosphorus in the Green River basin would alleviate eutrophication in Flaming Gorge Reservoir. To do so requires interpreting how a reduced load influences the effects of eutrophication (algal blooms, hypolimnetic oxygen depression, etc.) in the reservoir. A discussion of a theoretically permissible load to Flaming Gorge Reservoir and the relationship of these predicted loads to the permissible load is discussed in the section of this report entitled "Comparing Estimated and Permissible Phosphorus Loadings for Flaming Gorge Reservoir using a Vollenweider-type Model".

D. Subbasins extensively contributing phosphorus and dissolved solids

Water quality variables causing major problems in the Green River drainage are phosphorus and salinity (Miller et al. 1983). From the predicted loads for each subbasin in the Green River and Blacks Fork sections of the Green River basin (Tables 12 and 13), we calculated predicted areal loads (subbasin areal loads) for TP and TDS (Table 15). These areal loads pinpoint subbasins exporting relatively larger amounts of TP and TDS per unit area, and help focus mitigation efforts to subbasins where they will be most effective.

For an even finer-scale dissection of the subbasin loadings, we calculated "segment areal loads." These are defined as (the segment load)/(the segment area), or (difference in loading <u>between</u> a station and the station next upstream)/(drainage area along each segment of a watercourse between sampling stations). For headwater stations, we assumed that the segment areal load equaled the subbasin areal load (Table 15).

Total phosphorus

The Hams Fork above Granger (HFAG) is an obviously large contributor of TP per unit surface area (Figure 23). The point sources in this subbasin (Kemmerer Waste Treatment Plant, Opal Waste Treatment Facility, Viva Naughton Power Plant and Viva Naughton Marina, Appendix B) generate 9.4 tons/yr; without this contribution, the TP areal load from non-point sources (0.021 tons/mi²/yr) is significantly less than the combined source areal load (0.037 tons/mi²/yr, Table 15). The non- point source areal load is roughly twice that of areal TP loads in the remainder of the basin (Figure 23). This may be caused by erosion from phosphoria deposits in the subbasin (Miller 1977).

The mean annual TP loadings in the headwater subbasins NFAB and BSLS are less than zero (Figure 23). However, since the mean annual loads from subbasins NFAB and BSLS are not significantly different from zero (Table 12), these negative areal loadings are not significantly different from zero (Table 15), and therefore may not actually indicate phosphorus removal from waters in the subbasins. Indeed, both subbasins are relatively small, high mountain drainages; a large export of nutrients from such drainages would not be expected.

Disregarding these anomalous subbasins (HFAG, NFAB, and BSLS), yearly areal TP load in the Green River drainage as a whole is approximately 0.01 tons/mi²/yr (22 pounds/mi²/yr or 26 kg/km²/yr). For comparison, Lystrom, et. al (1978b) observed TP yield in the Susquehanna basin as 0.03 to 0.35 tons/mi²/yr; their simulated non-point source TP yield was 0.03 tons/mi²/yr. That their estimates are within the same order of magnitude as our estimate is a favorable argument for the multiple regression approach to modeling water quality in large basins.

The two segments of streams in the Green River drainage exhibiting the largest increase in areal TP load are on the Big Sandy River between stations BSBD and BSGB, and between stations BSGB and BSAC (Figure 24). Since there are no significant differences in predicted mean annual loads of TP between any of the stations on the Big Sandy (Table 12), these high areal loads may be an anomaly of the calculation procedure. We can think of no characteristic of the lower Big Sandy River drainage which would cause such large increases in areal TP loading.

Neglecting the high values in the Big Sandy and low values from headwater segments (as discussed above), the mean annual areal TP loading is again about 0.01 tons/mi²/yr. This estimate is within an order of magnitude of the estimate for the Susquehanna River basin as discussed above (Lystrom et al. 1979b).

Two other segments in the Green River drainage exhibit unusual areal TP loadings. One, below Fontenelle Dam, shows a definite negative areal yearly load (the segment GRBF to GRBI). High productivity and growth of dense algal mats in this stretch of the Green River have been noticed (Parker et al. 1984), as has a lack of wintertime sampling of water quality (Parker et al. 1985). Since samples were primarily taken in spring and summer when phosphorus is being sequestered in biomass, rather than in fall and winter when the sequestered phosphorus is released, it is possible that a perceived decrease in concentration of TP in this reach of river during the sampling period yields a net decrease in areal loading when the sampled concentrations are applied annually.

Second, the segment of the Blacks Fork between HFAG/BFAL and BFLA shows no increase in areal load of TP. This signifies that most of the TP loading in the Blacks Fork is from the subbasins upstream of stations HFAG and BFAL.

Total dissolved solids

Total dissolved solids are exported fairly constantly from both whole subbasins and segments thereof (Figures 25 and 26). Except for the large mean areal loading (157 tons/mi²/yr) above station BSLS on the Big Sandy River, the predicted yearly areal TDS loading in the Green River drainage is about 90 tons/mi²/yr (200000 kg/km²/yr). The dissolved solids areal export from the Susquehanna River watershed was between 33.4 and 308 tons/mi²/yr, while the predicted non-point source load was 16.9 to 36 tons/mi²/yr (Lystrom et al. 1979b). Again, the Susquehanna estimates are within the same order of magnitude as those from the Green River basin. Because of the geology and aridity of the Green River drainage, one would expect the larger non-point source export of dissolved substances shown by this basin compared to the Susquehanna.

E. Mitigation efforts

Mitigation efforts are best applied where one can reap the most benefit from the least investment. Those areas between stations which yield larger areal loadings are more likely to meet this criterion than areas with lower areal loadings. Thus practices to reduce loading of TP would best be applied to the Hams Fork above the sampling station at HFAG, and should be planned both to reduce point source inputs and diminish erosion of the natural phosphoria deposits.

The large input of phosphorus from point sources to the Green River downstream from Green River city (station GRGR) recommends this stretch of river for reduction of point source inputs. However, because these sources are almost entirely sewage effluent from Green River and Rock Springs, the funding required to accomplish this may argue against such efforts.

Salinity apparently is exported fairly evenly from each unit area of the Green River drainage. Thus mitigation efforts reasonably could be allocated to subbasins using criteria other than the amount of areal export.

In discussing mitigation, we must remember that our regressions are not based on cause and effect. Rather, they simply represent one way to associate a water quality parameter with one or more basin attributes. However, when suggesting a water quality parameter can be altered by changing a basin attribute, note that we do assume such a cause-effect relationship occurs.

One useful way to use our regression models does not require this assumption. We apply a model to a subbasin where only the independent variable, or basin attribute, is known, and predict a value for the water quality parameter and its 95% confidence interval for extrapolations (somewhat larger than the 95% confidence interval for interpolated estimates of water quality). In this way we can rank various subbasins by their loadings even if data on water quality are unavailable. In turn, this ranking could be used to allocate mitigation efforts.

If we assume the regressions do represent cause-effect relationships, most of the final regressions explain changes in water quality as a function of hydrological or topographical basin attributes (e.g., slope, area, channel length; Table 10). Thus, for example, reducing the length of the primary stream channel in the subbasin (CHANL) should reduce export of total phosphorus and alkalinity. And, while it would be imprudent to start a large mitigation effort based only on these models, they generally do suggest what variables should be considered.

Mitigation efforts often might be focused not on reducing the value of an independent variable itself (e.g., CHANL), but on altering a secondary factor which in turn would reduce the independent variable. For example, Maret et al. (1987) report the large effect of bank erosion on total phosphorus loads to a stream in southwestern Wyoming. In the study area, trapping of sediments and phosphorus by beaver ponds was important in reducing the export of phosphorus originating from bank erosion. The ponds also reduced TP loading by preventing meandering and consequent bank erosion, thus reducing the length of the stream channel. However, stabilizing the stream banks in other ways also could be used to control bank erosion and hence export of phosphorus.

If the models do not involve variables which are directly altered during mitigation, then how are the models useful? First, they can suggest the magnitude of change which must occur to reduce export by a given amount. Assuming cause and effect, a 50% reduction of irrigated cropland in a the Big Sandy subbasin should reduce nitrate-nitrogen export by 32 tons/yr, or 19%.

Second, the models are useful because of what they suggest in a more general way. The topographic and hydrologic independent variables are those experimental work also has found to be important in affecting water quality. The models can be interpreted to suggest that topography and hydrology control water quality. In most of the Green River drainage this seems reasonable. Lowham et al. (1982) and Maret et al. (1987) suggest that banks and bank erosion are important sources of sediment, phosphorus, and other dissolved substances.

In general, nonpoint source mitigation measures suggested by the models relate to reducing bank erosion (e.g., bank stabilization; reducing the power of water to erode by reducing water velocity). As suggested previously, one possibly important alternate mitigation strategy is to reduce point source loading during periods critical for the development of blooms in Flaming Gorge reservoir.

SECTION 3:

USE OF DATA AUGMENTATION TECHNIQUES AND TIME SERIES ANALYSIS FOR ESTIMATING LOADING TO FLAMING GORGE RESERVOIR

A. ESTIMATING LOADING USING DATA-AUGMENTATION TECHNIQUES

INTRODUCTION

Frequency of sampling for water quality parameters has varied substantially in the Green River drainage (daily, weekly, fortnightly, monthly, or intermittently; Wyoming Water Research Center 1983). Consequently, results of Section 2, which are based on these data, may be biased by infrequent and/or intermittent sampling. In this section, various sampling schemes are evaluated to determine an optimal sampling program for the most downstream station of the Green River basin (Green River at Green River city--GRGR). Station GRGR is very important for evaluating eutrophication in Flaming Gorge Reservoir; it is close to the reservoir (approximately five miles), and measurements made at this station, plus point source inputs into the remaining five miles of river, provide the best estimates of loading to the Green River Arm of the reservoir.

The obvious practical significance of optimum sampling programs for watershed investigations is that they provide the best balance between information gained and sampling effort. Other researchers have developed optimum sampling programs by resampling continuous or nearly continuous records of actual or artificially generated water quality data. The first step in these efforts is, of course, finding or generating such records. Chow (1964) termed sequential generation of such hydrologic information as "stochastic hydrology".

Most of the work in stochastic hydrology has used the techniques of Monte Carlo sampling and/or time series analyses (extrapolative methods), or resampling from long records of continuous or daily data (an interpolative method). Monte Carlo methods involve sampling from a distribution describing the probability that a certain phenomenon or phenomena will occur (such as a discharge in the upper 10% of daily discharges). The work of Richards et al. (1985), evaluating optimum sampling schemes for nutrient and sediment load estimation in northern Ohio, is an example of a Monte Carlo procedure applied as hydrologic modeling. The technique also was used to find variance estimates of food chain dynamics in a nutrient-cycle/lake-eutrophication model (Scavia 1981).

The extrapolative technique of time series analysis recently has been applied to model eutrophication dynamics in a Pennsylvania reservoir (Steiner et al. 1985). Time series models can be considered a variant of the regression modeling technique in which the value of a variable is dependent upon the value of the same variable at a different point in time.

While techniques of Monte Carlo and time series analysis produce data similar to actual records, such data are nevertheless artificial. Some of the error in the artificial data is a function of these extrapolative techniques. Other researchers have used continuous or nearly continuous records of observed water quantity or water quality data to explore alternative sampling frequencies and schemes. For example, a three year record of daily suspended sediment loads was used by Dickinson (1981) to evaluate five computational methods for determining load in Big Otter Creek, Ontario. For estimating suspended sediment loads in the River Creedy, Devon, UK, various interpolation methods were analyzed from subsamples of a seven year continuous record of turbidity (Walling and Webb 1981). Methods for estimating total phosphorus load from one year of daily measurements of phosphorus loads in the Grand River, Michigan, were appraised by Dolan et al. (1981).

This section of the report evaluates combinations of three sampling intervals and two sampling strategies for estimating yearly loads of total phosphorus (TP) and salinity (as total dissolved solids--TDS) to the Green River Arm of Flaming Gorge Reservoir. The resulting optimal sampling program is one which will: 1) provide estimated yearly loads not significantly different from loads estimated by daily sampling, and 2) require the least sampling frequency. Thus the optimal sampling program furnishes an estimate of loadings not significantly different from that acquired by daily sampling without the expense of daily sampling and analyses.

METHODS AND MATERIALS

Generation of augmented data

Data on total dissolved solids (TDS) or total phosphorus (TP) were not taken daily on the Green River at Green River city (USGS station #09217000--GRGR) during water years 1965 to 1979; when collected, samples were taken fortnightly. Therefore, daily values for TP concentrations and TDS loads were created, to augment the existing data, using daily records of discharge and suspended sediment by a two step process:

1. Using the daily records as independent variables and the partial record of TP and TDS as dependent variables, we ran bivariate regressions (PEARSCORR and SCATTERGRAM from SPSS--Nie et al. 1975) on untransformed and $\log_{10}$ transformed data. we selected the best relationships as determined by the squared correlation coefficient (R^2; Table 16).
2. We used these best regression equations (Table 16) to generate daily TP concentrations and daily TDS loads for the 15-year period. We consequently had daily records for discharge (ft^3/sec), concentration of suspended solids (mg/l), TDS load (tons/day), and TP (mg/l). The augmented data for TP concentration and TDS load are listed in Appendix D.

The resampling procedure

These augmented daily records of water quality were resampled using all six combinations of three sampling intervals (weekly, fortnightly, and monthly), and two sampling strategies (a random day within the interval or a fixed day of the interval). (The Fortran resampling program was provided by Joseph Meyer and David Gulley, University of Wyoming.) Resampling followed the two-step procedure below.

1) For the fixed sampling strategy, the program picked the parameter value for the first day of every sampling interval in the 15 years of data, and then calculated a yearly value for that day. Daily TP loads (L_s, tons/day) were calculated from the daily concentration (C_s, mg/l) and daily discharge (Q, ft^3/sec) as (Lystrom et al. 1978):

$$L_s = 0.0027\ C_sQ \qquad \text{Equation 4}$$

This process was repeated for each day of the interval (week, fortnight, month), and 7, 14, or 28 estimates of mean, standard deviation, and coefficient of variation for the yearly load, were calculated; each yearly estimate was a function of the day sampled in the interval. For example, the weekly sampling had a calculation of mean annual load, standard deviation, and coefficient of variation associated with sampling on Mondays only, Tuesdays only, etc., for a total of seven estimates within the sampling interval.

For the random sampling strategy, the procedure for the fixed strategy was followed, except that the day sampled within the interval was chosen randomly. For example, the weekly random sampling had a calculation of mean annual load, standard deviation, and coefficient of variation associated with sampling on a random day the first week, a random day the second week, etc. This random sampling was repeated seven times to yield seven estimates for the weekly sampling interval.

2) For each sampling strategy the program also calculated the yearly load for the interval (interval mean), the mean standard deviation (interval SD), and the mean coefficient of variation (interval CV) for each of the three sampling intervals. For weekly sampling, this yielded an interval mean, interval SD, and interval CV calculated from the respective estimates for each day of the week.

<u>The random strategy as a representative sampling</u>

While repetition of the fixed sampling strategy yields the same results time after time, results from the random strategy should vary. If the interval means are indeed randomly generated, the results of any random repetition should be as valid as any other. To determine whether results of the random strategy come from a random distribution of possible results, we followed the two step process outlined below.

1. We resampled the daily data set a statistically large number of times (31).
2. From a simple regression (SPSS SCATTERGRAM, Nie et al. 1975) of the sequence of their generation vs. the thirty-one interval means, interval SDs, and interval CVs, we tested for a) significant difference between the slope of the regression line and zero, and b) significant difference between the intercept of the regression line and the mean of the dependent variable (interval mean, etc.).

If the slope was not significantly different from zero, and the intercept and mean were not significantly different, then results of the random strategy do come from a random distribution of possible results. For the regressions of 31 interval means and interval CV's for all three sampling intervals, there was no significant difference between the slope and zero, nor between the intercept and the mean of the appropriate dependent variable (interval mean, interval SD, etc.). Therefore we expect that usually any result generated by the random strategy is as representative of the population as any other ($p=.05$).

We next independently resampled TP and TDS values in the daily data set one more time. The resulting interval means, interval CV's, strategy means, and strategy CV's were tested for significant effects and interactions using a simple two way analysis of variance for unequal numbers of cell means (SPSS ANOVA, Nie et al. 1975). The modification for unequal cell means is necessary because of the differing number of interval means and interval CV's generated for each interval (seven, fourteen, and twenty-eight). We also obtained 95% confidence intervals around the estimated interval means and interval CV's (SPSS CONDESCRIPTIVE, Nie et al. 1975).

RESULTS

Analysis of variance showed that none of the interactions between sampling interval and sampling strategy was significant ($p = 0.05$, Tables 17 and 18). There also was no significant ($p = 0.05$) main effect for strategy. However, a significant ($p = 0.05$) main effect was found for sampling interval. This occurred for TDS and TP loads, for both the interval means and interval CV's, and regardless of sampling strategy.

However, ANOVA shows only that main effects are significant. It does not indicate which means are different from each other. But examining the 95% confidence limits (Table 19) makes it apparent that the monthly sampling is significantly different from the fortnightly sampling, and the weekly sampling is not significantly different from the fortnightly sampling. Because of the loss of degrees of freedom with each comparison, the statistical comparison between weekly sampling and monthly sampling cannot be performed. Logically, though, if monthly sampling is different from fortnightly sampling and fortnightly sampling is not different from weekly sampling, then weekly sampling is different from monthly sampling. Also note that the daily sampling statistics lie within the confidence intervals of the weekly and fortnightly 95% confidence limits; only monthly sampling yields estimates significantly different from daily sampling.

Total dissolved solids were sampled more than was TP (274 TDS samples in the original data versus 52 TP samples). The TDS loading estimates derived from daily, weekly, and fortnightly resampling are not significantly different from those estimates obtained from the regression model in Section 2.

B. ESTIMATING LOADING USING TIME SERIES ANALYSES

INTRODUCTION

Loads estimated by regression modeling (Section 2) and resampling (Section 3) are mean annual loads calculated from data of the fifteen water years 1965 to 1979. However, no estimate of year-to-year variance of yearly loads is provided. This is a particularly important deficiency for total phosphorus (TP) loads because the application of yearly estimates to a Vollenweider model, or other cause-effect relationship, can pinpoint for closer investigation unusual eutrophic effects of those years having unusual loadings.

While the augmented data of Section 3-A can be used to calculate loads for each year, no relationship is established for estimating loads for years not in the data set; loads cannot be predicted for future years. Time series analysis is a procedure which can be used to generate yearly loads for each year in the daily data set, as well as predict loads for years outside the daily data set.

This section of the report discusses the use of time series analysis to estimate yearly total phosphorus loads at the most downstream station on the Green River--USGS station #09217000, Green River at Green River--GRGR. From the estimated yearly loads, we identified those years having significantly different loads, and loads significantly different from the mean annual load determined from 15 years of data. We also estimated goodness of fit of the values predicted by the time series model to the observed values. A major practical application of our loading estimates would be to evaluate schemes for mitigating eutrophication in Flaming Gorge Reservoir (e.g., see Section 4).

Time series analysis

Time series analysis allows extrapolation and interpolation of continuous or nearly continuous data through time (e.g., hydrologic information). Consider, for example, data on discharge measured fortnightly for 10 years. Time series can predict the discharge on any day in the future, or any unsampled day in the period of record; this is weakly analogous to a regression across years on a given date. Or, given two days of a year, time series analysis can predict discharge on any day between the chosen dates; this is weakly analogous to a regression across days of the average year. However, these simple analogies to regression are not exact, because, referring to the example, time series makes predictions using all data--both within and between years.

Components of time series models

The most common time series models are univariate Box-Jenkins models, also termed ARIMA models after the initials of the models' components--AutoRegressive Integrated Moving Average models (Box and Jenkins 1976). Most of the following discussion follows Pankratz (1983), a more easily readable text.

The two mechanisms generating an ARIMA model are the AutoRegressive equation (Equation 5) and the Moving Average equation (Equation 6):

$$z_t = C + f_1 z_{t-1} + a_t \qquad \text{Equation 5}$$

and

$$z_t = C - T_1 a_{t-1} + a_t \qquad \text{Equation 6}$$

where z_t and z_{t-1} are observations of the parameter of interest (say daily phosphorus load) and a_t and a_{t-1} are random functions relating z_t and z_{t-1}. The coefficients f_1 and T_1 are fixed values for the relations between z_t and z_{t-1}, and a_t and a_{t-1}, respectively. The C "...is a constant ... related to the mean of the process".

A notation for the models is ARIMA (p,d,q), where p is the order of the autoregressive equation, d is the differencing factor applied to ensure that the mean is constant over the period of record, and q is the order of the moving average portion of the equation (Ryan et al. 1981). A second order autoregressive equation (AR(2)) is:

$$z_t = C + f_1 z_{t-1} + f_2 z_{t-2} + a_t \qquad \text{Equation 7}$$

and a second order moving average equation (MA(2)) is:

$$z_t = C - T_1 a_{t-1} + T_2 a_{t-2} + a_t \qquad \text{Equation 8}$$

An ARIMA model is combination of AR and MA models, plus an Integrated differencing component. Equation 5 is ARIMA model ARIMA(1,0,0) and Equation 7 is ARIMA model ARIMA(2,0,0) because they contain first and second order AR equations, but no MA or Integrated differencing components. Similarly, the MA models in Equation 6 and Equation 8 can be represented as ARIMA(0,0,1) and ARIMA(0,0,2), respectively.

If there is a significant seasonal component, i.e., a regular, cyclical phenomenon, it must also be modeled by a seasonally adjusted ARIMA(p,d,q)(P,D,Q), where the uppercase variables are the seasonal counterpart to the simple model's lowercase variables.

The process of time series modeling

Necessary to determining both the types of models and the orders of the models are plots of the original data and the autocorrelation factors (ACF) and the partial autocorrelation factors (PACF) of the data. Autocorrelation is the simple correlation between numbers which are members of the same series. One would expect the autocorrelation between today's and yesterday's discharge in the Green River to be greater than the autocorrelation between today's discharge and discharge one month ago. The correlation between observations one day apart in such a series is termed the first autocorrelation factor (ACF). The correlation between discharges two days apart is the second ACF, and so on throughout the series. "First" and "second" denote the lag number of the factor. ACFs are bivariate because only two values are considered in their calculation. Partial autocorrelation factor (PACF) is the correlation between observations n days apart, but calculated using observations from the intervening days. PACFs are equivalent to regression coefficients of multiple regression, since the inclusion of intervening variables in calculating PACFs makes the relationship between the observations multivariate.

For AR(1) models and for MA(1) models there are two basic sets of ACF/PACF plots each. Typical plots for AR models show that values of ACF decay toward zero as lag number increases (Figure 27a), while values of PACF cut off to zero (Figure 27b). Specifically typical of an AR(1) model is only one large (in absolute value) PACF--the prominent "spike" at lag 1 on the PACF plot (Figure 27b). The number of large PACF absolute values indicates the order of the AR model. The value of the PACF spike for AR(1) models is the value of f_1 in the AR equation (c.f., Equation 7).

Of course, MA models have different typical plots (Figures 28a and 28b). PACF values decay toward zero (Figure 28b), while ACF values cut off to zero (Figure 28a). Specifically typical of the MA(1) model is only one large (in absolute value) ACF. In this case the number of ACF spikes indicates the order of the MA model; the value of the ACF spike for MA(1) models is the value of T_1 in the MA equation (c.f., Equation 8). However, a positive value for the ACF at lag 1, and PACF values alternating signs with successive lags (Figure 28b) indicate that T_1 is negative, rather than positive.

For time series models there is a tradeoff between accuracy and precision versus loss of information from the original data set. The tradeoff is related to the determination of ACF discussed above. For example, given that there is an annual cycle of TP loads, the correlation between TP loads on April 1 of this year and April 1 of last year is not as good on average as the correlation of the mean daily load for the first week of April this year with the mean daily load from the first week of April last year. Variability in daily loads tends to drown out seasonal and long-term trends. On the other hand, loss of too much of the variation in the original data will result in a poorly fitting time series model. Thus striking a balance between accuracy and precision in the model versus loss of information in the data is a problem in time series analysis.

Autoregressive and moving average models of other orders also possess different typical ACF and PACF plots, as do combinations of AR and MA models of varying orders. The interpretation of these plots, and determination of the integration factor to make the mean stationary, is part of the art of time series analysis.

The Box-Jenkins modeling procedure consists of three stages:

1. Identifying a candidate ARIMA model
2. Estimating the parameters (orders) of the model, and
3. Diagnostic checking of the model for accuracy. After the diagnostic checking, the model may be used for forecasting if it is considered adequate. But in most cases the initial, and several succeeding, diagnostic checks lead back to an identification or estimation step.

Interpretation of the ACF and PACF plots involves inspired guesswork in an iterative process. However, after the identification step, most statisticians use computers and software to perform the iterations until the values generated for the coefficients of the equation do not change from iteration to iteration.

METHODS AND MATERIALS

The augmented daily record of total phosphorus concentrations generated by regression was discussed previously (Section 3-A; Appendix D). Using these augmented data, we calculated weekly, fortnightly, and monthly means of total phosphorus (TP) concentration (mg/l) and discharge (ft^3/sec), and then we calculated daily, weekly, fortnightly, and monthly loads of TP (as L_s) from Equation 4 (Lystrom et al. 1979b):

$$L_s = 0.0027 * C_s * Q$$

where C_s is the mean TP concentration and Q the mean discharge for the appropriate interval.

We next made plots of ACFs and PACFs for the daily, weekly, fortnightly, and monthly means of TP loads (MINITAB procedures ACF and PACF, The Pennsylvania State University 1982). Based on these plots, we chose weekly means of daily loads as yielding most accuracy and precision in the model with least loss of information from the original data.

Finally, an ARIMA model was developed using MINITAB (ACF and PACF procedures), and a more powerful time series analysis program (SCA--Liu and Hudak 1984). We also ran a oneway analysis of variance (MINITAB ONEWAY AOV procedure) to find significant differences between yearly TP loads. Even though the model is based on weekly means of daily loads, the model predicts daily loads.

RESULTS

In short notation, the model derived for TP load is an ARIMA(201 100). That is, the model is a second order AR, first order MA, with no trend in the series [ARIMA(2 0 1)], coupled with a seasonal first order AR containing no trend in the seasonality [seasonal ARIMA(100)]. The seasonality was based on a lag of 52, the number of weeks in the year. The equation relating TP load at time t to TP load at time t-1 reflects the combination of AR and MA models, with no trend in the mean:

$$\begin{aligned} TP_t = {} & 1.2302(TP_{t-1}) - 0.3023(TP_{t-2}) + 0.1779(TP_{t-52}) - \\ & (1.2302 * 0.1779)(TP_{t-53}) + (.3023 * 0.1779)(TP_{t-54}) - \\ & 0.6955(a_{t-1}) + a_t \end{aligned}$$

Equation 9

where TP_t is the TP load on any day (t), TP_{t-n} is the TP load n days prior to TP_t, and a_t is a measure of random error.

According to the SCA analysis, after 13 iterations, the relative change in the standard error was negligible, and all of the coefficients in the equation were significantly different from zero ($p = 0.05$). This signifies that the model is the best-fitting, most parsimonious model given the initial ARIMA specifications (ARIMA(201 100)).

A oneway analysis of variance of the residuals (observed TP load less the predicted TP load) showed no significant differences between the errors of the model from year to year (Figure 29). Therefore the model fits the observed means of daily TP load equally well for all 15 years of data, consistently mimicking the observed data.

The primary purpose of this time series analysis was to derive loading estimates of combined sources (nonpoint sources plus point sources) of TP upstream of station GRGR. The mean annual load of TP predicted by the time series model was 150.6 tons/yr; including the point source loads to the Green River downstream of station GRGR (33.3 tons/yr, Appendix B), the total mean annual load to the Green River Arm of Flaming Gorge Reservoir is estimated at 184 tons/yr. This is 55 tons/yr (42%) greater than the upper 95% confidence limit from our multiple regression model (96.3 tons/yr [Table 12] plus 33.3 tons/yr = 129.6 tons/yr total), and 32 tons/yr (21%) greater than the estimate derived from weekly or fortnightly resampling studies (119 tons/yr [Table 19] plus 33.3 tons/yr = 152.3 tons/yr).

C. DISCUSSION OF PHOSPHORUS LOADING TO FLAMING GORGE

While mean annual P loading estimated from the time series analysis was large, exceeding estimates both from multiple regression and from all resampling studies (Tables 20, 25), of more interest is the large variation in yearly loads. The range in these loads is 121-261 tons/yr (Table 20); seven of the 15 values (47%) are significantly different from the mean annual load (Figure 30), and three are less than the excessive loading to Flaming Gorge Reservoir (Figure 32). With nonpoint source loading being highly variable but point source loading more constant, then in some years point sources may contribute more phosphorus than nonpoint sources.

For example if we assume point sources are constant and estimate nonpoint source loading using the 15 years of augmented data, then point sources contributed 14-42% of the whole reservoir's yearly P load during 1965-1979, and 12-52% of the yearly P load to the Green River arm (Tables 20, 21, 22, 24). Using all sources of data, the range of contributions from point sources is 12-52% of the total loading. The larger values for the relative importance of point source contributions are dramatically greater than previous estimates (e.g., 12% SWWQPA 1978).

Time series modeling is the only method used in this report which can predict such year to year variation, based on the past record. Since TP helps drive eutrophication, predicting years with large loading potentially could be useful in planning mitigation strategies.

There was another important result from the time series analysis: over the 15 years considered, no trend of increased or decreased TP loading occurred upstream from Green River city (no differencing term was necessary). This means that non-point source input via the Green River exhibited no trend of increasing through time. Thus, if changes in phosphorus loading caused the problems in Flaming Gorge Reservoir, then these changes must have occurred in point sources downstream from station GRGR (i.e., effluent from Green River city and from Rock Springs via Bitter Creek). However, based on our analysis, we cannot comment on whether a change in loading per se is responsible for problems in the reservoir.

There are several practical implications of the work on sampling strategies (resampling augmented data, Section 3-A). First, for station GRGR, the optimal sampling scheme to minimize sampling frequency and maximize accuracy, is fortnightly sampling on either a fixed or random day in the period. Second, if scheduled sampling of any frequency cannot be completed, for example, on Monday, it doesn't matter as long as the sample is taken sometime during the scheduled interval (week, fortnight, or month). Third, if sampling cannot be conducted within a scheduled interval, significant error in the estimate of yearly load may result. The importance of sampling interval in determining an optimal scheme is not unexpected; others have noted that as the number of samples increases, estimates converge to the actual value for yearly load. For example Dickinson (1981) found that loads of suspended solids can be overestimated by as much as 30% when only monthly sampling occurs (see also Dolan et al. 1981).

These findings are important to consider when using data for station GRGR from USGS water year books (U.S. Geological Survey 1965-1979); while sampling apparently was scheduled every two weeks, it was usually conducted once monthly at best. Therefore, estimates of yearly values based on these data are likely to be inaccurate. For example, all estimates of yearly load of TP from our resampling study, daily through monthly, significantly exceed by ten to forty tons/yr those estimates obtained from the regression models in Section 2 (compare Table 19 with Table 12). However, TDS were sampled more often than was TP (274 TDS samples in the original data versus 52 TP samples). Estimates of TDS loading derived from daily, weekly, and fortnightly resampling are not significantly different from that obtained from the TP regression model in Section 2.

For the future, we recommend the following to adequately monitor loading to Flaming Gorge Reservoir:

1) Sample discharge and concentration of TP in the Green River on a fortnightly schedule.
2) This sampling should be done at or near USGS station #09217010, which is downstream from important point-source inputs of P, but upstream from Flaming Gorge Reservoir. The point sources are waste treatment plants for the city of Green River, and Bitter Creek, which carries the outflow from waste treatment facilities at and around Rock Springs, Wyoming. Bitter Creek is now perennial; prior to the treatment facilities in Rock Springs, it was intermittent.
3) Sampling at USGS station #09224700--Blacks Fork at Little America (BFLA)--should be modified to include fortnightly phosphorus analyses. This would provide loading data for the Blacks Fork arm of Flaming Gorge Reservoir.

Next, before choosing "best" estimates of loading to Flaming Gorge, we first consider the accuracy of these loads. While calculations were made for five water quality parameters in the Green River drainage (NO_3, TP, TDS, suspended solids and turbidity), only TP loads were estimated by all methods. Because accuracy of estimates from each method were discussed previously, only a comparison of TP loads across methods is considered here.

Methods used to derive TP load estimates were:

1. A simple mean of grab samples (TP as mg/l) recorded generally monthly, but actually intermittently by the USGS at its water quality monitoring stations, with mean annual TP load for the 15 year record (water years 1965 to 1979) finally estimated as a product of average daily TP concentration (mg/l) and average daily discharge (ft^3/sec);
2. A mean annual load for the 15 year record, with confidence interval, estimated from a linear regression model of the association of length of the main channel of each subbasin with the observed total phosphorus load;
3. A mean annual load for the 15 year record found from an association of daily suspended solids concentration and total phosphorus concentration, with mean annual load for the 15 year record finally calculated as a product of average daily TP concentration (mg/l) and average daily discharge (ft^3/sec);
4. An estimate of the mean annual load for a 15 year record derived from the synthetic record of daily phosphorus values generated in 3, above, for three intervals of resampling--weekly, fortnightly, and monthly;
5. Estimates of yearly load estimated for each of the 15 years of synthetic daily values for total phosphorus concentrations gen-

erated in 3, above. Again, load was calculated as a product of TP concentration and discharge;

6. A mean annual load for the 15 year period estimated by a time series analysis of phosphorus loads. Again, the loads were calculated as a product of TP concentration and discharge using daily concentration synthetic records generated in 3, above, and;
7. Yearly estimates of loads for each of the 15 years calculated from the daily phosphorus loads predicted by the time series model in 6.

These calculated loads are listed in Tables 24 and 20. Table 24 depicts nonpoint source loads only, while Table 20 includes significant point sources in the Blacks Fork section of the Green River drainage, and point sources downstream from station GRGR to the Green River proper.

Although the augmented, daily phosphorus records generated in Section 3-A are synthetic, the function deriving them explained 80% of the variation in TP (Table 16). And, monthly resampling significantly underestimated the yearly load when compared to estimates from daily, weekly, or fortnightly sampling. Thus if we choose fortnightly or more frequent sampling as best representing the true load, then we imply that monthly or less frequent sampling always significantly underestimates the total phosphorus load.

Similarly, if we assume that the best estimate of mean annual load occurs from fortnightly or more frequent sampling, then we again underestimate the true value with either the mean of observed values (n = 52) or the load derived from multiple regression modeling for station GRGR (Section 2). The latter may occur because although the regression of channel length and observed TP fit the data from the entire Green River drainage well, it was not optimized to predict best at station GRGR. Adjustments such as weighting the value of GRGR more heavily could optimize the prediction at GRGR, but only at the expense of less accurate loads for other, smaller, subbasins in the basin. Also, because TP and TDS were sampled intermittently at station GRGR, a bias correction based on the resampling study cannot be applied to bring the estimates from the regression models (Table 12) into "compliance" with estimates from the resampling study in this section (Table 19). Such methods are based upon data sampled at regular, not intermittent, intervals.

Others have made estimates of the yearly TP load, based at least in part on data from the USGS also used by us (USEPA 1977; WRRI 1977; SWWQPA 1978; Hern and Lambou 1979). There is no consistent pattern in the magnitude of these estimates compared to those made by us; some are larger than our values while others are smaller (Table 20).

In summary, note that the field data used both by us and by others to estimate loading represents irregular and infrequent sampling. Therefore, the observed load almost certainly is inaccurate and cannot be considered the best estimate. We feel the best estimates of TP load from the Green River drainage are the yearly and mean annual loads calculated from the augmented data. These estimates are chosen because 1) they are based on daily records of suspended solids and discharge, 2) the concentration of TP is significantly and strongly related to suspended solids (Table 16), and 3) as the number of samples increases, estimates should converge to the true yearly and mean annual loads.

SECTION 4:

POTENTIAL EFFECTS OF LOADING ON EUTROPHICATION IN FLAMING GORGE RESERVOIR; ANALYSIS WITH A VOLLENWEIDER MODEL

INTRODUCTION

To illustrate a practical application of the various loading estimates, and to demonstrate their potential biological significance, we now use our estimates in a model predicting the trophic state of lakes as a function of phosphorus loading. The simple model is based on two thresholds for TP loading; an upper or excessive threshold, beyond which marked water quality problems are assumed to occur (eutrophic state), and a lower or permissible threshold, below which water quality is assumed to be excellent (oligotrophic state). In particular, we used the Vollenweider III model because (see below for a more detailed discussion):

1. All parameters could be obtained from topographic maps of the reservoir, or from U.S. Geological Survey information.
2. Mueller (1982) recommended it as one of three benchmark eutrophication models, for use primarily where phosphorus retention data is unavailable.
3. Despite criticisms of the model, it has been widely applied to many lakes in North America (Rast and Lee 1978, USEPA 1977), including Flaming Gorge Reservoir (USEPA 1977, Hern and Lambou 1979).

Major shortcomings of using this model to evaluate eutrophication in Flaming Gorge include:

1. As used, no estimate of uncertainty is associated with predictions from the model. That is, we can reach conclusions, but cannot state whether we have little or much confidence in them.
2. The model is empirical, cross-sectional, and based on data from lakes not reservoirs, and particularly not reservoirs in the semi-arid, western U.S. (see Reckhow and Chapra 1983).
3. The model cannot explicitly account for the observed longitudinal gradient of trophic state in the reservoir, from eutrophic in riverine portions to oligotrophic at the dam.
4. Strictly, assumptions of the derivation are not fulfilled.

In an attempt to account for the obvious longitudinal gradient of water quality in Flaming Gorge Reservoir, we performed three separate analyses with the Vollenweider model. First, the Green River arm was modeled because problems occur there, the best loading data are available for this section, and it receives the point source inputs. Second, the section of the reservoir upstream from Buckboard Wash was studied because algal blooms are documented to occur downstream to Buckboard Wash in the autumn (Fannin 1983). Finally, the entire reservoir was modeled to enable comparison with other researchers' work. In modeling, all of the phosphorus loading estimates discussed previously are used in an attempt a) to illustrate possible reasons for the sensitivity of the upper section of the reservoir, and b) to demonstrate what effect eliminating point sources from the Green River drainage might have on eutrophication of Flaming Gorge Reservoir.

BACKGROUND

The Concept of Permissible Loading

General reviews of eutrophication and eutrophication research have been published (c.f., NAS 1969, Hutchinson 1973, Lee et al. 1978, Medine and Porcella 1981, Medine and Porcella 1982, and Lee and Jones 1986). The models of Vollenweider (1969, 1976) directly evaluate the nutrient loading required to change a waterbody from a less productive to a more productive state. They also have been used to evaluate the reduction in loading necessary to sensibly improve the trophic condition of a lake. So, the significance of nutrient loading to eutrophication is:

> "...that a quantifiable relationship exists between the amount of nutrients reaching a lake and its trophic degree measurable with some kind of trophic scale index" (Vollenweider 1976).

Application of this concept requires, then, both a model of the "quantifiable relationship" and a method to index the trophic state of the receiving waterbody.

Traditionally, waterbodies have been grouped into one of three major trophic categories (oligotrophic, mesotrophic, or eutrophic) based on perceived effects of eutrophication (great primary productivity, algal growth, decreased transparency of the water, hypolimnetic oxygen depletion). For example, clear, cold, deep lakes are classed oligotrophic, while lakes with blue-green algal blooms and summertime anoxia are termed eutrophic. However, such classification is inadequate for anything but general description. This is because values for productivity, etc., of lakes form a continuum, so uncertainty exists about which trophic classification different values of productivity, etc., represent. Quantitative trophic state indices were developed to circumvent this problem by providing explicit rules for assigning lakes to trophic categories (e.g. Carlson 1977).

Nutrient concentrations and/or transparency have been mathematically related to primary productivity (c.f., Jones and Bachmann 1976, Carlson 1977, Canfield and Bachmann 1981, and Lambou et al. 1982), and quantitative measures of the trophic status of waterbodies have resulted (Carlson 1977, Rast and Lee 1978). Vollenweider used concentration of phosphorus in the water column at spring turnover to classify waterbodies into one of the three traditional categories.

Vollenweider's models were empirically derived. Plots of log-transformed values of mean depth and hydraulic retention of several north-temperate lakes against their respective nutrient loading suggested that lakes of generally similar productivity plotted more closely than lakes of different productivities. The classification into trophic categories was based on "critical concentrations" of nutrients at spring turnover (postulated in Sawyer 1947 [ex. Rast and Lee 1978]). Sawyer found that in New England lakes, a springtime phosphorus concentration less than 10 mg/m^3 did not lead to eutrophic conditions later in the season. Use of this concentration as a boundary allowed Vollenweider to quantify the assignment of lakes to the three traditional trophic classes. Vollenweider classed as oligotrophic those lakes with areal phosphorus loadings yielding concentrations less than 10 mg/m^3. Eutrophic lakes had loadings producing concentrations greater than 20 mg/m^3, while mesotrophic lakes had loadings yielding concentrations in the water column between 10 and 20 mg/m^3. Vollenweider further assumed that loadings characteristic of oligotrophic lakes were "permissible", while loadings of eutrophic lakes were "excessive". Permissible loadings are those which allow a lake to retain (or regain) its oligotrophic character, while excessive loadings are sufficient to cause an oligotrophic lake to become eutrophic.

Vollenweider models

The original Vollenweider model (Vollenweider 1969) incorporated only mean depth of the waterbody as an independent variable to predict permissible and excessive total phosphorus or nitrogen loading (in grams/m^2/year). The association of mean depth with "productivity" of a waterbody had previously been noted by Rawson (1952); he found a positive log-log relationship between mean depth and commercial fish production of several Canadian lakes. Mean depth of a waterbody was also incorporated into the well-known Morphoedaphic Index for estimating fish production in lakes (Ryder 1965). The Vollenweider I model for "permissible" phosphorus loading is:

$$L_c(P) = 25\ z^{-0.6} \qquad \text{Equation 10}$$

which incorporates only mean depth (z, meters) of the waterbody as a predictor of permissible yearly areal phosphorus loading to the lake ($L_c(P)$, mg/m^2/yr).

The corresponding Vollenweider I model for permissible nitrogen loading assumes that nitrogen requirements of algae are 15 times that for phosphorus, and the equation is therefore:

$$L_c(N) = 15\ (25\ z^{-0.6}) \qquad \text{Equation 11}$$

where $L_c(N)$ is the permissible yearly areal nitrogen loading to the waterbody.

Dillon (1975) showed the importance of flushing rate (lake volume/outflow) to trophic state by investigating two lakes in Canada. Cameron Lake was classified by the Vollenweider I model as a lake receiving excessive phosphorus loading, but the lake did not show signs of eutrophication (e.g., algal blooms and summertime hypolimnetic oxygen deficit). A revised model, including a flushing coefficient, corrected this deficiency (Vollenweider 1976):

$$L_c(P) = 100\ (z/T_w)^{0.5} \qquad \text{Equation 12}$$

where T_w is the hydraulic residence time (years), a measure of how many years it would require to refill the basin of the lake. Vollenweider did not develop a second model for nitrogen because he felt that phosphorus most often determines trophic status in lakes (Rast and Lee 1978).

The Vollenweider II phosphorus loading model was subsequently refined (Vollenweider 1976) to incorporate a sink for phosphorus--a sedimentation parameter. The importance of phosphorus retention upon in-lake phosphorus concentration also was suggested by Dillon and Rigler (1974). A general form of the Vollenweider III model is:

$L(P) = [P]_{inf} \cdot z\ (1/T_w + S_p)$ Equation 13

where L(P) is the areal yearly phosphorus load, $[P]_{inf}$ is the steady-state phosphorus concentration, and S_p is the phosphorus sedimentation rate coefficient. Some difficulties in estimating sedimentation coefficients were illuminated by Kirchner and Dillon (1975) and Sonzogni et al. (1976); Snodgrass and O'Melia (1975) described an alternative method for estimating S_p which incorporates the area of sediment-water interface. Vollenweider (1975) derived an empirical relation between S_p and z for the lakes he discussed in 1969:

$\ln S_p = \ln 5.5 - 0.85 \ln z$ Equation 14

or approximately,

$S_p = 10/z$

Also, $[P]_{inf}$, the steady-state phosphorus concentration, is approached at spring turnover. If Sawyer's (1947) critical phosphorus concentration is substituted for $[P]_{inf}$, the Vollenweider III model results (Figure 31):

$$L_c(P) = (10\ mg/m^3) \cdot z\ (1/T_w + 10/z) = 100 + (10 \cdot (z/T_w))$$ Equation 15

where, again, $L_c(P)$ is the permissible yearly areal phosphorus loading ($mg/m^2/yr$), z is mean depth (m), and T_w is the hydraulic residence time (years) of the lake.

The model used to calculate excessive loading is:

$$L(P) = (20\ mg/m^3) \cdot z\ (1/T_w + 10/z) = 200 + (20 \cdot (z/T_w))$$ Equation 16

where L(P) is the excessive yearly areal phosphorus loading, z is mean depth, and T_w is the hydraulic residence time of the lake.

Contemporaneous with and subsequent to Vollenweider's efforts, other researchers formulated similar nutrient-budget/steady-state models. These models fall into one or more of the following groups:

1. Refinements of one or more of the parameters, such as the sedimentation coefficient, implicit in Vollenweider's models (c.f., Snodgrass and O'Melia 1975, Jones and Bachmann 1976, Sonzogni et al. 1976, Hern and Lambou 1979),
2. Refinements for geographical regions or classes of lakes (c.f., Dillon and Rigler 1974, Tapp 1978, LaBaugh and Winter 1981, Mueller 1982),
3. Application of models to parameters dependent on phosphorus loading and/or concentration, but which better index esthetic symptoms of eutrophy, e.g. chlorophyll a concentration, Secchi depth visibility or hypolimnetic oxygen deficit (Jones and Bachmann 1976, Canfield and Bachmann 1981), and
4. Explicit calculation of the uncertainty in models' estimates of trophic status (c.f., Chapra and Reckhow 1978, Reckhow 1979, Reckhow 1981, and Walker 1982).

Assumptions of the Vollenweider III model

Assumptions of the Vollenweider III model are:

1. The lake approximates a completely mixed reactor (Reckhow and Chapra 1983), in which the change in phosphorus concentration ([P]) over time is a function of the phosphorus load to the reservoir minus the outflow and sedimentation losses.
2. The [P] in the outflow equals the [P] in the lake.
3. The inflow rate equals the outflow rate.
4. There is no internal loading of phosphorus.
5. Phosphorus sedimentation is depth dependent, not constant.

In Flaming Gorge Reservoir, the assumption of a completely mixed reactor is perhaps most closely approximated in the riverine portion. For the whole reservoir, assumption 2 is violated, since the gradient of water quality means that [P] in the upper portion of the reservoir is greater than in the lower portion. Considering smaller segments of the reservoir, the assumption is more reasonable since the [P] in an upstream segment is the [P] flowing into the next segment downstream.

Assumption 3 is violated for the whole reservoir, since evaporation causes large loss of water from reservoirs in semiarid areas, and especially since the reservoir is artificially regulated. The inflow probably does not equal the outflow, even considered annually.

Assumption 4 also is violated. There may be considerable internal phosphorus loading to the upper sections of Flaming Gorge Reservoir (Messer et al. 1983, 1984).

Assumption 5 has motivated several criticisms of the Vollenweider model. Other measures of sedimentation rate have been proposed which assume a constant settling velocity of phosphorus (Dillon and Rigler 1974 and Chapra 1975). However, Chapra and Reckhow (1983) have shown that sedimentation variables in the three models are all geomorphologically or hydrologically dependent, and intercorrelated as well. Therefore, the choice of the sediment removal term, and hence the form of the model, should be empirically based.

Hern and Lambou (1979) take specific exception to the value of S_p being 10/z. They found an empirical sedimentation coefficient of 0.83 which they applied to models of eutrophication in Flaming Gorge Reservoir. While this sedimentation coefficient predicts substantially greater excessive loads for the entire reservoir than the excessive loading predicted using $S_p = 10/z$ (845 vs. 483 $mg/m^2/yr$), differences in the excessive loads predicted for the Green River arm (2181 vs. 2289 $mg/m^2/yr$) and Buckboard section (1569 vs. 1640 $mg/m^2/yr$) are slight. Thus for the upper sections of the reservoir, the empirically derived settling coefficient appears applicable, especially given the fact that most suspended sediments (and associated phosphorus) settle out in the upper sections of Flaming Gorge Reservoir.

METHODS AND MATERIALS

The methods employed to estimate phosphorus loading to Flaming Gorge Reservoir are found in the appropriate sections of the report. In addition to the loadings we derived, we also used estimates of loading from USEPA (1977), WRRI (1977), SWWQPA (1978), and Hern and Lambou (1979; see Tables 21 and 20); these estimates are based at least in part on data obtained by the USGS which we used to generate our estimates of loading.

We calculated areal loading using the different surface areas of the three sections of the reservoir (Green River Arm; the reservoir upstream from Buckboard wash; the whole reservoir). Areas, volumes, and mean depths of the three sections were obtained with a digitizer from USGS 15-minute quadrangle topographic maps of the reservoir. Our calculations of morphometric parameters followed Lind (1979).

Recollect that combined loads (Table 22) include point source loads and nonpoint source loads upstream of USGS station #09217000--Green River at Green River city (GRGR), but do not include any inputs to the Green River between that station and the reservoir. Since point sources upstream of station GRGR were insignificant when compared to the combined load (Section 2), combined loads can be considered equivalent to nonpoint source loads in the Green River section of the Green River drainage. Therefore, the total loading to the Green River Arm (Table 21) is the combined source load (Table 22) plus 33.3 tons/yr of point source load (Appendix B) input just downstream of station GRGR.

Comparing the four types of estimated loads (from observed, multiple regression, resampling and time series; Tables 22 and 21) and the permissible and excessive loads predicted by the Vollenweider model (Tables 22, 21, and 23) required several steps.

1) Morphometric variables necessary for applying the model to the three sections of the reservoir were calculated.
2) We used Equations 15 and 16 to compute the excessive areal loads for the three sections of the reservoir (Table 23). The estimated excessive areal loads are of two types, corresponding to the two types of estimated loads: 1) loads for a specific year (yearly loads), and 2) loads based on all 15 water years from 1965 to 1979 (mean annual loads).
3) We back-calculated to find the loads of phosphorus which would just produce permissible and excessive loads for each section. These back-calculated loads are listed in English units to assist comparison with the summary tables.

RESULTS AND DISCUSSION

Comparing our estimated loads to the predicted excessive loads, we see clearly that if Flaming Gorge Reservoir were confined to the Green River arm, then the model predicts highly eutrophic conditions would occur (Tables 22 and 21, and Figure 32). All but one of the loading estimates are greater than both i) the excessive mean annual load, and ii) the excessive yearly loads. In fact, the model predicts eutrophic conditions when even as little as 50% of the mean annual TP load acts in this arm during a year of mean annual runoff.[1] Also, eliminating point sources from the basin never is predicted to reduce TP loading below the excessive threshold (Tables 24, 20; Figure 32).

A similar conclusion is reached when considering the Buckboard section of the reservoir (Figure 32). Estimated loads (Table 20) exceed considerably both i) the excessive mean annual load and ii) the yearly loads (Table 23). And we again predict that eliminating point sources always will leave this section of the reservoir in a eutrophic state (Table 24).

While our estimates of loading to the reservoir as a whole must be somewhat underestimated, the model still predicts that all loads are excessive, and that conditions overall should be eutrophic (Table 20; Figure 32). If all point sources were eliminated, only in three of the 15 years between 1965-1979 should the reservoir have been mesotrophic (Table 24).

USEPA (1977) and Hern and Lambou (1979) also classified the entire reservoir as eutrophic according to Vollenweider's models, although two other models they considered categorized the reservoir as mesotrophic. Other estimates of yearly loading to the entire reservoir also have exceeded excessive yearly loads (USEPA 1977, WRRI 1977, and SWWQPA 1978; see Table 20). Thus the consequences of loading predicted by others are similar to those discussed above by us.

As suggested by the model, eutrophic conditions clearly sometimes occur in the upper reservoir (USEPA 1977, SWWQPA 1978). However, truly nuisance conditions do not occur often in the Buckboard area as suggested, and anyone in a boat near the dam would never consider conditions eutrophic. How then, with some predictions appearing reasonable and others unreasonable, does one decide whether to believe a particular result from the model? The accuracy of predictions can be determined by comparison to observed eutrophication in Flaming Gorge Reservoir. However, no data for springtime phosphorus concentration, summer chlorophyll concentration, algal biomass, or dissolved oxygen appear in USGS water year books for 1965-1979. Thus we were unable to evaluate the accuracy of our conclusions, and we cannot specify the degree of uncertainty associated with our conclusions.

This poses a real dilemma for managers wishing to use our modeling efforts in decision making. For example, we suggest above that eliminating point sources would still leave all sections of the reservoir eutrophic. But assuming all point source input is stopped, and making several other assumptions which reduce the effect of phosphorus from existing nonpoint

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1) The value of 50% was computed by dividing the excessive mean annual loading back-calculated for the Green River arm (39 tons/yr; Table 23) by the mean annual load without point sources (Table 22, 79 tons/yr, from multiple regression modeling).

sources,[2] we conclude that trophic conditions could be noticeably improved, at least during some years: the Green River arm would not be eutrophic in 5 of 15 years, the Buckboard section in 8 of 15 years, and the whole reservoir in 14 of 15 years. But because we cannot state the uncertainty associated with any of our conclusions, these exercises are not particularly useful in deciding whether to mitigate problems via eliminating point source input of phosphorus.

Another factor complicating interpretation of the effects of phosphorus loading is release of phosphorus from sediments, or internal loading. In the Green River arm the amounts released can be unusually large (up to 12.8 mg $P/m^2/day$ from anaerobic sediments; Messer et al. 1983). This unusual release may reflect desorption by particulates of much bioavailable phosphorus taken up from sewage effluent several miles upstream. But while the unusual release of phosphorus might be diminished by eliminating effluent (point sources), some internal loading always would occur, especially if anoxic conditions still prevailed. Thus we again are uncertain about the usefulness of mitigating problems by eliminating point source input.

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2) Estimate loading using values of the lower 95% confidence limits (Tables 20, 21, 22, 24), assume that errors associated with use of a cross-sectional model developed for lakes rather than reservoirs leads to overestimating the effects of phosphorus (e.g., lesser bioavailability for phosphorus from nonpoint sources, waters of upper Flaming Gorge are more turbid than water of the lakes used to derive the model).

SUMMARY

PREDICTING EXPORT OF WATER QUALITY PARAMETERS FROM THE GREEN RIVER BASIN TO FLAMING GORGE RESERVOIR; MULTIPLE REGRESSION USING BASIN CHARACTERISTICS

Multiple regression models were developed for export of total phosphorus (TP), nitrate-nitrogen, total dissolved solids (TDS), total alkalinity and turbidity as functions of basin attributes. Poor availability of data on water quality limited to 16 the number of subbasins which could be modeled. While the initial set of basin attributes contained more than 60 variables (Appendix A), only 1-2 topographic and/or hydrologic variables were retained in the final regression equations (Table 10). The models were verified temporally by a split-plot analysis (Table 11) and spatially by application to an adjacent drainage (Table 14):

Model	Temporal	Spatial
Nitrate-nitrogen (A)	no	yes
Nitrate-nitrogen (B)	no	possible
Total Phosphorus	no	possible
Total Alkalinity (A)	possible	no
Total Alkalinity (B)	yes	yes
Total Dissolved Solids	yes	possible
Turbidity	possible	no

The amount of each water quality parameter exported by each subbasin was quantified, which allows identifying major sources for possible mitigation efforts (Figures 23-26). However, because the subbasins modeled were large, such efforts would need to be applied to very large management units.

USE OF DATA AUGMENTATION TECHNIQUES AND TIME SERIES ANALYSIS FOR ESTIMATING LOADING TO FLAMING GORGE RESERVOIR

In developing the basin-attribute regressions, the inadequacy of data became very evident; for most parameters sampling was infrequent and irregular. To help remedy this situation, we developed an augmented data set for the export of total phosphorus and total dissolved solids from the Green River basin -- we created records for daily loads at Green River city during the 15 years 1965-1979 (Appendix D). These records were created using daily records of discharge and suspended sediment via a two-step process:

1. Using the daily records for independent variables and the partial record of TP and TDS for dependent variables, we created bivariate regressions (Table 16).
2. We used these regression equations to generate daily TP concentrations and daily TDS loads for the 15-year period. We consequently had daily records for discharge (ft^3/sec), concentration of suspended solids (mg/l), TDS load (tons/day), and TP (mg/l). Loads of TP then were calculated as the product of discharge times concentration.

By resampling the daily data on loads, we determined the mean annual load and yearly loads of TP based on three different sampling intervals (weekly, fortnightly, monthly) and two sampling strategies (random or fixed day within an interval). The optimum sampling plan among the six possibilities was fortnightly sampling on either fixed or random days; sampling more frequently should not improve estimates significantly but would be more expensive, while less frequent sampling should produce significant underestimates.

These findings are important to consider when using data for station GRGR from USGS water year books (U.S. Geological Survey 1965-1979); while sampling apparently was scheduled every two weeks, it was usually conducted once monthly at best. Therefore, estimates of yearly values based on these data are likely to be inaccurate.

Next we applied time series analyses to the 15 years of augmented data for loading of TP. The time series model developed to predict TP load was an ARIMA(201 100) (Equation 9; Tables 20, 21, 22, 24). No differencing term was needed to account for long-term trends, so apparently no significant increase or decrease in nonpoint source loading occurred upstream from Green River city during 1965-1979.

Great variation was predicted by the resampling and time series studies to occur in the yearly TP loads to Flaming Gorge Reservoir from nonpoint sources; a range of 41-259 tons/yr was predicted from resampling, and 121-261 tons/yr from time series. If we assume point sources are constant and estimate nonpoint source loading using the 15 years of augmented data, then point sources contributed 14-42% of the whole reservoir's yearly phosphorus load during 1965-1979, and 12-52% of the yearly phosphorus load to the Green River arm (Tables 20, 21, 22, 24; point source input to the Green River arm is essentially sewage effluent from the towns of Green River and Rock Springs).

The larger values for the relative importance of point source contributions are dramatically greater than previous estimates (e.g., 12% SWWQPA 1978). Because time series modeling is the only method used in this report which can predict such year-to-year variation based on the past record, our analysis may be useful in planning mitigation strategies.

Considering all estimates of total phosphorus loading, both ours and those of others, we feel that the best estimates of TP load from the Green River drainage are the yearly and mean annual loads calculated from augmented data via resampling. These estimates are chosen because 1) they are based on <u>daily</u> records of suspended solids and discharge, 2) the concentration of TP is significantly and strongly related to suspended solids (Table 16), and 3) as the number of samples increases, estimates should converge to the true yearly and mean annual loads.

POTENTIAL EFFECTS OF LOADING ON EUTROPHICATION IN FLAMING GORGE RESERVOIR; ANALYSIS WITH A VOLLENWEIDER MODEL

We used a very simple model (Equations 15, 16) to evaluate whether excessive loading is predicted to occur for Flaming Gorge reservoir, and whether elimination of point source input might alter its trophic status. One scenario suggests that no improvement of conditions ever would be expected to result from eliminating point source input (Tables 20, 21, 22, 23, 24); another suggested that marked improvement might occur, especially during some years. However, we cannot state the uncertainty associated with any of our conclusions. Thus, practically, the exercise was not useful in deciding whether to mitigate problems in Flaming Gorge reservoir via eliminating point source input of phosphorus.

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TABLES

Table 1. Correspondence between sampling stations in this study and those of the WRDS (Water Resources Data System) database.

Station code	WRDS and USGS code	Site location
Green River Section		
GRWB	9188500	Green River at Warren Bridge
GRBP	9192600	Green River at Big Piney
NFAB	9201000	New Fork at Boulder
NFBP	9205000	New Fork at Big Piney
GRLB	9209400	Green River at Boulder
GRBF	9211200	Green River below Fontenelle Reservoir
BSLS	9214500	Little Sandy River
BSAF	9216000	Big Sandy River at Farson
BSBD	7135*	Big Sandy River at Bone Draw
BSGB	9216050	Big Sandy River at Gasson Bridge
BSAC	8011*	Big Sandy River at Confluence
GRBI	9216300	Green River at Big Island
GRGR	9217000	Green River at Green River city
Blacks Fork Section		
BFAL	9222000	Blacks Fork at Lyman
HFAG	9224450	Hams Fork at Granger
BFLA	9224700	Blacks Fork at Little America

Table 2. Initial water quality variables chosen from the WRDS (Water Resources Data System) database. These are the dependent variables for the respective water quality/basin attribute multiple regression models.

WRDS Parameter	Variable	Units
665	Total Phosphorus	mg/l as P
71851	Nitrate	mg/l as NO_3
70301	Dissolved Solids	mg/l
70302	" "	tons/day
410	Total Alkalinity	mg/l as $CaCO_3$
70	Turbidity	JTU*
930	Dissolved Sodium	mg/l as Na
95	Conductivity	umhos at 25°C
900	Total Hardness	mg/l as $CaCO_3$

*Jackson Turbidity Units

Table 3. Significant differences between standard error of concentration estimate (SEE) from regressions of log-concentration/log-discharge, and variance (s^2) of observed concentration means. Data are presented for five water quality parameters. A significant difference in the F probability indicates that annual loads should not be calculated as the product of mean annual concentrations and mean annual discharges.

Parameter	SEE	s^2	F Ratio	F Probability
Phosphorus	0.7182	0.6870	0.127	0.7255
Nitrate	0.5975	0.3847	3.19	0.0879
Dissolved solids	0.1037	0.1967	20.5	0.0002**
Alkalinity	0.0768	0.0910	1.15	0.3083
Turbidity	0.5321	0.5750	0.280	0.6027

**Significantly different at p = 0.01.

Table 4. Multiple regression models predicting nitrate-nitrogen loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

NO3-N load (tons/yr) models created by the SPSS Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)			$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	13	FLOD25			0.92435	0.83623	77.616	0.335	poor
2	13	FLOD10			0.9006	0.78747	88.419	0.382	poor
3	13	CROPI			0.87429	0.73493	98.746	0.426	fair
4	13	PKPOR			0.87338	0.73314	99.079	0.428	poor
5	13	SCONIF			0.87303	0.73245	99.207	0.428	fair +
6	13	QUART			0.85852	0.70419	104.314	0.450	fair -
7	13	PCAM			0.85151	0.6907	106.666	0.461	fair
8	13	PK6579	MIXEDR	BMINT				0.000	
9	13	LACUS			0.83278	0.66566	110.900	0.479	good
10	13	ALPA	LBASINS		0.89711	0.76578	92.822	0.401	good
11	13	C2C	BMINT		0.87744	0.72387	100.784	0.435	excellent
12	13	FLOD2			0.76881	0.55389	128.104	0.553	fair
13	13	LSLENG	BMINT		0.86349	0.69473	105.970	0.458	poor
14	13	CHANL	BMINT		0.84539	0.65761	112.227	0.485	poor

Table 4 (continued). Multiple regression models predicting nitrate-nitrogen loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

NO3-N load (tons/yr) models created by the SPSS Forward Stepwise NEW REGRESSION Program

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	13	FLOD25	0.92435	0.83623	77.616	0.335	poor
2	13	FLOD10	0.9006	0.78747	88.419	0.382	poor
3	13	CROPI	0.87429	0.73493	98.746	0.426	fair
4	13	PKPOR	0.87338	0.73314	99.079	0.428	poor
5	13	SCONIF	0.87303	0.73245	99.207	0.428	fair +

NO3-N load (tons/yr) models created by the SPSS Backward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	13	PK6579	0.8386	0.66616	110.817	0.478	fair
2	13	FLOD2	0.76881	0.53995	130.089	0.561	fair(-)
3	13	BMINT LBASINS	0.83717	0.61539	118.946	0.513	fair (-)
4	13	SCONIF	0.87303	0.73245	99.207	0.428	fair(-)
5	13	PKPOR	0.87338	0.73314	99.078	0.427	poor

Table 4 (continued). Multiple regression models predicting nitrate-nitrogen loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

NO3-N load (tons/yr) models created by the BMDP Allsubsets BMDP9R Regression Program.

Equation#	n=	Independent variable(s)		$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	13	TERT	FLOD25	0.88559	0.86271	71.065	0.306	fair(-)

Table 5. Multiple regression models predicting total phosphorus loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Total Phosphorus load (tons/yr) models created by the SPSS Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	11	CHANL	0.87504	0.72664	14.129	0.549	good
2	11	AREA1	0.87475	0.72606	14.143	0.549	good
3	11	SLENG	0.87102	0.71845	14.339	0.557	good
4	11	SAGE	0.86772	0.71177	14.508	0.564	good
5	11	HBASINS	0.85871	0.69361	14.958	0.581	fair
6	11	TERT	0.83861	0.65293	15.920	0.618	excellent
7	11	QUART	0.83699	0.65065	15.972	0.620	fair -
8	11	CROPI	0.81703	0.61213	16.829	0.654	poor
9	11	SCONIF	0.81593	0.61003	16.875	0.655	poor
10	11	PCAM	0.79133	0.5639	17.845	0.693	poor
11	11	C2C	0.79114	0.56355	17.852	0.693	poor
12	11	LACUS	0.79038	0.56214	17.881	0.695	poor

Table 5 (continued). Multiple regression models predicting total phosphorus loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Total Phosphorus load (tons/yr) models created by the SPSS Forward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	11	CHANL	0.87504	0.72664	14.129	0.549	good
2	11	AREA1	0.87475	0.72606	14.143	0.549	good
3	11	SLENG	0.87102	0.71845	14.339	0.557	good
4	11	SAGE	0.86772	0.71177	14.508	0.564	good
5	11	HBASINS	0.85871	0.69361	14.958	0.581	fair

Total Phosphorus load (tons/yr) models created by the SPSS Backward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	11	HBASINS	0.85871	0.69361	14.957	0.581	fair(-)
2	11	SCONIF	0.81593	0.61003	16.874	0.655	poor
3	11	MIXEDR FLOD2	0.89712	0.72675	14.125	0.548	fair(-)
4	11	SAGE	0.86772	0.71177	14.507	0.563	good
5	11	LACUS	0.79038	0.56214	17.880	0.694	fair(-)

Table 5 (continued). Multiple regression models predicting total phosphorus loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Total Phosphorus load (tons/yr) models created by the BMDP All Subsets BMDP9R Multiple Regression Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	11	AREA1	0.76519	0.7391	13.802	0.536	fair (-)

Table 6. Multiple regression models predicting alkalinity loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Alkalinity load (tons/yr) models created by the SPSS Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)			$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	SCONIF			0.99056	0.97911	13877.483	0.142	poor
2	14	QUART			0.98842	0.97442	15356.766	0.158	poor
3	14	FLOD10	MIXEDR		0.99944	0.99861	3582.141	0.037	poor
4	14	CROPI	MIXEDR	LCHANS					
5	14	FLOD25	HBASINS		0.97862	0.94712	22081.791	0.227	fair (-)
6	14	C2C	MIXEDR	HMINT	0.99732	0.99236	8390.374	0.086	poor
7	14	PK6579			0.9432	0.87737	33626.056	0.345	poor
8	14	ALPA	CHANL		0.9847	0.96204	18708.085	0.192	good
9	14	PCAM			0.92249	0.83443	39071.721	0.401	good
10	14	AREA1	HMINT		0.95651	0.89365	31314.184	0.321	excellent
11	14	CHANL			0.91885	0.82698	39941.431	0.410	excellent
12	14	SLENG	HMINT		0.9523	0.88995	31855.011	0.327	excellent
13	14	LACUS	SAGE		0.93005	0.84044	38356.692	0.394	good
14	14	SAGE	HMINT		0.93014	0.84064	38331.752	0.393	good

Table 6 (continued). Multiple regression models predicting alkalinity loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Alkalinity load (tons/yr) models created by the SPSS Forward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)			$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	SCONIF			0.99056	0.97911	13877.483	0.142	poor
2	14	QUART			0.98842	0.97442	15356.766	0.158	poor
3	14	FLOD10	MIXEDR		0.99944	0.99861	3582.141	0.037	poor
4	14	CROPI	MIXEDR	LCHANS					
5	14	FLOD25	HBASINS		0.97862	0.94712	22081.791	0.227	fair (-)

Alkalinity load (tons/yr) models created by the SPSS Backward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)		$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	HMINT	TERT	0.90173	0.76639	46410.73	0.476	good
2	14	SCONIF		0.99056	0.97911	13877.48	0.142	poor
3	14	MIXEDR		0.6191	0.31475	79487.15	0.815	fair
4	14	SAGE	FLOD2	0.97574	0.94009	23502.30	0.241	fair
5	14	LACUS		0.89315	0.77524	45522.90	0.467	fair(+)

Table 6 (continued). Multiple regression models predicting alkalinity loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Alkalinity load (tons/yr) models created by the BMDP All Subsets BMDP9R Multiple Regression Program.

Equation#	n=	Independent variable(s)				$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	MIXEDR	SCONIF	HMINTT		0.98961	0.98649	11159.64	0.114	good
2	14	SCONIF				0.981202	0.979635			
3	14	SCONIF	HMINTT			0.987687	0.985448			
4	14	LCHANS	SCONIF			0.984122	0.981235			
5	14	MIXEDR	SCONIF			0.983004	0.979914			
6	14	MIXEDR	SCONIF	HMINTT		0.98961	0.986493			
7	14	LCHANS	SCONIF	HMINTT		0.988122	0.984558			
8	14	LCHANS	MIXEDR	SCONIF		0.986528	0.982487			
9	14	LCHANS	MIXEDR	SCONIF	HMINTT	0.990304	0.985994			

Table 7. Multiple regression models predicting total dissolved solids loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Total Dissolved Solids load (tons/yr) models created by the SPSS Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)			$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	SLENG	HBASINS		0.99399	0.98501	22433.142	0.114	poor
2	14	AREA1			0.98386	0.96442	34560.551	0.176	good
3	14	CHANL	MIXEDR		0.98825	0.97079	31316.341	0.160	poor
4	14	SAGE	ALPA		0.9883	0.97091	31248.987	0.159	poor
5	14	TERT			0.94317	0.87731	64179.377	0.328	good
6	14	CROPI	MIXEDR		0.99317	0.983	23893.069	0.122	poor
7	14	QUART	MIXEDR		0.99673	0.99185	16544.395	0.084	poor
8	14	SCONIF			0.92579	0.84121	73013.565	0.373	fair
9	14	C2C			0.92246	0.83437	74569.782	0.381	good
10	14	FLOD25	MIXEDR	HBASINS	0.9773	0.93587	46392.063	0.237	fair
11	14	FLOD10	MIXEDR	HBASINS	0.99095	0.97427	29388.510	0.150	poor
12	14	DISCHG	MIXEDR		0.97731	0.94393	43387.530	0.221	fair
13	14	HBASINS	ALPA	MIXEDR	0.99388	0.98156	24198.041	0.123	poor
14	14	PCAM			0.84056	0.67394	104625.997	0.534	good

Table 7 (continued). Multiple regression models predicting total dissolved solids loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Total Dissolved Solids load (tons/yr) models created by the SPSS Forward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)		$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	SLENG	HBASINS	0.99399	0.98501	22433.1420	0.114	poor
2	14	AREA1		0.98386	0.96442	34560.5513	0.176	good
3	14	CHANL	MIXEDR	0.98825	0.97079	31316.3411	0.160	poor
4	14	SAGE	ALPA	0.9883	0.97091	31248.9870	0.159	poor
5	14	TERT		0.94317	0.87731	64179.3771	0.328	good

Total Dissolved Solids load (tons/yr) models created by the SPSS Backward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)		$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	SCONIF		0.92579	0.84121	73013.56	0.372	good
2	14	MIXEDR		0.77266	0.55223	122608.2	0.625	fair
3	14	SAGE	PKPOR	0.97614	0.94106	44483.78	0.227	good
4	14	LACUS	HBASINS	0.93409	0.84065	73141.08	0.373	excellent
5	14	CROPI		0.93118	0.85233	70410.17	0.359	excellent

Table 7 (continued). Multiple regression models predicting total dissolved solids loads (tons/yr) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Total Dissolved Solids load (tons/yr) models created by the BMDP All Subsets BMDP9R Multiple Regression Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	14	CHANL	0.95108	0.94701	42180.12	0.215	good

Table 8. Multiple regression models predicting turbidity loads (JTU) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Turbidity (JTU) models created by the SPSS Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	12	LALPA	0.76639	0.54609	40.526	1.008	poor
2	12	LCONIF	0.7575	0.53119	41.185	1.024	poor
3	12	PHSOIL	0.58788	0.28016	51.034	1.269	poor
4	12	MAST	0.57674	0.26589	51.537	1.282	poor
5	12	MINT	0.93755	0.86171	22.368	0.556	fair
6	12	HFLDRAT PHSOIL	0.98843	0.96933	10.533	0.262	poor
7	12	HDDEN LALPA	0.88262	0.7299	31.261	0.777	fair
8	12	LALPA	0.76639	0.54609	40.526	1.008	poor

Turbidity (JTU) models created by the SPSS Forward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)	$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	12	MINT	0.93755	0.86171	22.368	0.556	fair
2	12	HFLDRAT PHSOIL	0.98843	0.96933	10.533	0.262	poor
3	12	HDDEN LALPA	0.88262	0.7299	31.261	0.777	fair
4	12	LALPA	0.76639	0.54609	40.526	1.008	poor
5	12	LCONIF	0.7575	0.53119	41.085	1.022	poor

Table 8 (continued). Multiple regression models predicting turbidity loads (JTU) in the Green River and its tributaries as functions of unique basin attributes. N is the number of water quality stations, $R^2_{mult.}$ is the variation explained by the regression, $R^2_{adj.}$ is the $R^2_{mult.}$ adjusted for degrees of freedom, Std error regrn is the standard error of the regression, and PSEE is the percent standard error of the estimate. Full names for the independent variables are in Appendix A.

Turbidity (JTU) models created by the SPSS Backward Stepwise NEW REGRESSION Program.

Equation#	n=	Independent variable(s)		$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	12	MINT	HDDEN	0.96216	0.90099	18.926	0.471	poor
2	12	LCONIF	HDDEN	0.8699	0.67563	34.257	0.852	good
3	12	LALPA	HDDEN	0.88262	0.70535	32.651	0.812	fair(+)
4	12	PHSOIL	HFLDRAT	0.98843	0.96933	10.533	0.262	poor
5	12	MAST	HFLDRAT	0.97853	0.94335	14.316	0.356	poor

Turbidity (JTU) models created by the BMDP All Subsets BMDP9R Multiple Regression Program.

Equation#	n=	Independent variable(s)			$R^2_{mult.}$	$R^2_{adj.}$	Std error regrn	PSEE	Quality of Residuals
1	12	MINTT			0.879	0.8669	21.945	0.545	poor
2	12	CHANS	MINTT		0.884	0.8580			
3	12	PHSOIL	MINTT		0.879	0.852			
4	12	CHANS	PHSOIL	MINTT	0.883	0.840			

Table 9. Multiple regression models predicting water quality in the Green River drainage from basin attributes. The models were derived for water quality variables which had acceptable residuals plots in SPSS STEPWISE analyses. N is the number of water quality stations, $AdjR^2$ is the variation explained by the regression, adjusted for degrees of freedom, PRESS is the predicted error sum of squares, and $R^2_{predicted}$ is variation in new data explained by the model. The equation numbers correspond to those in the SPSS NEW REGRESSION STEPWISE portions of Table 4. Full names for the independent variables are in Appendix A.

Section A: Nitrate-nitrogen load (tons/yr) multiple regression models.

Equation#	n=	IV 1	IV 2	IV 3	Adj R2	PRESS	$R^2_{predicted}$	Residuals quality
3	13	CROPI			0.73493	185662	0.5794	fair
5	13	SCONIF			0.73245	190648	0.5681	good
6	13	QUART			0.70419	215661	0.5114	fair -
7	13	PCAM			0.6907	203608	0.5387	fair
9	13	LACUS			0.66566	227476	0.4847	good
10	13	ALPA	LBASINS		0.76578	183686	0.5839	good
11	13	C2C	BMINT		0.72387	479802	0.0	excellent

Section B: Total phosphorus load (tons/yr) multiple regression models.

Equation#	n=	IV 1	IV 2	IV 3	Adj R2	PRESS	$R^2_{predicted}$	Residuals quality
1	11	CHANL			0.72664	3523	0.3106	good
2	11	AREA1			0.72606	4427	0.1338	good
3	11	SLENG			0.71845	4623	0.0953	good
4	11	SAGE			0.71177	4437	0.1317	good
5	11	HBASINS			0.69361	3419	0.3311	fair
6	11	TERT			0.65293	4944	0.0325	excellent
7	11	QUART			0.65065	4541	0.1114	fair -

Table 9 (continued). Multiple regression models predicting water quality in the Green River drainage from basin attributes. The models were derived for water quality variables which had acceptable residuals plots in SPSS STEPWISE analyses. N is the number of water quality stations, AdjR^2 is the variation explained by the regression, adjusted for degrees of freedom, PRESS is the predicted error sum of squares, and $R^2_{predicted}$ is variation in new data explained by the model. The equation numbers correspond to those in the SPSS NEW REGRESSION STEPWISE portions of Table 4. Full names for the independent variables are in Appendix A.

Section C: Alkalinity load (tons/yr) multiple regression models.

Equation#	n=	IV 1	IV 2	IV 3	Adj R2	PRESS	$R^2_{predicted}$	Residuals quality
8	14	ALPA	CHANL		0.96204	9239460964	0.8998	good
9	14	PCAM			0.83443	23794603770	0.7419	good
10	14	AREA1	HMINT		0.89365	17115001447	0.8144	excellent
11	14	CHANL			0.82698	25944602337	0.7186	excellent
12	14	SLENG	HMINT		0.88995	18479413180	0.8458	excellent
13	14	LACUS	SAGE		0.84044	28343603902	0.7635	good
14	14	SAGE	HMINT		0.84064	26588190200	0.7782	good

Section D: Total dissolved solids load (tons/yr) multiple regression models.

Equation#	n=	IV 1	IV 2	IV 3	Adj R2	PRESS	$R^2_{predicted}$	Residuals quality
2	14	AREA1			0.96442	23018997589	0.9314	good
5	14	TERT			0.87731	62979435081	0.8124	good
8	14	SCONIF			0.84121	99335805271	0.7041	fair
9	14	C2C			0.83437	99420834570	0.7039	good
10	14	FLOD25	MIXEDR	HBASINS	0.93587			fair
12	14	DISCHG	MIXEDR		0.94393	91053404637	0.7288	fair
14	14	PCAM			0.67394	189353395891	0.4360	good

Table 9 (continued). Multiple regression models predicting water quality in the Green River drainage from basin attributes. The models were derived for water quality variables which had acceptable residuals plots in SPSS STEPWISE analyses. N is the number of water quality stations, AdjR^2 is the variation explained by the regression, adjusted for degrees of freedom, PRESS is the predicted error sum of squares, and $R^2_{predicted}$ is variation in new data explained by the model. The equation numbers correspond to those in the SPSS NEW REGRESSION STEPWISE portions of Table 4. Full names for the independent variables are in Appendix A.

Section E: Turbidity multiple regression models.

Equation#	n=	IV 1	IV 2	IV 3	Adj R2	PRESS	$R^2_{predicted}$	Residuals quality
5	12	MINT			0.86171	7558	0.7389	fair
7	12	HDDEN	LALPA		0.7299	34074	0.1438	fair

Table 10. Final regression models best predicting water quality in the Green River drainage as functions of basin attributes.

Nitrate-nitrogen (tons/year NO_3):

Model A:

NITRATE-NITROGEN LOAD = [0.8204 (IRRIGATED CROPLAND)] + 73.03

Model B:

NITRATE-NITROGEN LOAD = [2.204 (ALPINE AREA)] - [185.8 (Ln BASIN SLOPE)] + 948.7

Total phosphorus (tons/year P):

TOTAL PHOSPHORUS LOAD = [0.5322 (MAIN CHANNEL LENGTH)] - 22.91

Total alkalinity (tons/year $CaCO_3$):

Model A:
TOTAL ALKALINITY = [1985 (MAIN CHANNEL LENGTH)] - 84121

Model B:

TOTAL ALKALINITY = [37.23 (SUBBASIN AREA)] + [0.5047 (Hyperbolic transform MINIMUM JANUARY TEMPERATURE)] - 56451

Total dissolved solids (tons/year):

TOTAL DISSOLVED SOLIDS = [82.53 (SUBBASIN AREA)] + 11048

Turbidity (JTU):

TURBIDITY = [25.43 (Hyperbolic transform MINIMUM JANUARY TEMPERATURE)] - 6409

Table 11. Comparison metrics for the final regression models (Table 10) which best predict water quality of the Green River drainage as functions of basin attributes. More accurate models have higher values for $R^2_{adjusted}$ and lower values for PSEE (percent standard error of the estimate); a higher $R^2_{predicted}$ signifies a more robust model. An asterisk (*) denotes a model with greater than 10% reduction in the amount of variance in new data explained by the model; a double asterisk (**) denotes models with over 20% reduction in explained variance.

Model:	$R^2_{adjusted}$	$R^2_{predicted}$	PSEE
Nitrate-nitrogen Model A [CROPI]:	0.7349	0.5794**	0.426
Nitrate-nitrogen Model B [ALPA/LBASINS]:	0.7658	0.5839**	0.401
Total Phosphorus Model A [CHANL]:	0.7266	0.3106**	0.549
Total Alkalinity Model A [CHANL]:	0.8270	0.7186*	0.410
Total Alkalinity Model B [AREA1/HMINT]:	0.8937	0.8144	0.321
Total Dissolved Solids Model A [AREA1]:	0.9644	0.9314	0.176
Turbidity Model A [MINT]:	0.8617	0.7389*	0.556

Table 12. Loads and turbidities predicted by the five bivariate multiple regression models predicting water quality from basin attributes of the Green River drainage. The models represented are those designated in Table 10 for Nitrate-nitrogen (NO_3) Model A, Total Phosphorus (TP), Alkalinity (Alk.), Total Dissolved Solids (TDS), and Turbidity. LCL and UCL denote the lower and upper 95% confidence limits for the predicted loads or turbidity.

STATION	NO3 load (tons/yr)	LCL	UCL	TP load (tons/yr)	LCL	UCL	Alk. load (tons/yr)	LCL	UCL
GRWB	73.0	-15.9	162.0	4.23	-7.30	15.76	17151	-10862	45165
GRBP	219.9	159.3	280.5	25.36	17.18	33.53	95986	75361	116610
NFAB	141.9	69.5	214.4	-0.82	-13.56	11.91	-1713	-32794	29367
NFBP	202.7	140.3	265.0	8.76	-1.79	19.30	34030	8462	59599
GRLB	470.1	375.7	564.5	43.24	34.23	52.25	162707	137743	187670
GRBF	478.3	381.7	575.0	52.02	41.45	62.59	195472	165659	225284
BSLS	73.0	-15.9	162.0	-2.69	-15.88	10.51	-8663	-40944	23618
BSAF	115.7	37.4	193.9	14.72	5.29	24.15	56271	33334	79208
BSBD	115.7	37.4	193.9	14.72	5.29	24.15	56271	33334	79208
BSGB	115.7	37.4	193.9	19.72	11.02	28.42	74937	53525	96348
BSAC	115.7	37.4	193.9	24.61	16.39	32.84	93206	72539	113872
GRBI	525.1	414.8	635.3	66.98	52.85	81.10	251271	211314	291228
GRGR	525.1	414.8	635.3	78.95	61.56	96.34	295950	247008	344893
BFAL	203.5	141.2	265.7	9.07	-1.41	19.56	35222	9813	60631
HFAG	97.6	15.0	180.2	22.43	14.03	30.84	85064	64164	105964
BFLA	232.2	172.5	291.9	30.63	22.61	38.65	115645	94768	136521

Table 12 (continued). Loads and turbidities predicted by the five bivariate multiple regression models relating basin attributes to water quality variables in the Green River drainage. The models represented are those designated in Table 10 for Nitrate-nitrogen (NO_3) Model A, Total Phosphorus (TP), Alkalinity (Alk.), Total Dissolved Solids (TDS), and Turbidity. LCL and UCL denote the lower and upper 95% confidence limits for the predicted loads or turbidity.

*

STATION	TDS load (tons/yr)	LCL	UCL	Turbidity (JTU)	LCL	UCL
GRWB	48597	25304	71891	11.00	-3.22	25.21
GRBP	112555	92661	132449	-2.99	-18.75	12.76
NFAB	53549	30560	76538	25.24	12.15	38.32
NFBP	109584	89562	129607	11.00	-3.22	25.21
GRLB	322254	301122	343386	-2.99	-18.75	12.76
GRBF	353036	330174	375898	-2.99	-18.75	12.76
BSLS	23262	-1673	48196	39.22	26.71	51.74
BSAF	130628	111444	149812	25.24	12.15	38.32
BSBD	130628	111444	149812	25.24	12.15	38.32
BSGB	139871	120998	158744	25.24	12.15	38.32
BSAC	143997	125252	162743	25.24	12.15	38.32
GRBI	570080	530607	609553	11.00	-3.22	25.21
GRGR	608785	565953	651617	25.24	12.15	38.32
BFAL	75666	53959	97373	194.87	162.44	227.29
HFAG	60976	38432	83520	81.70	67.26	96.13
BFLA	251942	233539	270344	152.40	127.60	177.19

Table 13. Loads predicted by the two multivariate multiple regression models predicting water quality from basin attributes of the Green River drainage. The models represented are those designated Nitrate-nitrogen (NO_3) Model B and Alkalinity (Alk.) Model B in Table 10. LCL and UCL denote the lower and upper 95% confidence limits for the predicted loads.

Station	NO3 load (tons/yr)	LCL	UCL	Station	Alk. load (tons/yr)	LCL	UCL
GRWB	158.3	5.8	310.8	GRWB	43934	21205	66663
GRBP	315.8	259.5	372.1	GRBP	97117	67898	126336
NFAB	135.4	45.9	224.9	NFAB	30855	11122	50589
NFBP	199.8	136.6	263.0	NFBP	71448	51838	91057
GRLB	446.0	359.7	532.4	GRLB	191700	165502	217898
GRBF	498.2	399.9	596.6	GRBF	205600	178851	232349
BSLS	-60.2	-269.6	149.2	BSLS	6666	-14935	28268
BSAF	141.0	65.5	216.6	BSAF	65628	49237	82020
BSBD	141.0	96.4	185.6	BSBD	65628	49237	82020
BSGB	138.1	63.4	212.8	BSGB	69798	53676	85921
BSAC	203.0	86.0	320.0	BSAC	71660	55649	87671
GRBI	490.0	396.0	584.1	GRBI	279200	245446	312954
GRGR	530.6	423.5	637.7	GRGR	281300	243184	319416
BFAL	106.1	24.9	187.4	BFAL	-5608	-37401	26186
HFAG	108.3	26.6	190.1	HFAG	5546	-18909	30002
BFLA	153.5	47.9	259.1	BFLA	78269	46757	109781

Table 14. Loads predicted by applying models derived from data in the Green River drainage to basin attributes of the Sweetwater River near Alcova, Wyoming (USGS station #663900). LCL and UCL are the lower and upper 96% confidence limits, respectively. An asterisk (*) denotes a difference in confidence limits between observed loads and predicted loads within the same order of magnitude; a double asterisk (**) denotes no significant difference between observed and predicted loads.

	Observed	LCL	UCL	Predicted	LCL	UCL
NO3 (tons/yr)	18.6	-36.0	73.0			
Model A**				73.0	-15.9	161.9
Model B*				169.6	41.2	298.0
TP (tons/yr)*	4.7	-5.0	15.0	41.0	30.7	51.2
Alkalinity (tons/yr)	17978	-29933	65890			
Model A				154168	131299	177038
Model B**				52958	20991	84295
TDS (tons/yr)*	28286	-47686	104258	203086	185222	220950
TURB (JTU)	13.00	-44.00	71.00	180.40	155.90	204.90

Table 15. Predicted annual areal loads of total phosphorus (TP) and total dissolved solids (TDS) calculated as export from entire subbasins, and from segments of subbasins between sampling points, in the Green River basin.

Station	TP pred. (tons/yr)	Subbasin area (mi2)	Subbasin areal load (tons/mi2/yr)	Segment area (mi2)	Segment load (tons/yr)	Segment areal load (tons/mi2/yr)
GRWB	4.2	455	0.009	455	4.2	0.009
GRBP	25.4	1230	0.021	775	21.1	0.027
NFAB	-0.8	515	-0.002	515	-0.8	-0.002
NFBP	8.8	1194	0.007	679	9.6	0.014
GRLB	43.2	3771	0.011	1347	9.1	0.007
GRBF	52.0	4144	0.013	373	8.8	0.024
BSLS	-2.7	148	-0.018	148	-2.7	-0.018
BSAF	14.7	1449	0.010	1301	17.4	0.013
BSBD	14.7	1449	0.010	0	0.0	0.000
BSGB	19.7	1561	0.013	112	5.0	0.045
BSAC	24.6	1611	0.015	50	4.9	0.098
GRBI	67.0	6774	0.010	1019	-9.7	-0.009
GRGR	79.0	7243	0.011	469	12.0	0.026
BFAL	9.1	783	0.012	783	9.1	0.012
HFAG	22.4	605	0.037	605	22.4	0.037
BFLA	30.6	2919	0.010	1531	-0.9	-0.001

Station	TDS pred. (tons/yr)	Subbasin area (mi2)	Subbasin areal load (tons/mi2/yr)	Segment area (mi2)	Segment load (tons/yr)	Segment areal load (tons/mi2/yr)
GRWB	48597	455	107	455	48597	107
GRBP	112555	1230	92	775	63958	83
NFAB	53549	515	104	515	53549	104
NFBP	109584	1194	92	679	56035	83
GRLB	322254	3771	85	1347	100115	74
GRBF	353036	4144	85	373	30782	83
BSLS	23262	148	157	148	23262	157
BSAF	130628	1449	90	1301	107367	83
BSBD	130628	1449	90	0	0	0
BSGB	139900	1561	90	112	9272	83
BSAC	144000	1611	89	50	4100	82
GRBI	570080	6774	84	1019	73044	72
GRGR	608785	7243	84	469	38705	83
BFAL	75666	783	97	783	75666	97
HFAG	60976	605	101	605	60976	101
BFLA	251942	2919	86	1531	115300	75

Table 16. Results from Pearson correlation analyses of the best relations between daily and partial records for selected water quality parameters measured at USGS water quality station #09217000--Green River at Green River (GRGR).

Total phosphorus (mg/l) = [Suspended solids (mg/l) * 0.00078] + 0.01645

R = 0.89	Standard error of the estimate = 0.033
R^2 = 0.79	Regression significant at p = 0.00001
Number of samples = 51	

Log [Total dissolved solids (tons/day)] =

[(Log Discharge (cfs)) * 0.603] + 1.270

R = 0.88	Standard error of the estimate = 0.117
R^2 = 0.78	Regression significant at p = 0.00001
Number of samples = 275	

Table 17. Analysis of variance of mean annual loads of total phosphorus and total dissolved solids predicted by resampling daily data.

Total Phosphorus annual load: analysis of variance by strategy and interval

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	2058.957	3	686.319	6.825	.001
STRATEGY	.099	1	.099	.001	.975
INTERVAL	2058.858	2	1029.429	10.238	.001
2-WAY INTERACTIONS	29.469	2	14.735	.147	.864
STRATEGY INTERVAL	29.469	2	14.735	.147	.864
EXPLAINED	2088.426	5	417.685	4.154	.002
RESIDUAL	9251.004	92	100.554		
TOTAL	11339.430	97	116.901		

Total Dissolved Solids annual load: analysis of variance by strategy and interval

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	.289E+11	3	.963E+10	288.937	.001
STRATEGY	50810587.469	1	.508E+08	1.525	.220
INTERVAL	.288E+11	2	.144E+11	432.643	.001
2-WAY INTERACTIONS	13328361.696	2	.666E+07	.200	.819
STRATEGY INTERVAL	13328361.696	2	.666E+07	.200	.819
EXPLAINED	.289E+11	5	.578E+10	173.442	.001
RESIDUAL	.307E+10	92	.333E+08		
TOTAL	.320E+11	97	.330E+09		

Table 18. Analysis of variance for mean coefficients of variation obtained by resampling the daily augmented data for total phosphorus and total dissolved solids.

Total Phosphorus coefficients of variation: analysis of variance by strategy and interval

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	.524	3	.175	19.531	.001
STRATEGY	.016	1	.016	1.842	.178
INTERVAL	.507	2	.254	28.375	.001
2-WAY INTERACTIONS	.038	2	.019	2.124	.125
STRATEGY INTERVAL	.038	2	.019	2.124	.125
EXPLAINED	.561	5	.112	12.568	.001
RESIDUAL	.822	92	.009		
TOTAL	1.384	97	.014		

Total Dissolved Solids coefficients of variation: analysis of variance by strategy and interval

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	.009	3	.003	39.966	.001
STRATEGY	.000	1	.000	3.643	.059
INTERVAL	.008	2	.004	58.127	.001
2-WAY INTERACTIONS	.000	2	.000	.731	.484
STRATEGY INTERVAL	.000	2	.000	.731	.484
EXPLAINED	.009	5	.002	24.272	.001
RESIDUAL	.007	92	.000		
TOTAL	.015	97	.000		

Table 19. Interval means and 95% confidence limits for Total phosphorus and Total dissolved solids mean annual loads and coefficients of variation found by resampling their daily augmented records at station GRGR—Green River at Green River. Overlapping confidence limits indicate no significant difference between the estimates. Significant differences between fortnightly and monthly, and fortnightly and weekly estimates are marked with an asterisk (*). LCL = lower 95% confidence limit and UCL = upper 95% confidence limit.

Total phosphorus load (tons/yr)

Interval	Estimate	LCL	UCL
Daily	117		
Weekly	117	115	119
Fortnightly	116	113	119
	*		
Monthly	107	104	110

Total dissolved solids load (tons/yr)

Interval	Estimate	LCL	UCL
Daily	575731		
Weekly	575487	574756	576218
Fortnightly	574466	573017	575915
	*		
Monthly	540149	538262	542037

Total phosphorus coefficient of variation

Interval	Estimate	LCL	UCL
Daily	0.480		
Weekly	0.480	0.449	0.502
Fortnightly	0.520	0.490	0.540
	*		
Monthly	0.650	0.614	0.676

Total dissolved solids coefficient of variation

Interval	Estimate	LCL	UCL
Daily	0.180		
Weekly	0.180	0.175	0.180
Fortnightly	0.180	0.176	0.181
	*		
Monthly	0.200	0.194	0.200

Table 20. Total phosphorus loads (tons/yr) to Flaming Gorge Reservoir from all sources upstream of Buckboard Wash. These loads include all point source inputs to the Green River downstream of USGS water quality sampling station #09217000--Green River at Green River city (GRGR), and all point sources in the Blacks Fork. Excessive loads (tons/yr) are those predicted by the Vollenweider III model for the entire reservoir and for the Buckboard section only.

Total phosphorus observed (Appendix A):

Station	Mean Annual Load	Excessive load Buckboard	Excessive load Entire
GRGR	129	49	73
BFLA	not sampled		

Total phosphorus from multiple regression modeling (Section 1):

Mean Annual Load: Load	LCL	UCL	Excessive load: Buckb'd	Entire
143	118	169	49	73

Total phosphorus estimates from resampling (Section 2):

Interval	Mean annual load: Load	LCL	UCL	Excessive load: Buckb'd	Entire
Daily	182			49	73
Weekly	181	171	191	49	73
Fortnightly	181	169	192	49	73
Monthly	172	160	182	49	73

Total phosphorus estimates from resampling (Section 2):

Yearly load	Year	Load	LCL	UCL	Excessive load: Buckb'd	Entire
	1965	323	248	408	63	88
	1966	154	128	181	40	65
	1967	202	163	243	53	78
	1968	135	112	161	37	62
	1969	208	152	270	51	75
	1970	115	96	133	39	63
	1971	236	191	285	59	83
	1972	207	172	247	68	92
	1973	185	149	220	46	71
	1974	179	149	211	54	78
	1975	142	121	165	50	74
	1976	187	154	220	54	78
	1977	105	86	125	26	51
	1978	218	176	266	53	78
	1979	129	108	151	39	64

Table 20 (continued). Total phosphorus loads (tons/yr) for Flaming Gorge Reservoir from all sources upstream of Buckboard Wash.

Total phosphorus load estimated by time series (Section 3):

Mean annual load	Excessive load	
	Buckboard	Entire
215	49	73

Total phosphorus yearly loads estimated by time series (Section 3):

			Excessive load	
Yearly load	Year	Load	Buckboard	Entire
	1966	191	40	65
	1967	241	53	78
	1968	178	37	62
	1969	256	51	75
	1970	145	39	63
	1971	244	59	83
	1972	261	68	92
	1973	203	46	71
	1974	206	54	78
	1975	183	50	74
	1976	212	54	78
	1977	121	26	51
	1978	244	53	78
	1979	151	39	64

Yearly load (USEPA 1977):

		Excessive load	
	Load	Buckboard	Entire
all	178	50	74

Yearly load (SWWQPA 1978):

		Excessive load	
Year	Load	Buckboard	Entire
1975	123	50	74
1976	326	54	78

Yearly load (WRRI 1977):

		Excessive load	
Year	Load	Buckboard	Entire
1975	84	50	74

Mean Annual load (Hern and Lambou 1979):

	Excessive load	
Load	Buckboard	Entire
204	49	73

Table 21. Total phosphorus loading (tons/yr) to the Green River Arm of Flaming Gorge Reservoir. These loads include the combined source total phosphorus loads generated by all methods used in this report (Table 14), plus all permitted point source inputs to the Green River downstream of USGS water quality sampling station #09217000--Green River at Green River city (GRGR) listed in Appendix B. Excessive loads (tons/yr) are those predicted for the Green River arm by the Vollenweider III model.

Total phosphorus observed (Appendix A):

Station	Mean annual load	Excessive load
GRGR	129	39

Total phosphorus from multiple regression modeling (Section 1):

	Mean annual load			Excessive load
Station	Load	LCL	UCL	
GRGR	112	95	130	39

Total phosphorus estimates from resampling (Section 2):

	Mean annual load			Excessive load
Interval	Load	LCL	UCL	
Daily	151			39
Weekly	150	148	152	39
Fortnightly	150	146	153	39
Monthly	141	137	143	39

Total phosphorus estimates from resampling (Section 2):

Yearly loads	Year	Load	LCL	UCL	Excessive load
	1965	292	225	369	54
	1966	123	105	142	31
	1967	171	140	204	44
	1968	104	89	122	28
	1969	177	129	231	41
	1970	84	73	94	29
	1971	205	168	246	49
	1972	176	149	208	58
	1973	154	126	181	37
	1974	148	126	172	44
	1975	111	98	126	41
	1976	156	131	181	44
	1977	74	63	86	17
	1978	187	153	227	44
	1979	98	85	112	30

Table 21 (continued). Total phosphorus loading (tons/yr) to the Green River Arm of Flaming Gorge Reservoir.

Total phosphorus annual loads estimated by time series (Section 3):

Mean annual load	Excessive load
184	39

Total phosphorus yearly loads estimated by time series (Section 3):

Yearly load	Year	Load	Excessive load
	1966	160	31
	1967	210	44
	1968	147	28
	1969	225	41
	1970	114	29
	1971	213	49
	1972	230	58
	1973	172	37
	1974	175	44
	1975	152	41
	1976	181	44
	1977	90	17
	1978	213	44
	1979	120	30

Yearly load (USEPA 1977):

	Load	Excessive load
nonpoint	53	41
all	97	41

Yearly load (SWWQPA 1978):

Year	Load	Excessive load
1975	123	41
1976	326	44

Yearly load (WRRI 1977):

Year	Load	Excessive load
1975	84	41

Mean annual load (Hern and Lambou 1979):

Load	Excessive load
204	39

Table 22. Total phosphorus loads (tons/yr) to the Green River Arm of Flaming Gorge Reservoir. Since point sources in the Green River section are insignificant, these combined source loads are equivalent to nonpoint source loads. Also, these loads do not include any point source or nonpoint source inputs to the Green River downstream of USGS water quality sampling station #09217000—Green River at Green River city (GRGR). Excessive loads are those predicted for the Green River arm by the Vollenweider III model.

Total phosphorus observed (Appendix A):

Station	Mean annual Load	Excessive load
GRGR	95	39

Total phosphorus from multiple regression modeling (Section 1):

	Mean annual load			Excessive load
Station	Load	LCL	UCL	
GRGR	79	62	96	39

Total phosphorus estimates from resampling (Section 2):

	Mean annual load			Excessive load
Interval	Load	LCL	UCL	
Daily	117			39
Weekly	117	115	119	39
Fortnightly	116	113	119	39
Monthly	107	104	110	39

Total phosphorus estimates from resampling (Section 2):

Yearly loads	Year	Load	LCL	UCL	Excessive load
	1965	259	192	336	54
	1966	89	72	109	31
	1967	138	106	170	44
	1968	71	55	89	28
	1969	144	96	198	41
	1970	50	40	61	29
	1971	172	135	213	49
	1972	142	116	175	58
	1973	120	93	148	37
	1974	115	93	139	44
	1975	78	64	93	41
	1976	123	98	148	44
	1977	41	30	52	17
	1978	154	119	194	44
	1979	65	52	79	30

Table 22 (continued). Total phosphorus loads (tons/yr) to the Green River Arm of Flaming Gorge Reservoir.

Total phosphorus load estimated by time series (Section 3):

Mean annual load	Excessive load
151	39

Total phosphorus yearly loads estimated by time series (Section 3):

	Year	Load	Excessive load
Yearly load	1966	126	31
	1967	177	44
	1968	114	28
	1969	192	41
	1970	81	29
	1971	180	49
	1972	196	58
	1973	139	37
	1974	142	44
	1975	118	41
	1976	147	44
	1977	57	17
	1978	179	44
	1979	87	30

Table 23. Permissible and excessive phosphorus areal and mean annual loadings predicted by the Vollenweider III model for each section of Flaming Gorge Reservoir. T_w is the hydraulic residence time (years), and z is the mean depth (meters). Discharge is the mean annual discharge during water years 1965-1979.

Green River Arm

Discharge (cfs) = 1825
Discharge (m^3/sec) = 51.68
Discharge (m^3/yr) = 1.631×10^9 z = 5.566 m
T_w = 0.0533 yr Volume = 8.700×10^7 m^3
z/T_w = 104.4 m/yr Surface area = 1.563×10^7 m^2
Permissible loading = 1144 mg/m^2/yr
Excessive loading = 2287 mg/m^2/yr
Back-calculated permissible loading = 20 tons/yr
Back-calculated excessive loading = 39 tons/yr

Upstream of Buckboard Wash

Discharge (cfs) = 2178
Discharge (m^3/s) = 61.68
Discharge (m^3/yr) = 1.947×10^9 z = 7.763 m
T_w = 0.1078 yr Volume = 2.098×10^8 m^3
z/T_w = 72.02 m/yr Surface area = 2.703×10^7 m^2
Permissible loading = 820 mg/m^2/yr
Excessive loading = 1640 mg/m^2/yr
Back-calculated permissible loading = 24 tons/yr
Back-calculated excessive loading = 49 tons/yr

Entire reservoir

Discharge (cfs) = 2178
Discharge (m^3/s) = 61.68
Discharge (m^3/yr) = 1.947×10^9 z = 33.9 m
T_w = 2.398 yr Volume = 4.667×10^9 m^3
z/T_w = 14.14 m/yr Surface area = 1.377×10^8 m^2
Permissible loading = 241 mg/m^2/yr
Excessive loading = 483 mg/m^2/yr
Back-calculated permissible loading = 37 tons/yr
Back-calculated excessive loading = 73 tons/yr

Table 24. Nonpoint source total phosphorus loads (tons/yr) to Flaming Gorge Reservoir upstream of Buckboard Wash. These loads do not include any point source or nonpoint source inputs to the Green River downstream of water quality sampling station #09217000--GRGR, and the contribution of point sources in the Blacks Fork (10.6 tons/yr) has been excluded. Since the point sources in the Green River section of the Green River drainage are insignificant, these figures can be considered nonpoint source inputs to Flaming Gorge Reservoir. Excessive loads (tons/yr) are those predicted by the Vollenweider III model for the entire reservoir and the Buckboard section only.

Total phosphorus observed (Appendix A):

Station	Mean annual load	Excessive load Buckboard	Excessive load Entire
GRGR	95	49	73
BFLA	not sampled		

Total phosphorus from multiple regression modeling (Section 1):

Mean annual Load: Load	LCL	UCL	Excessive load: Buckb'd	Entire
99	74	124	49	73

Total phosphorus estimates from resampling (Section 2):

Interval	Mean annual load: Load	LCL	UCL	Excessive load: Buckb'd	Entire
Daily	137			49	73
Weekly	137	127	147	49	73
Fortnightly	136	125	147	49	73
Monthly	127	116	138	49	73

Total phosphorus estimates from resampling (Section 2):

	Year	Load	LCL	UCL	Excessive load: Buckb'd	Entire
Yearly load	1965	279	204	364	63	88
	1966	109	84	137	40	65
	1967	158	118	198	53	78
	1968	91	67	117	37	62
	1969	164	108	226	51	75
	1970	70	52	89	39	63
	1971	192	147	241	59	83
	1972	162	128	203	68	92
	1973	140	105	176	46	71
	1974	135	105	167	54	78
	1975	98	76	121	50	74
	1976	143	110	176	54	78
	1977	61	42	80	26	51
	1978	174	131	222	53	78
	1979	85	64	107	39	64

Table 24 (continued). Nonpoint source total phosphorus loads (tons/yr) to Flaming Gorge Reservoir upstream of Buckboard Wash.

Total phosphorus load estimated by time series (Section 3):

	Excessive load	
Mean annual load	Buckboard	Entire
171	49	73

Total phosphorus yearly loads estimated by time series (Section 3):

			Excessive load	
	Year	Load	Buckboard	Entire
Yearly load	1966	146	40	65
	1967	197	53	78
	1968	134	37	62
	1969	212	51	75
	1970	101	39	63
	1971	200	59	83
	1972	216	68	92
	1973	159	46	71
	1974	162	54	78
	1975	138	50	74
	1976	167	54	78
	1977	77	26	51
	1978	199	53	78
	1979	107	39	64

Table 25. Yearly combined source total phosphorus loads at Green River at Green River (station GRGR) derived from the ARIMA(201 100) model. Asterisks (*) denote years with a load significantly different from the 15-year mean annual load. The total load to the Green River Arm of Flaming Gorge Reservoir is calculated by adding 33.3 tons/yr to these tabulated yearly loads.

Water year	Mean daily load (tons/day)	Yearly load (tons/yr)
1966	0.346	126
1967	0.483	176
1968*	0.310	113
1969	0.525	191
1970*	0.222	81
1971	0.492	179
1972*	0.536	196
1973	0.380	138
1974	0.388	141
1975*	0.324	118
1976	0.402	147
1977*	0.155	56
1978	0.491	179
1979*	0.238	87

FIGURES

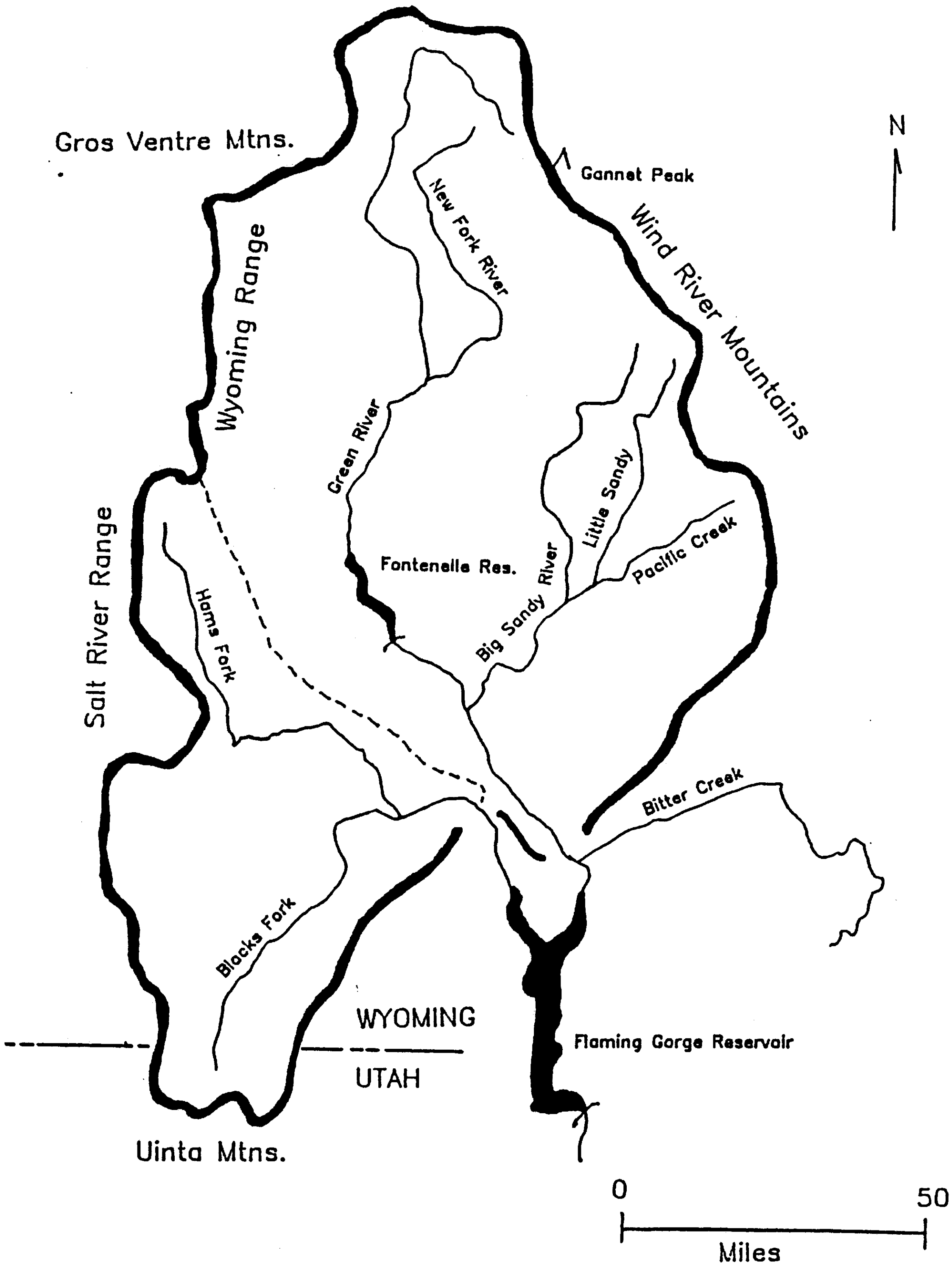

Figure 1. Physiographic features of the upper Green River drainage.

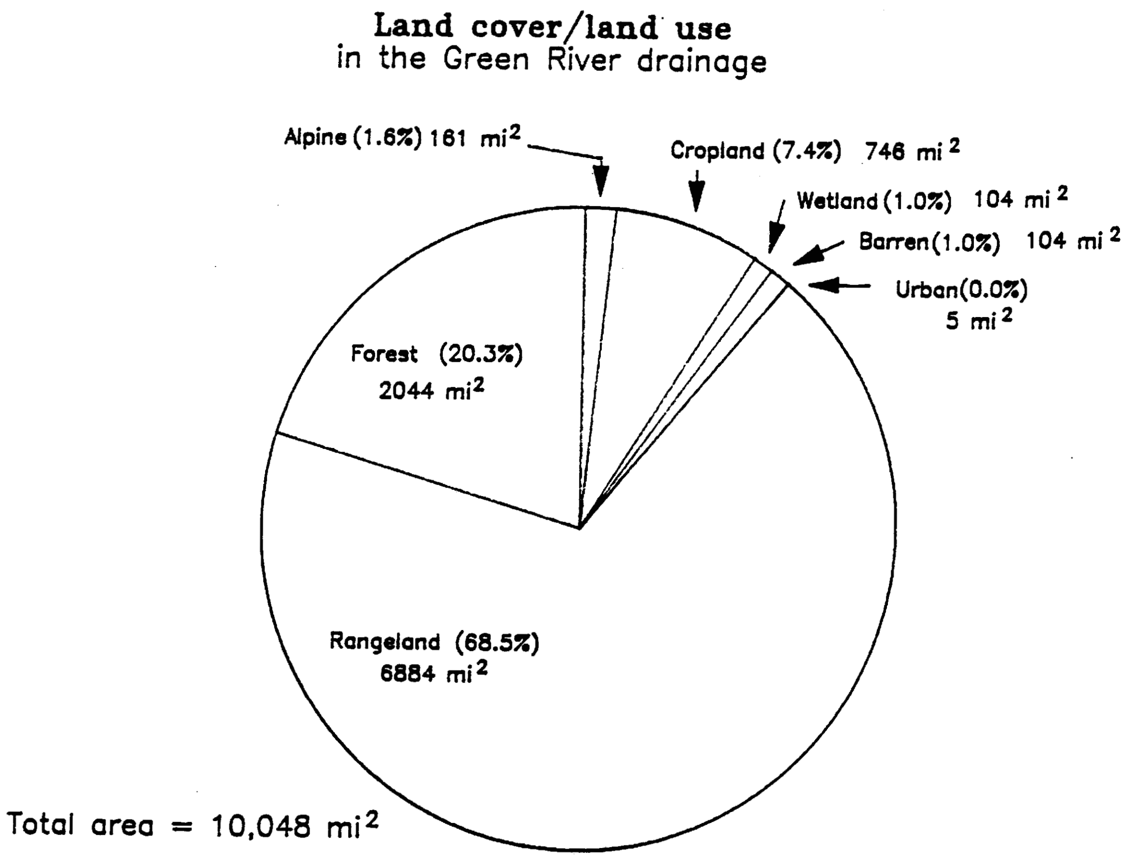

Figure 2. Land use and land cover classes in the upper Green River drainage. Both the Blacks Fork section and Green River section of the basin are included.

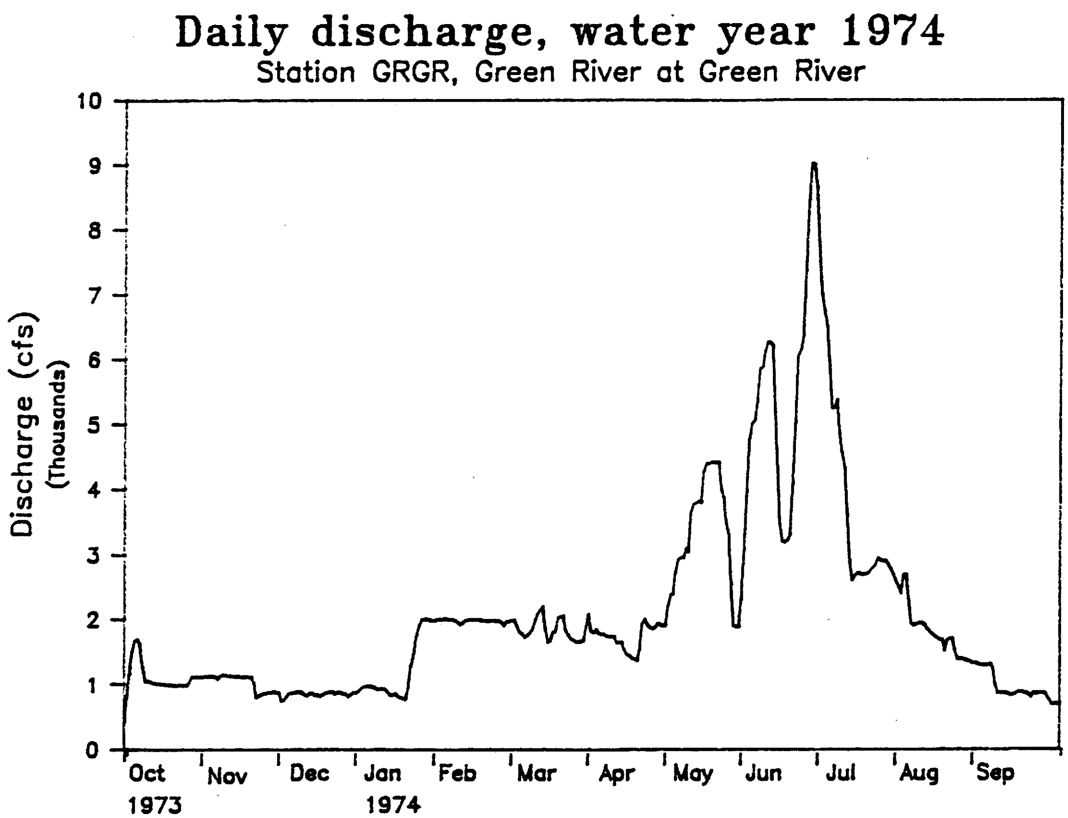

Figure 3. Daily discharge (cfs) measured at USGS station #09217000--
Green River at Green River city (GRGR) for water year 1974.

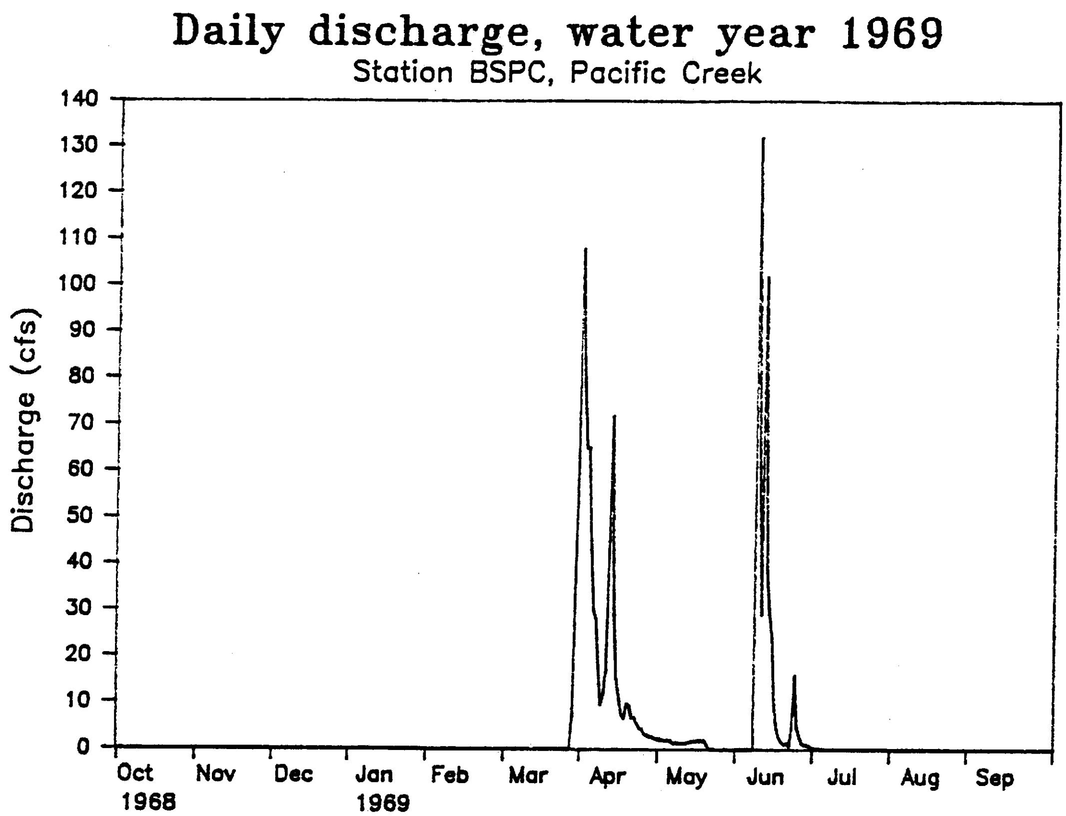

Figure 4. Daily discharge (cfs) measured at USGS station #09215000--Pacific Creek for water year 1969.

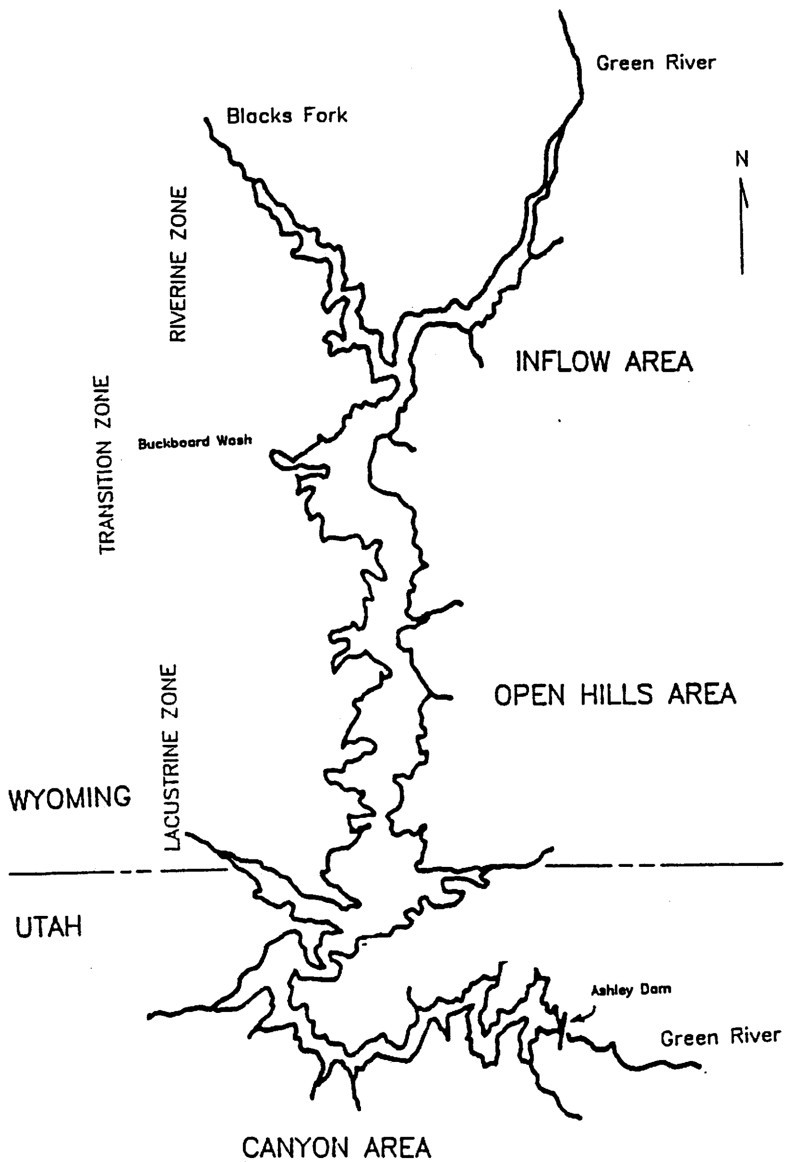

Figure 5. Outline map of Flaming Gorge Reservoir. The three longitudinal zones are illustrated at left (riverine, transition and lacustrine zones), and the three physiographic sections are labeled on the right (inflow, open hills and canyon areas).

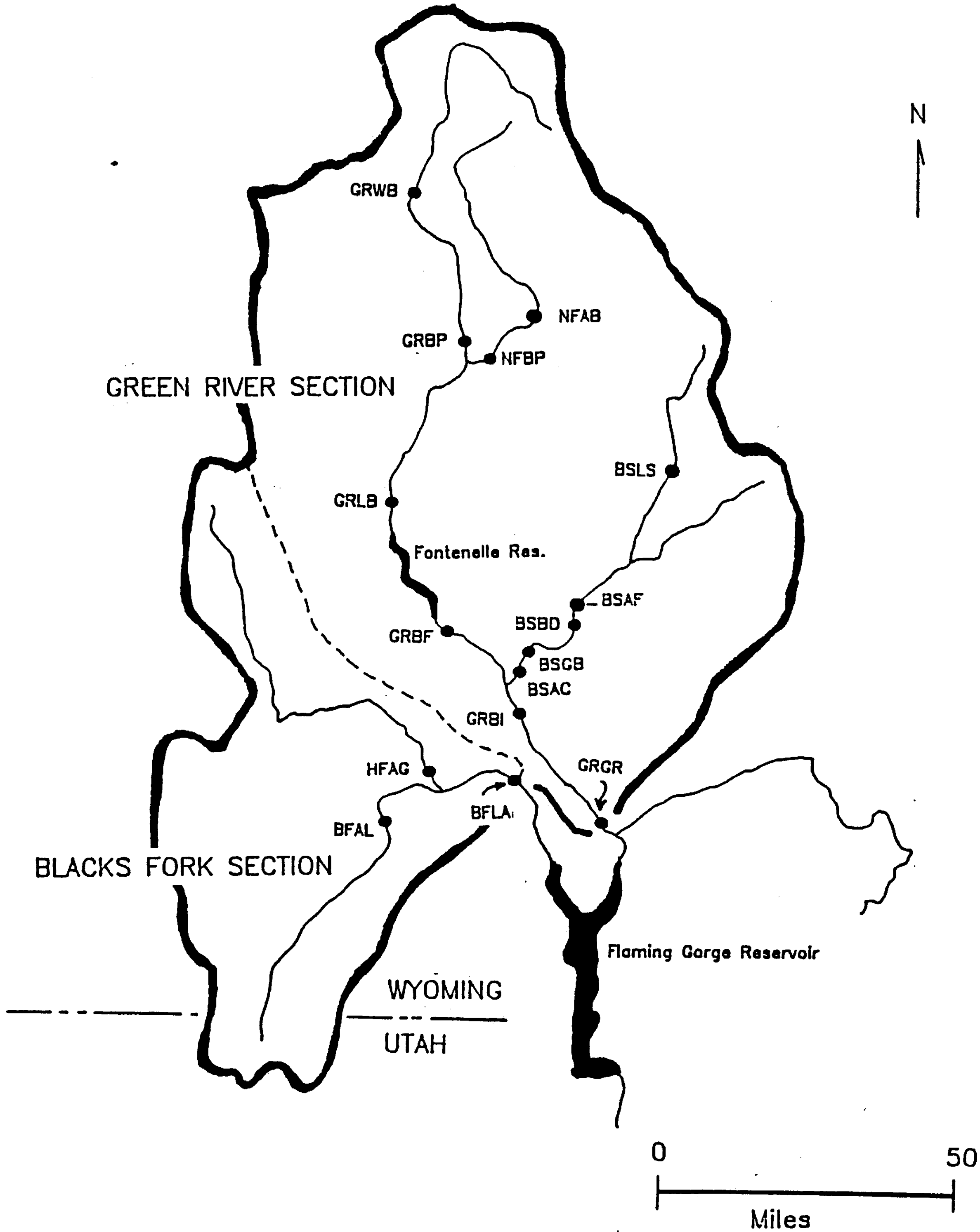

Figure 6. Location of water quality sampling stations in both the Blacks Fork and Green River sections of the Green River drainage.

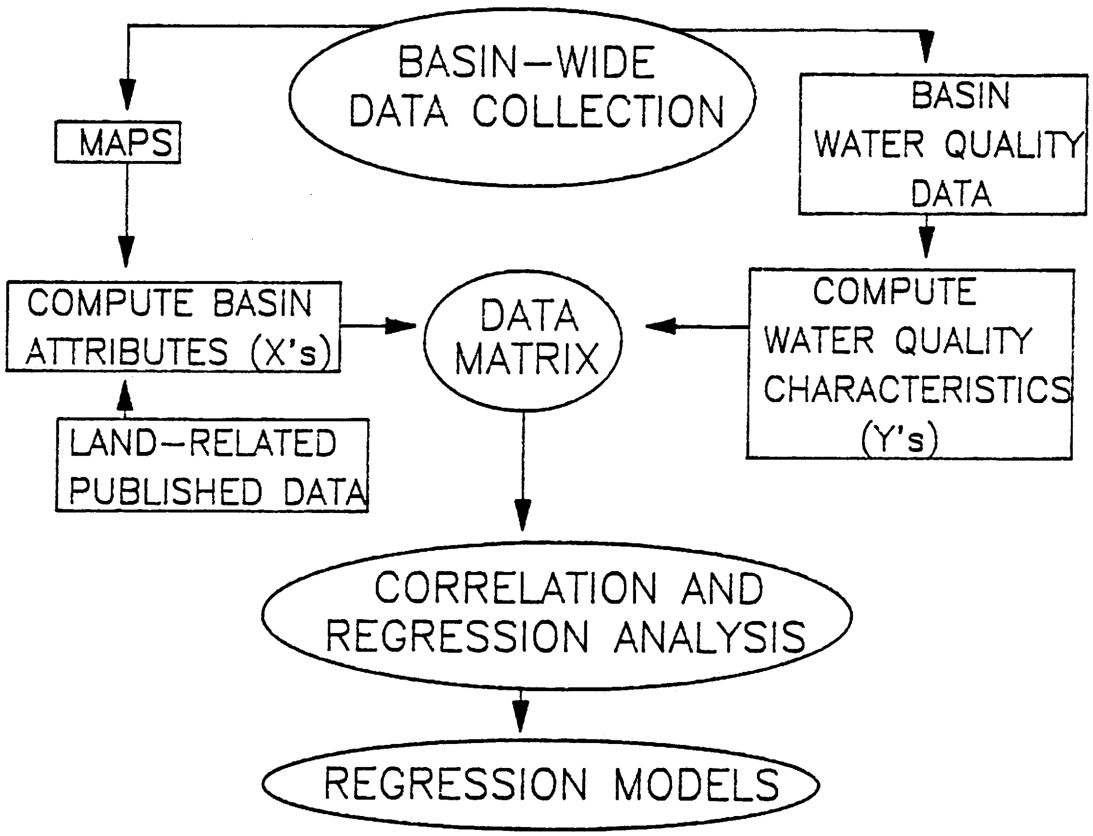

Figure 7. General scheme for modeling, by multiple regression, water quality in the Green River drainage as functions of basin attributes.

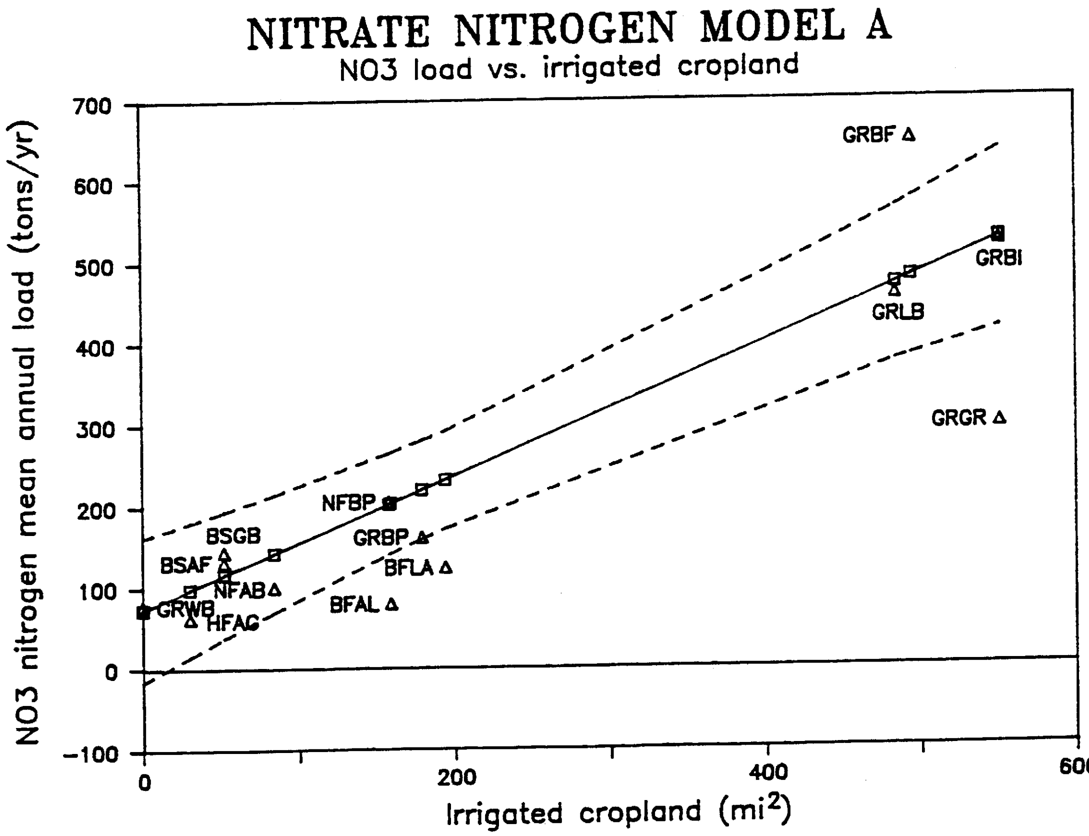

Figure 8. Nitrate-nitrogen Model A relating mean annual load of nitrate-nitrogen to the area of irrigated cropland in the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

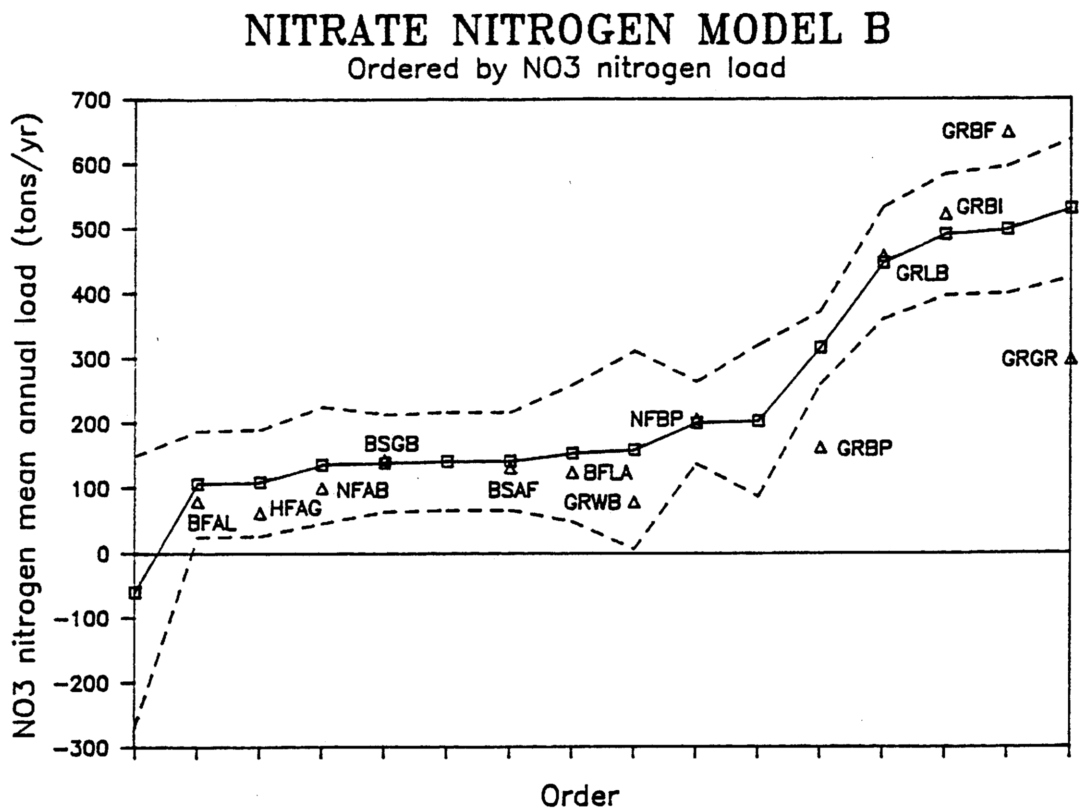

Figure 9. Nitrate-nitrogen Model B relating mean annual load of nitrate-nitrogen to alpine area and the natural log of subbasin slope in the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

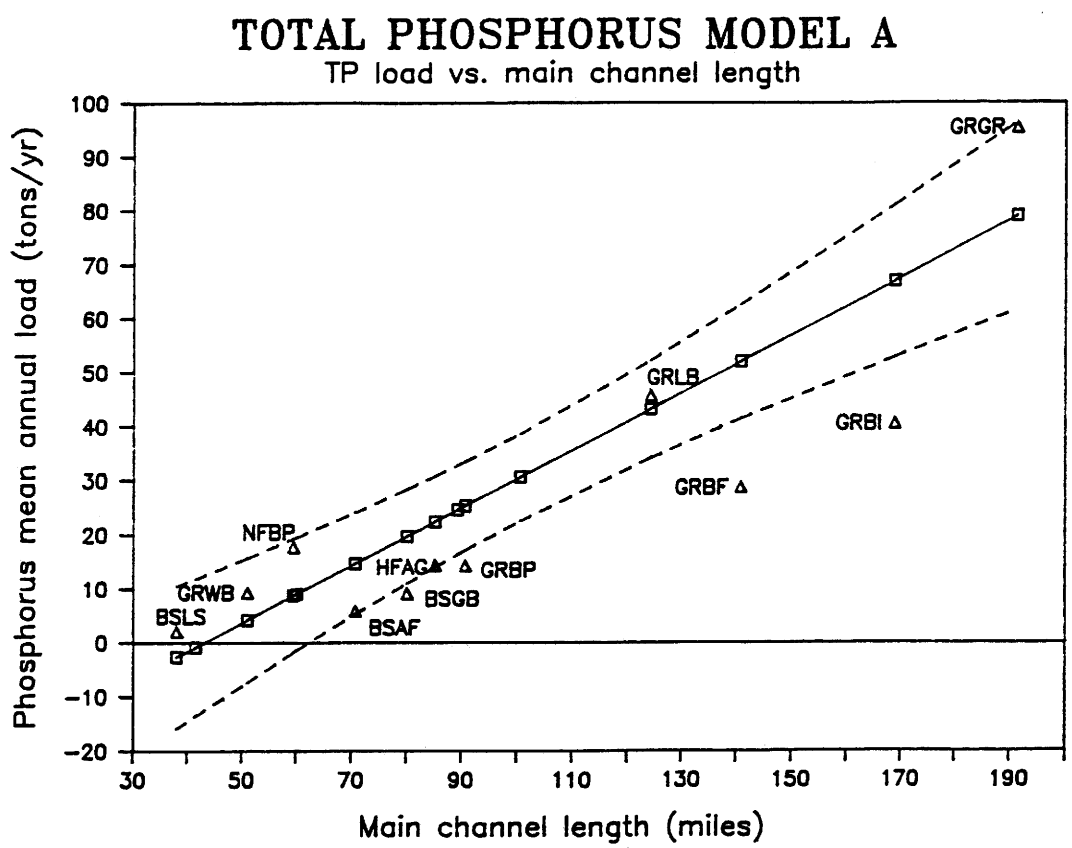

Figure 10. Total Phosphorus Model A relating mean annual load of total phosphorus to length of the main channel in subbasins of the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

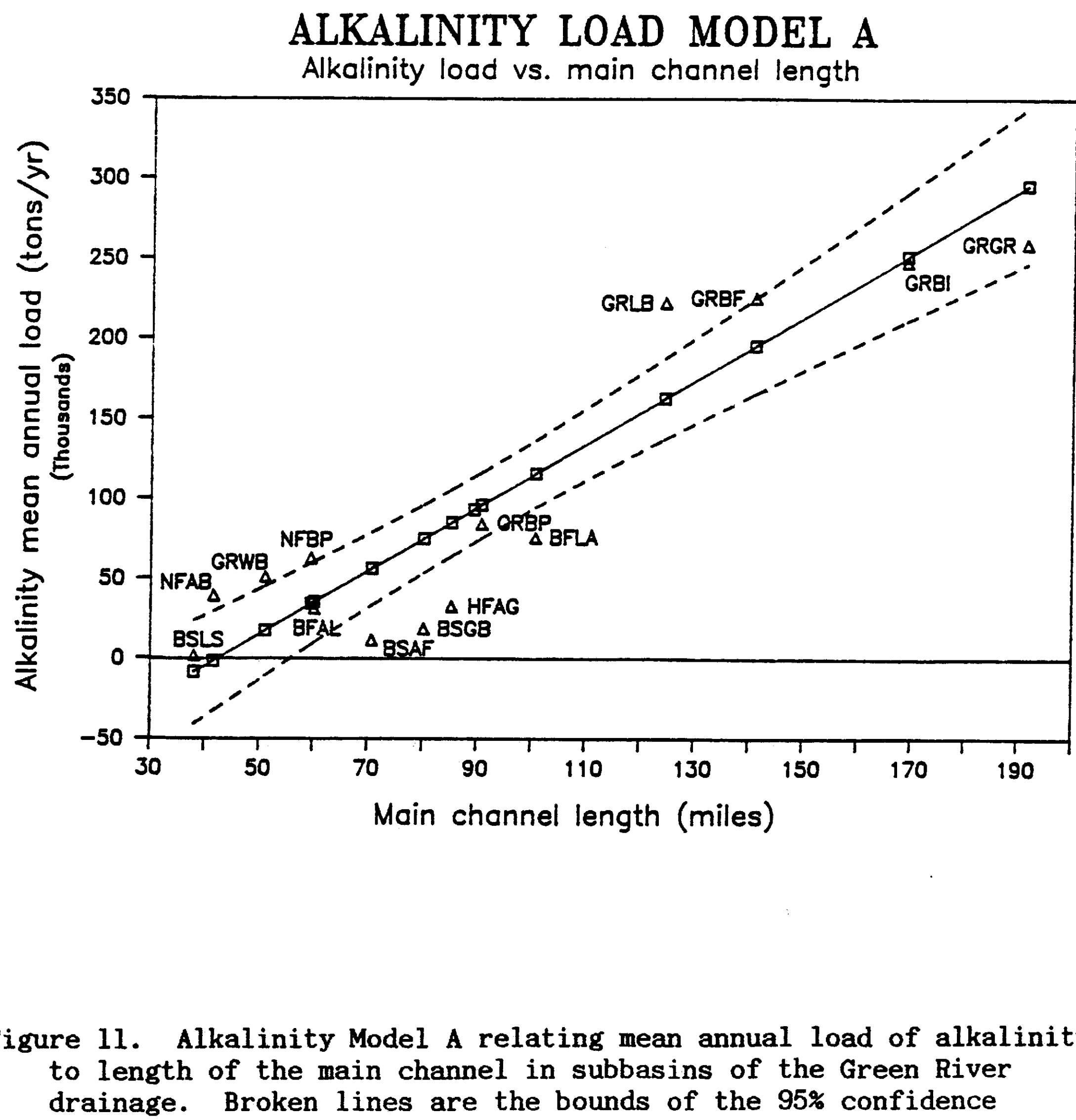

Figure 11. Alkalinity Model A relating mean annual load of alkalinity to length of the main channel in subbasins of the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

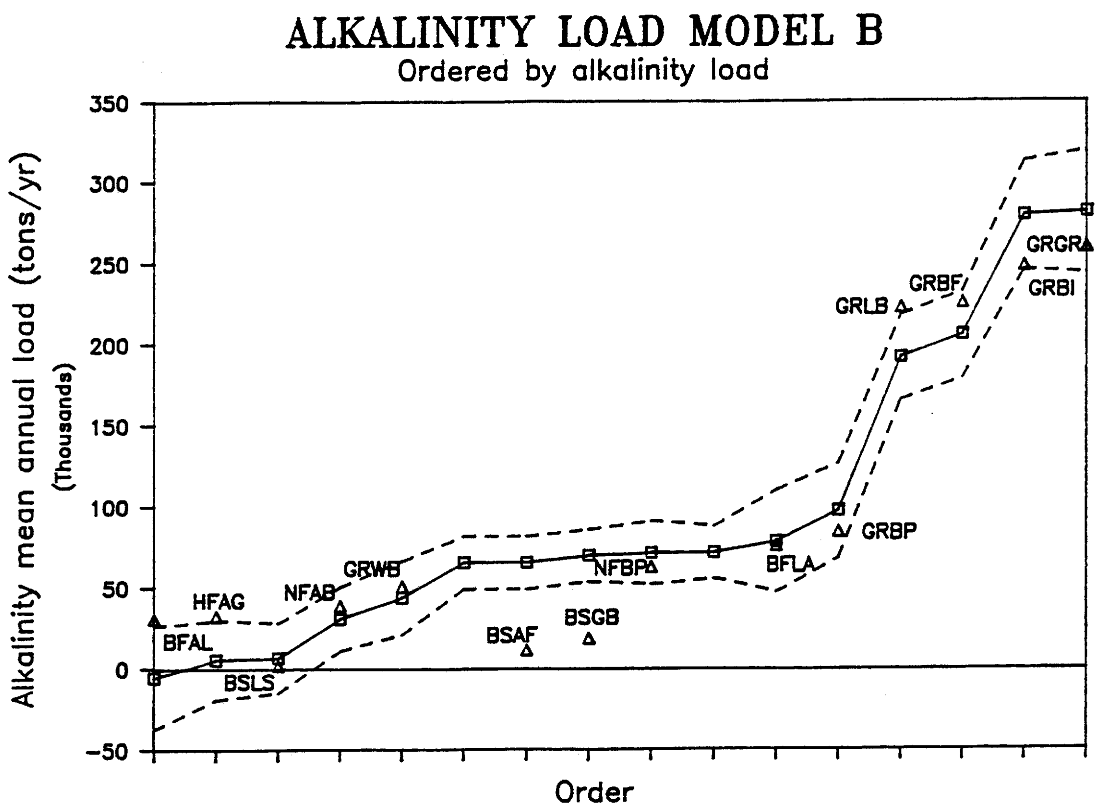

Figure 12. Alkalinity Model B relating mean annual load of alkalinity to subbasin area and a hyperbolic transformation of the January mean minimum temperature in subbasins of the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

TOTAL DISSOLVED SOLIDS MODEL A

TDS load vs. subbasin area

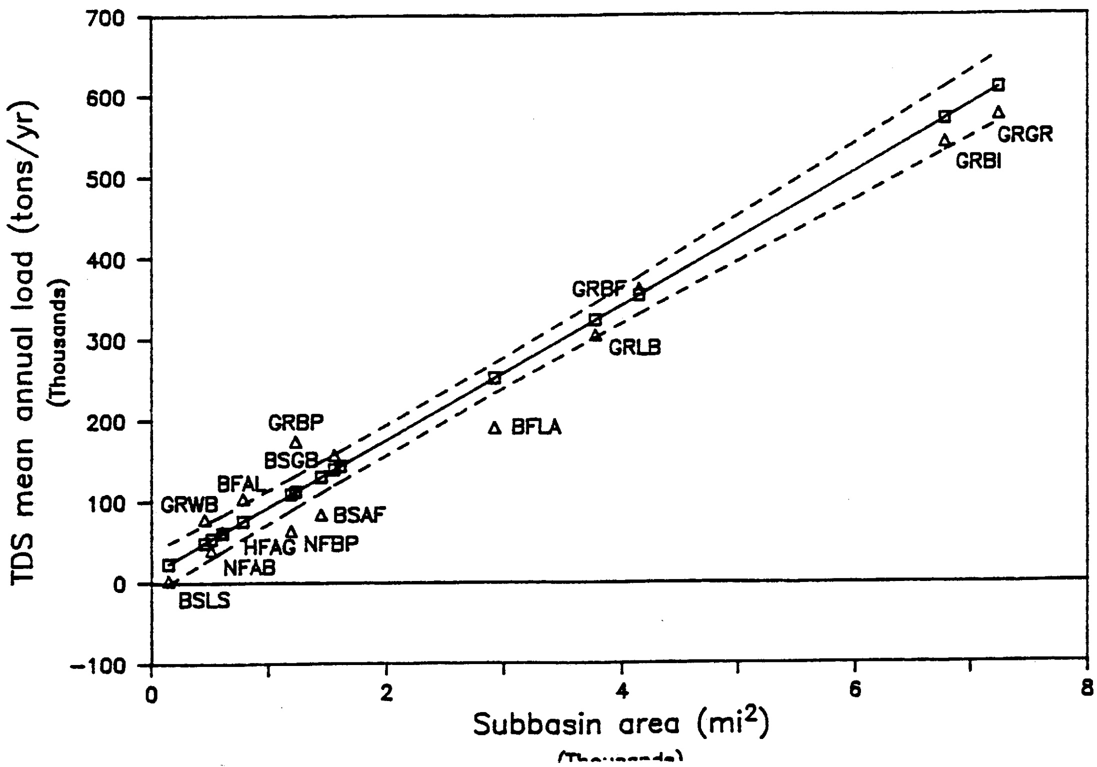

Figure 13. Total Dissolved Solids Model A relating mean annual load of dissolved solids to the area of subbasins in the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

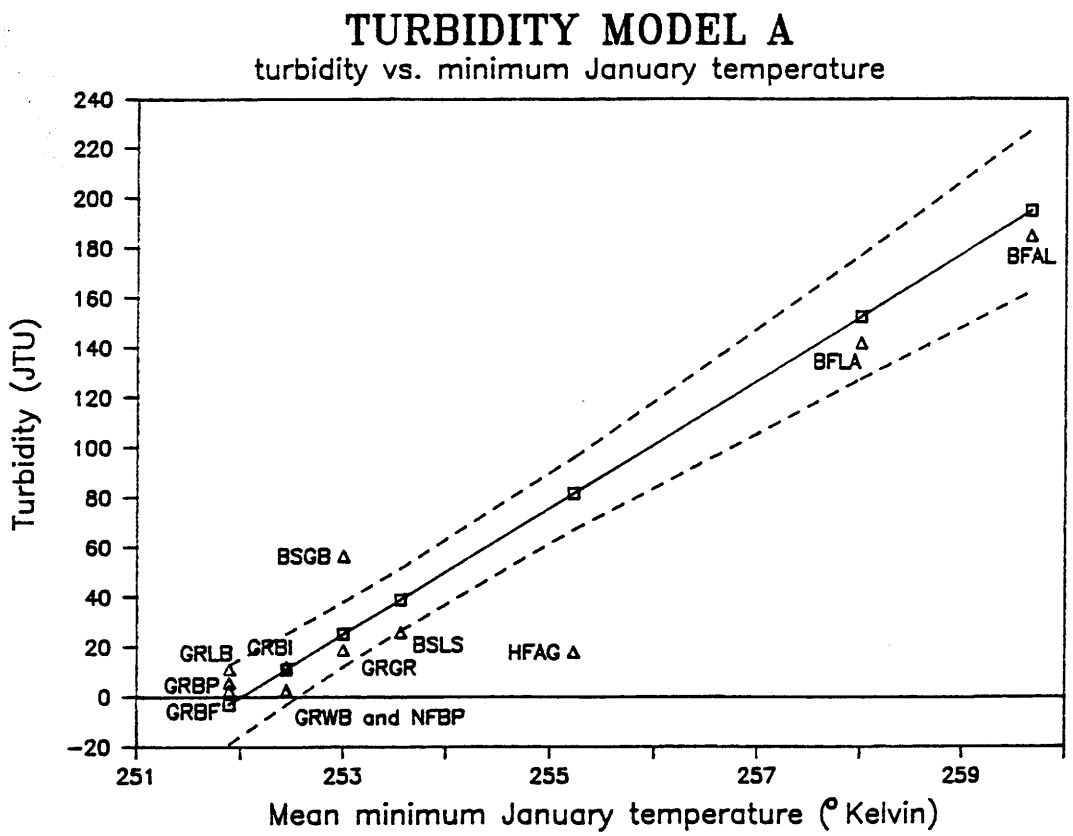

Figure 14. Turbidity Model A relating mean annual turbidity to a hyperbolic transformation of the January mean minimum temperature in subbasins of the Green River drainage. Broken lines are the bounds of the 95% confidence interval.

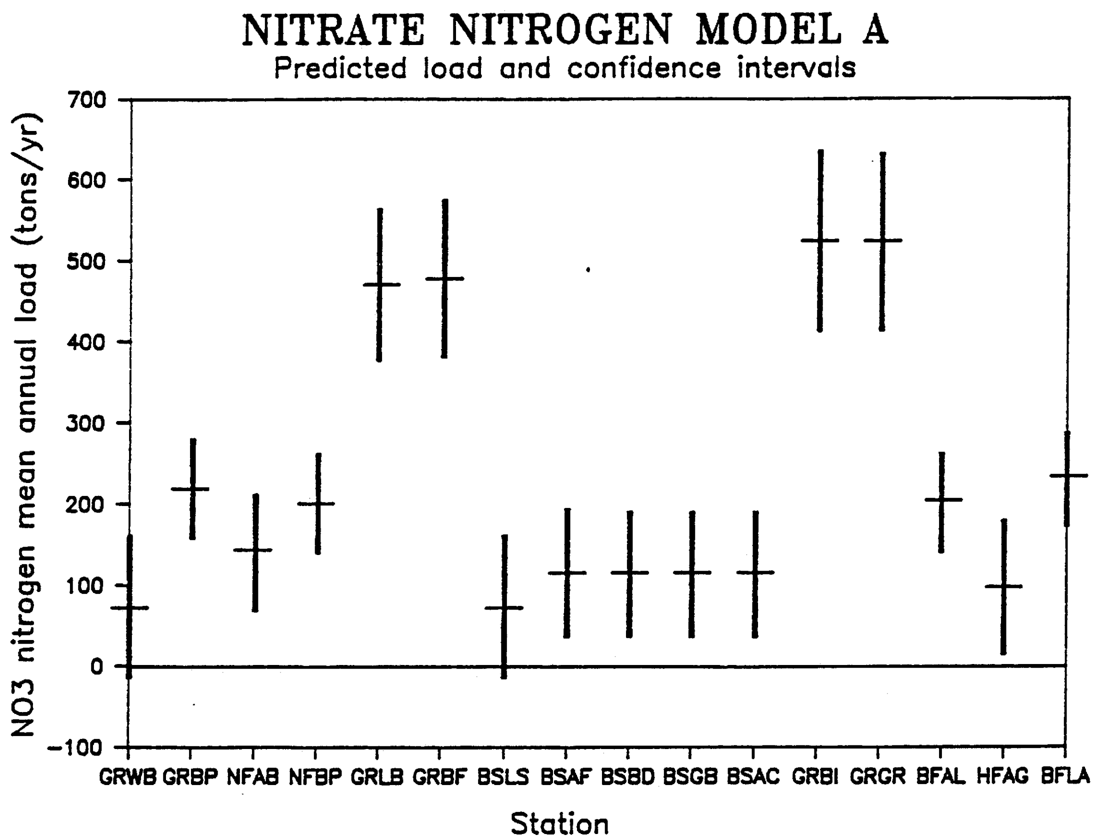

Figure 15. Mean annual loading and 95% confidence limits predicted by Nitrate-nitrogen Model A for subbasins of the Green River drainage.

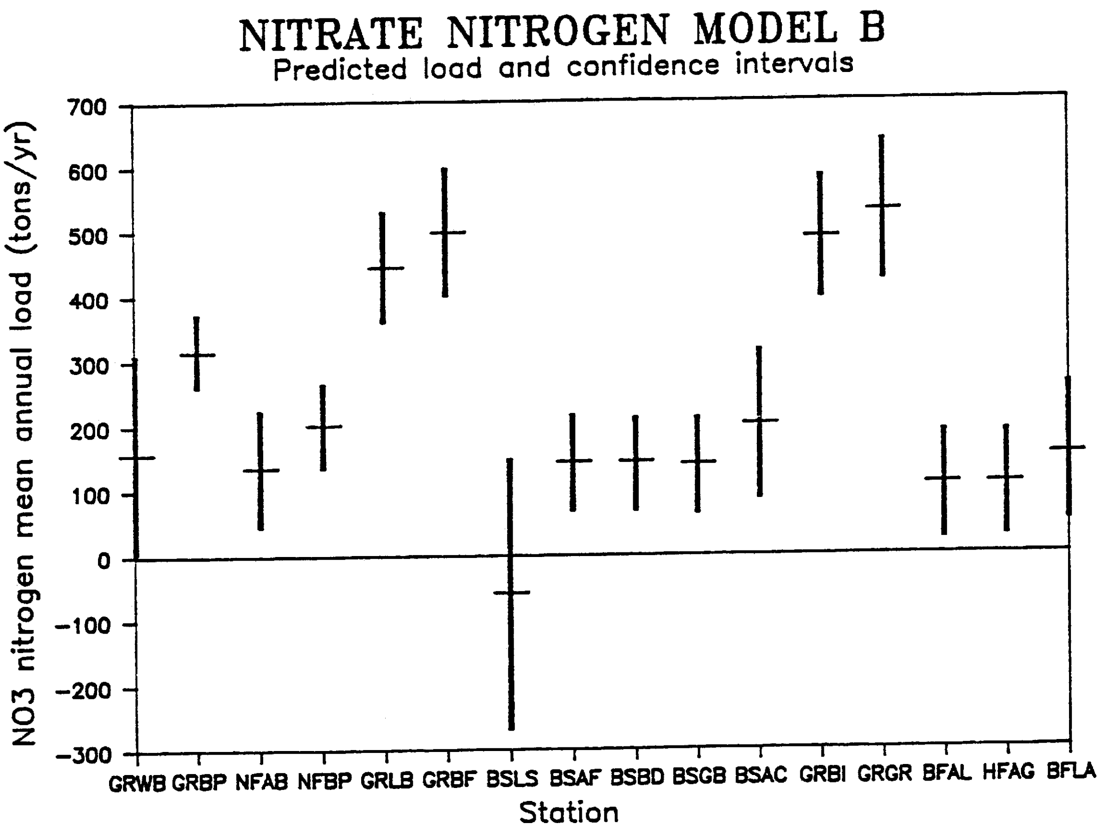

Figure 16. Mean annual loading and 95% confidence limits predicted by Nitrate-nitrogen Model B for subbasins of the Green River drainage.

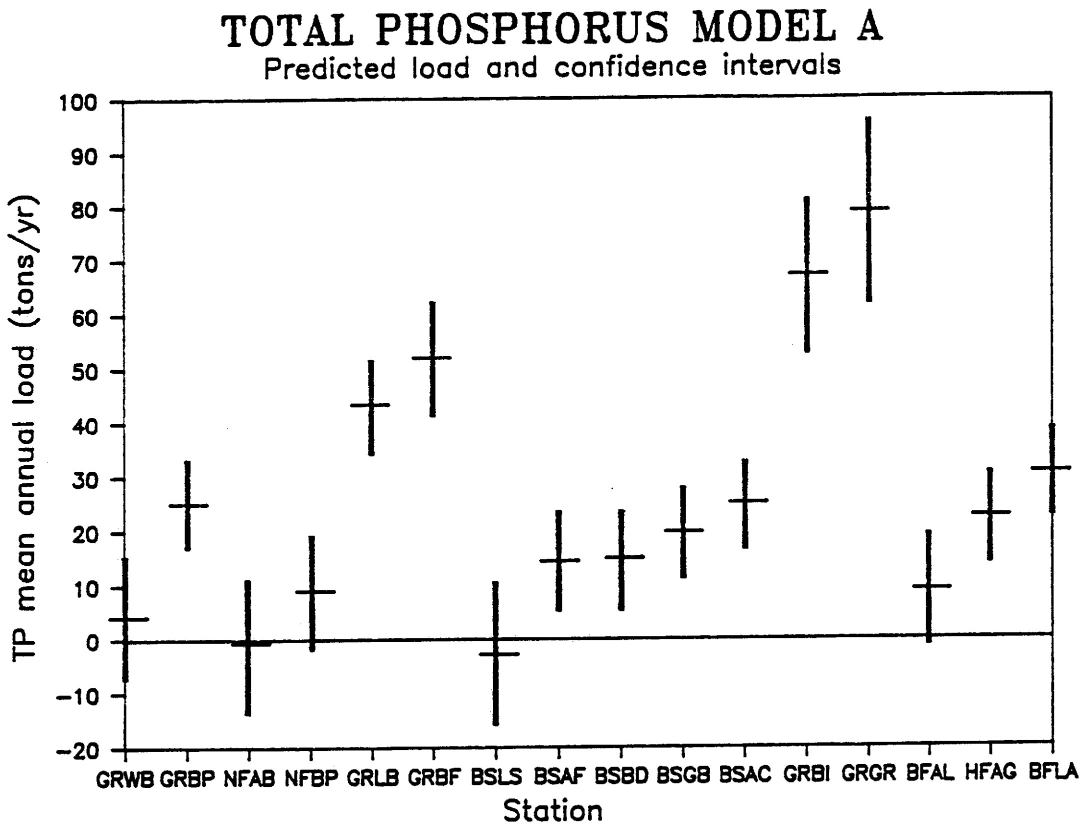

Figure 17. Mean annual loading and 95% confidence limits predicted by Total Phosphorus Model A for subbasins of the Green River drainage.

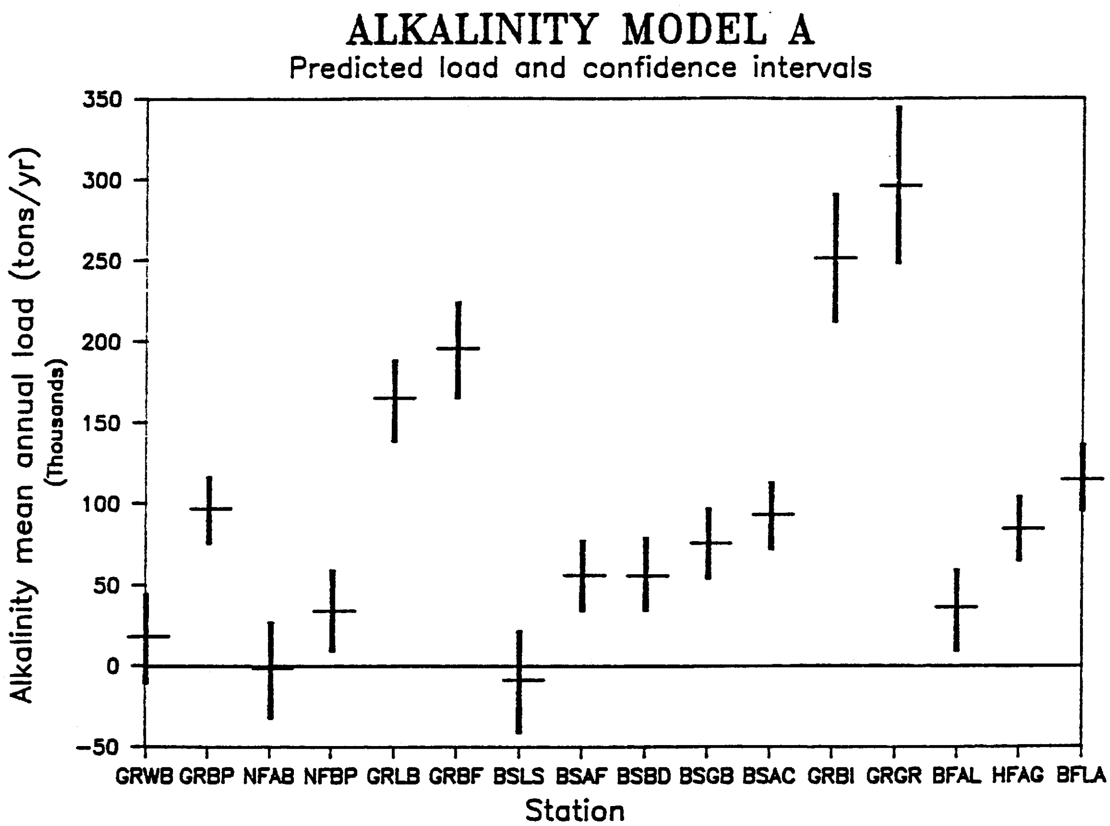

Figure 18. Mean annual loading and 95% confidence limits predicted by Alkalinity Model A for subbasins of the Green River drainage.

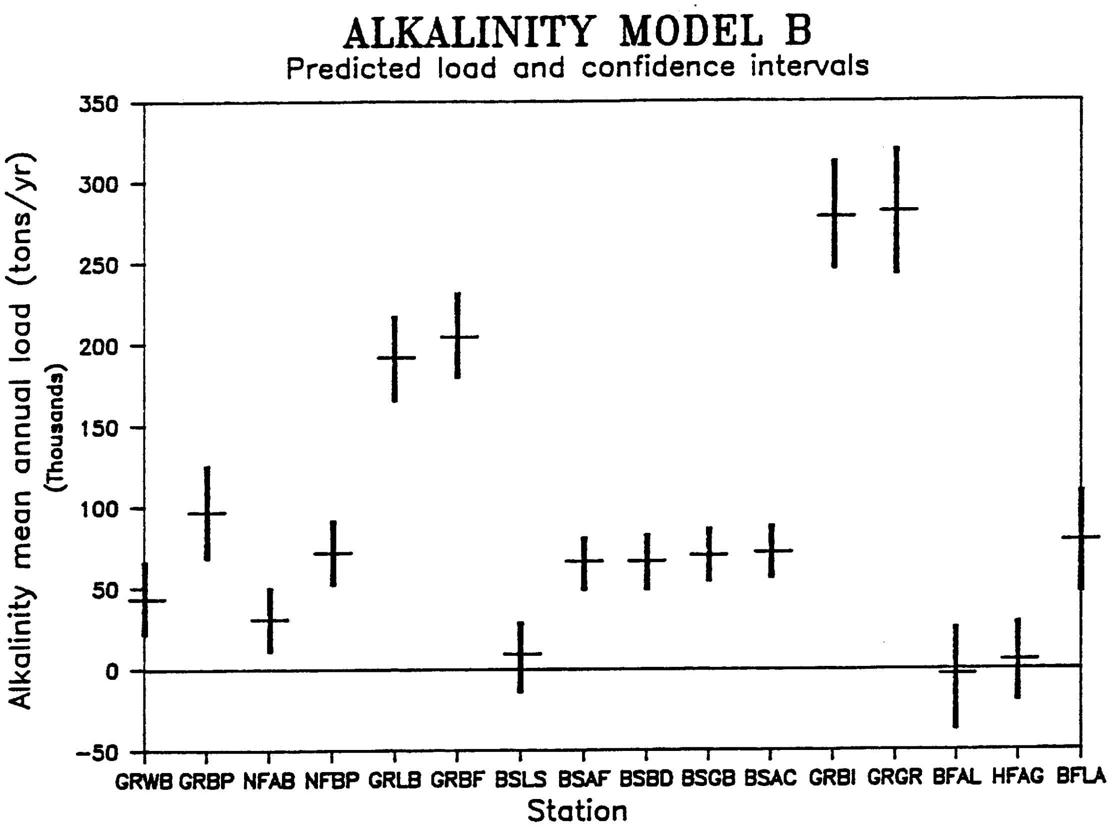

Figure 19. Mean annual loading and 95% confidence limits predicted by Alkalinity Model B for subbasins of the Green River drainage.

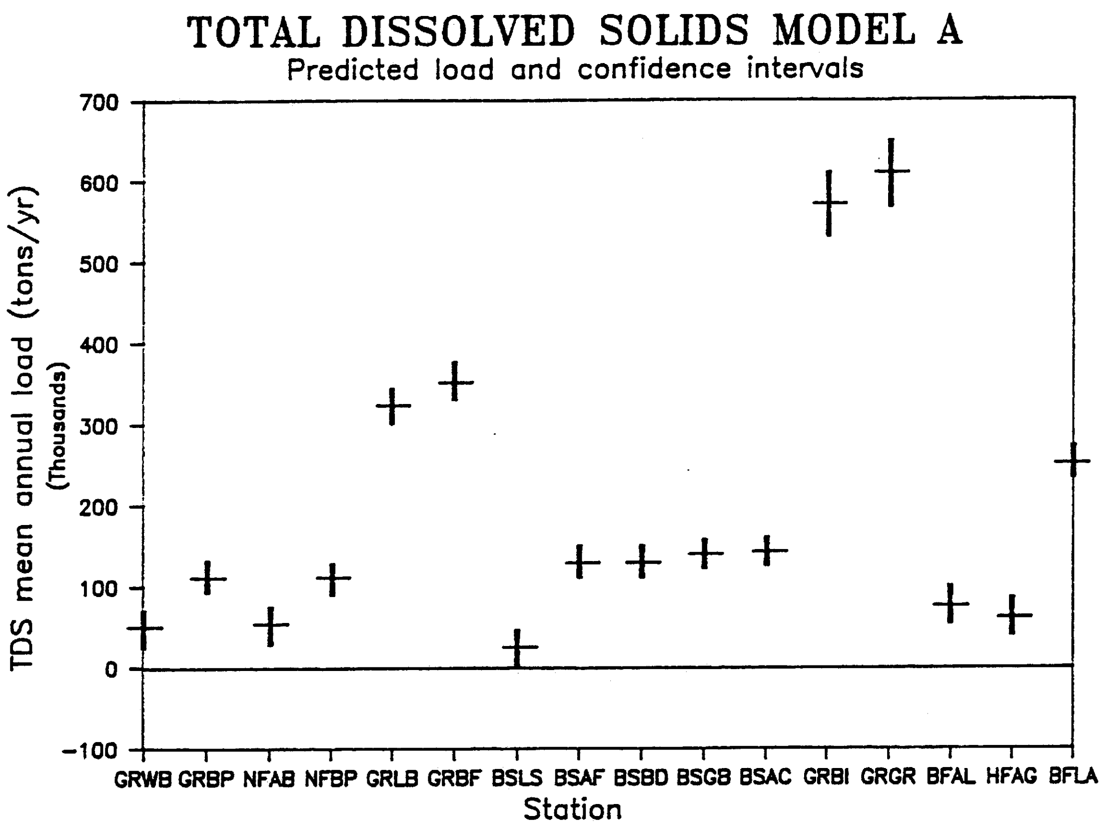

Figure 20. Mean annual loading and 95% confidence limits predicted by Total Dissolved Solids Model A for subbasins of the Green River drainage.

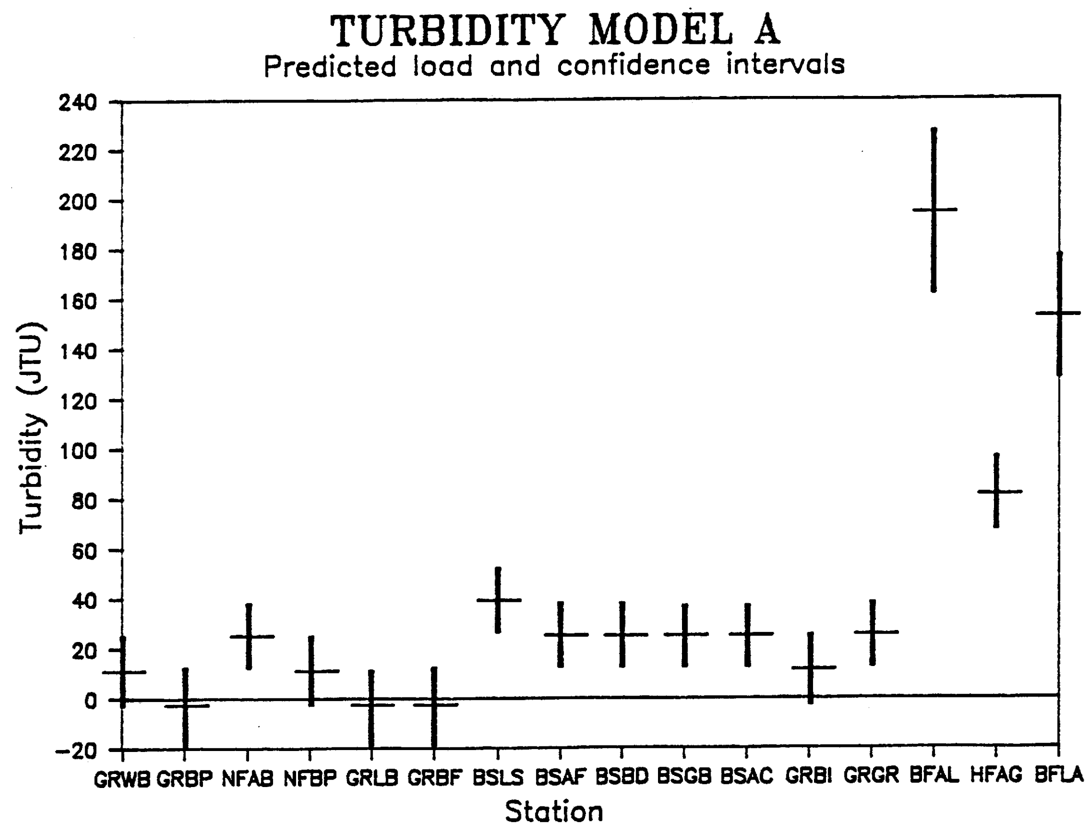

Figure 21. Mean annual turbidity and 95% confidence limits predicted by Turbidity Model A for subbasins of the Green River drainage.

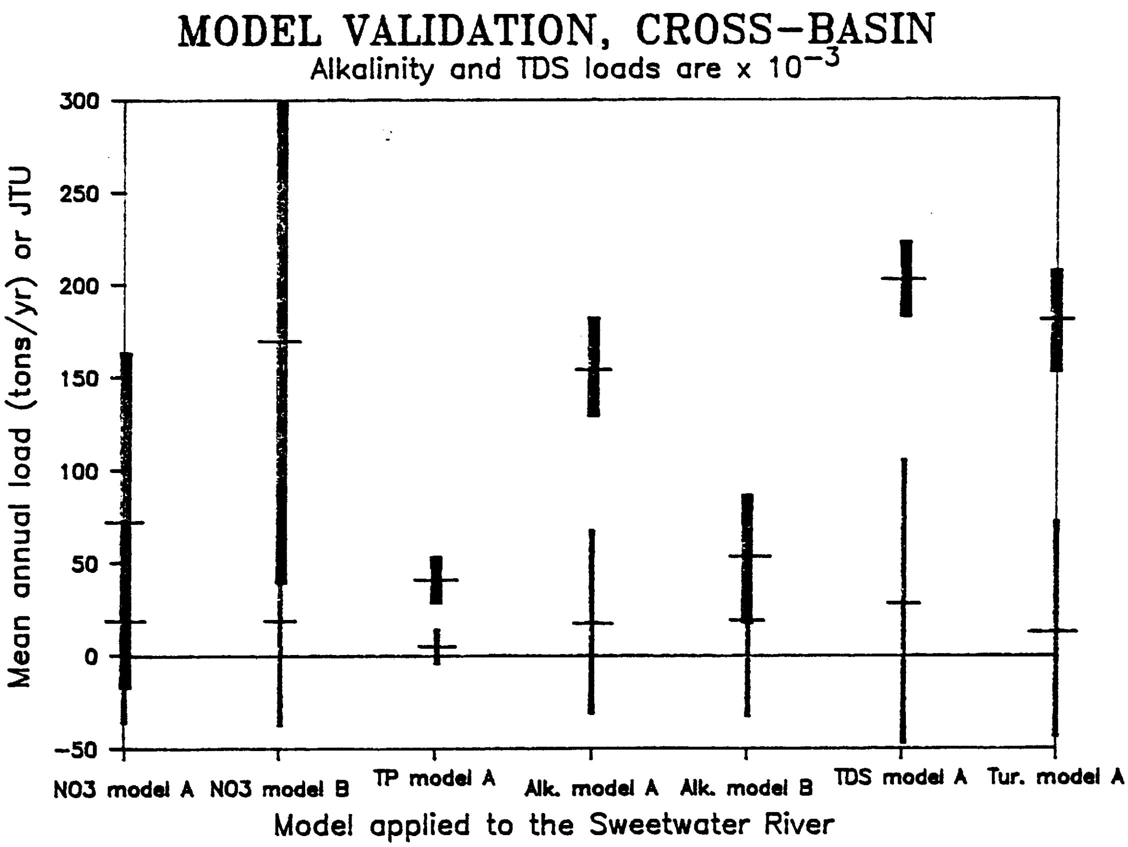

Figure 22. Cross basin validation of water quality models derived from Green River drainage data when they are applied to data from the Sweetwater River. Wide bars represent loads and turbidity, and 95% confidence intervals, predicted by water quality models derived from Green River drainage data when they are applied to data from the Sweetwater River. Narrow bars symbolize loads and turbidity, and 95% confidence intervals, observed in the Sweetwater River.

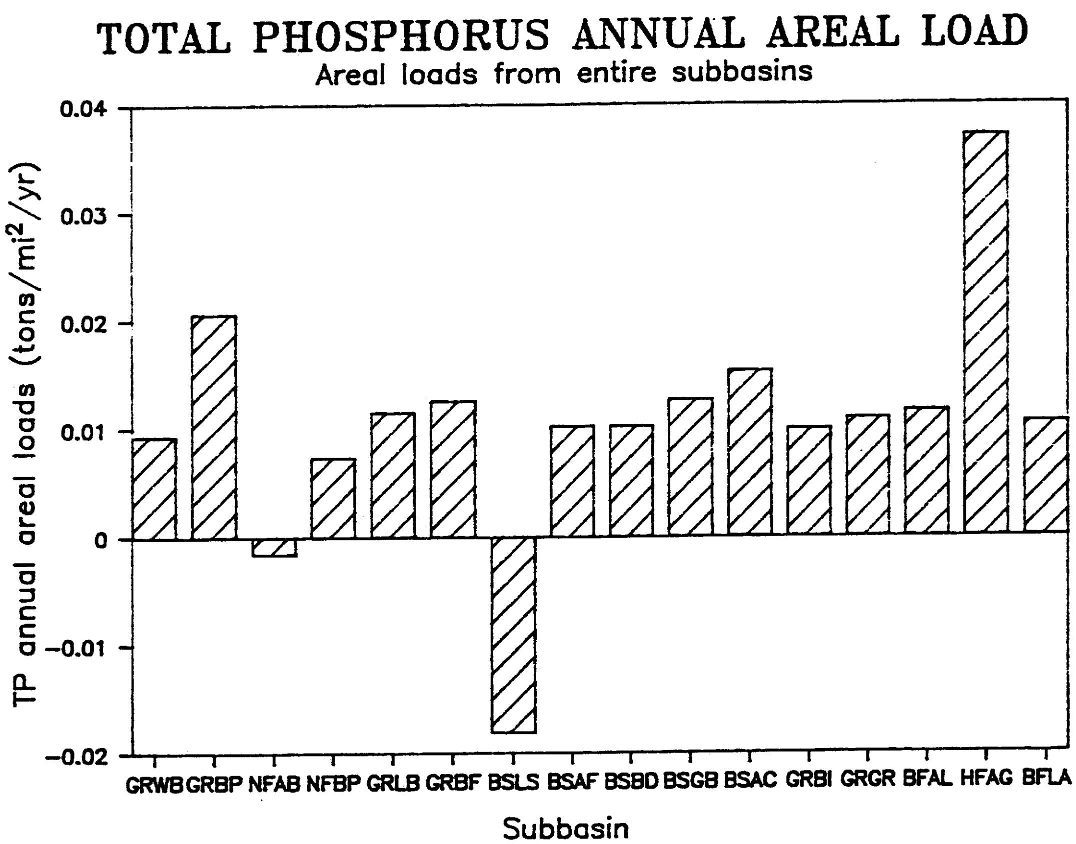

Figure 23. Annual areal load of total phosphorus exported from entire subbasins of the Green River drainage as predicted by Total Phosphorus Model A.

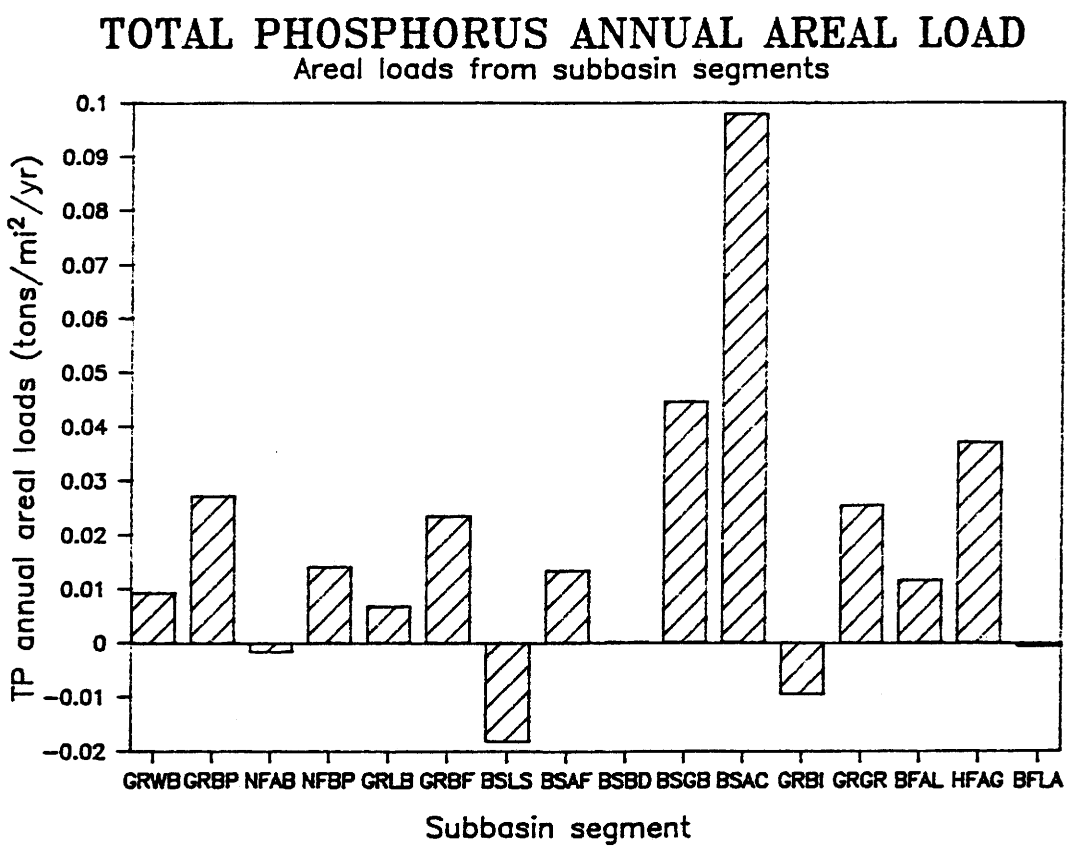

Figure 24. Annual areal load of total phosphorus in segments of streams between sampling stations as predicted by Total Phosphorus Model A in the Green River drainage.

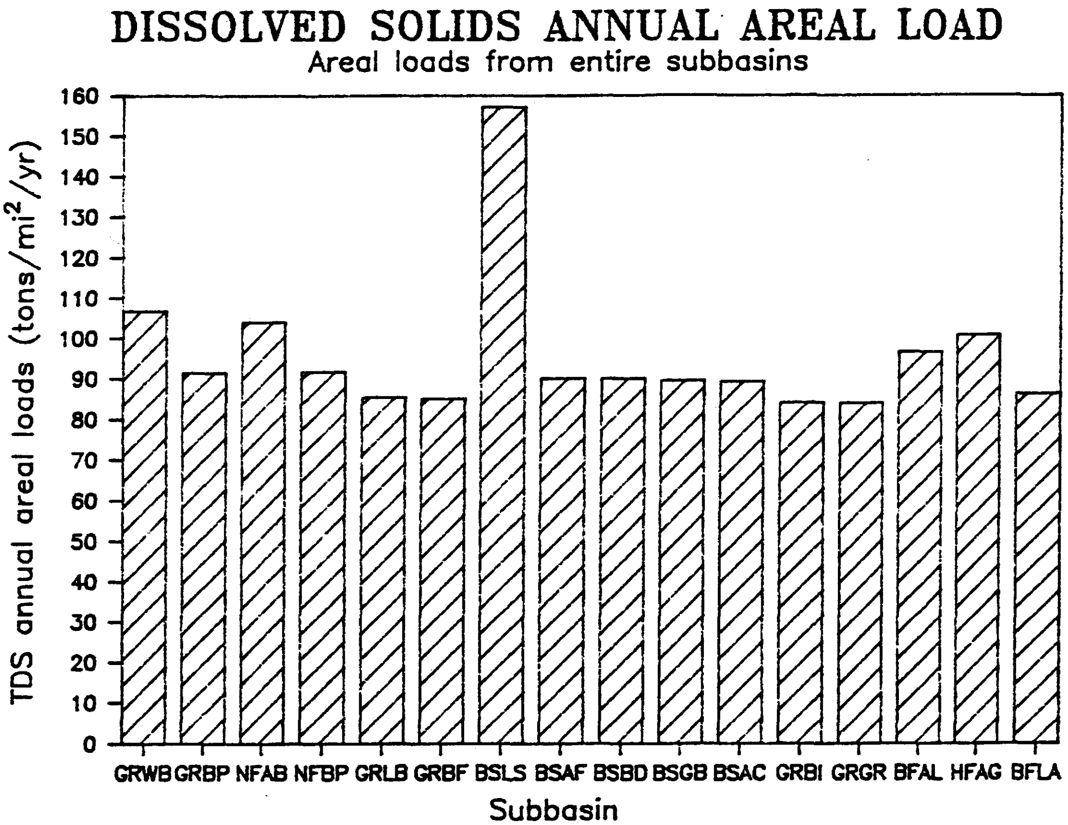

Figure 25. Annual areal load of total dissolved solids exported from entire subbasins of the Green River drainage as predicted by Total Dissolved Solids Model A.

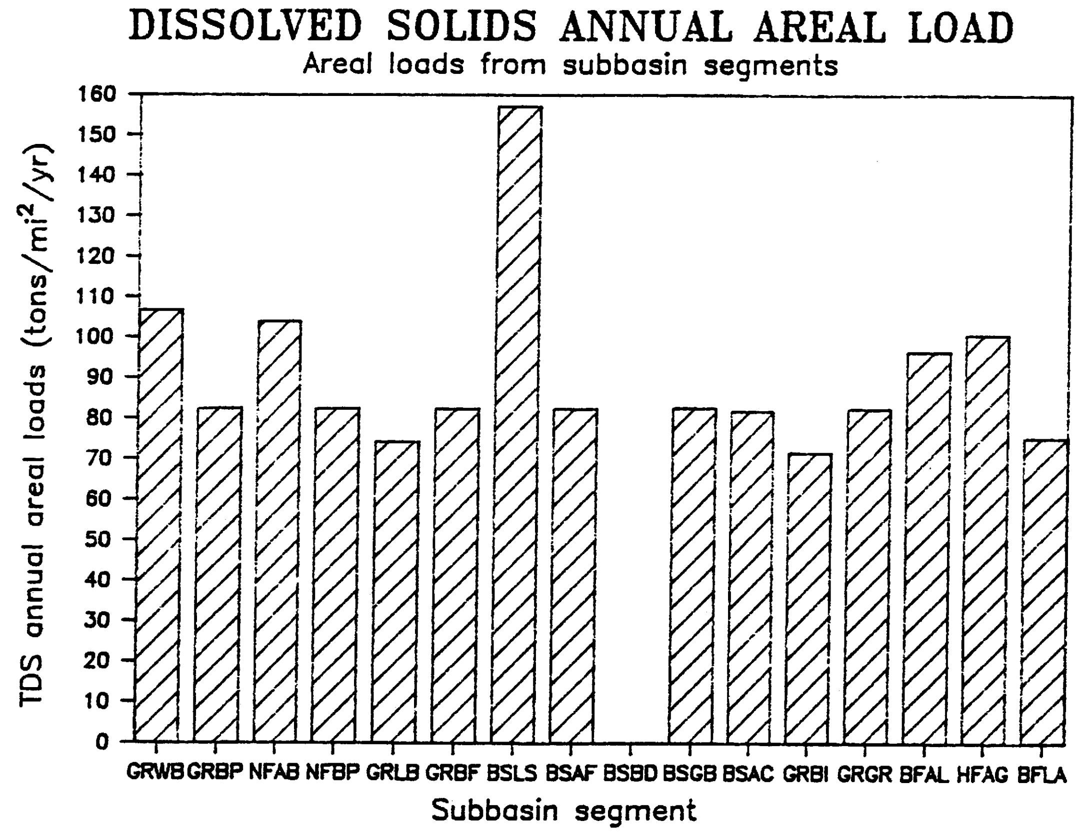

Figure 26. Annual areal load of total dissolved solids in segments of streams between sampling stations as predicted by Total Dissolved Solids Model A in the Green River drainage.

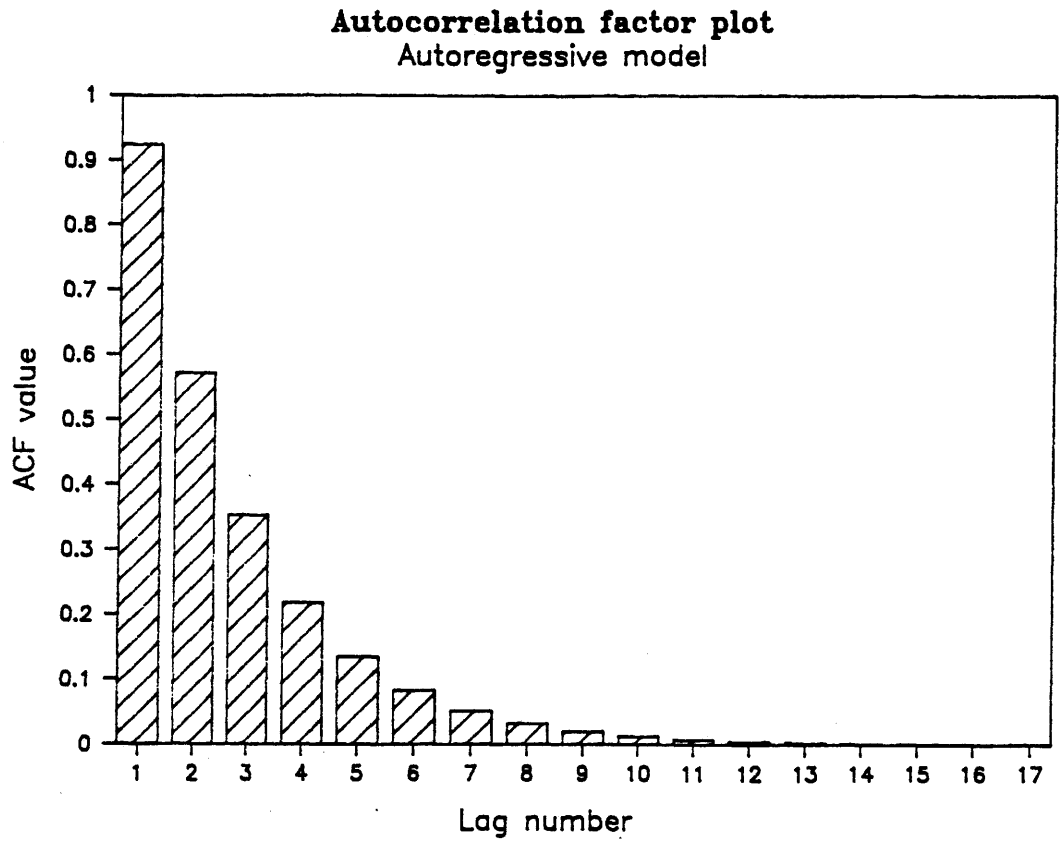

Figure 27a. Autocorrelation factor plot typical of autoregressive time series models.

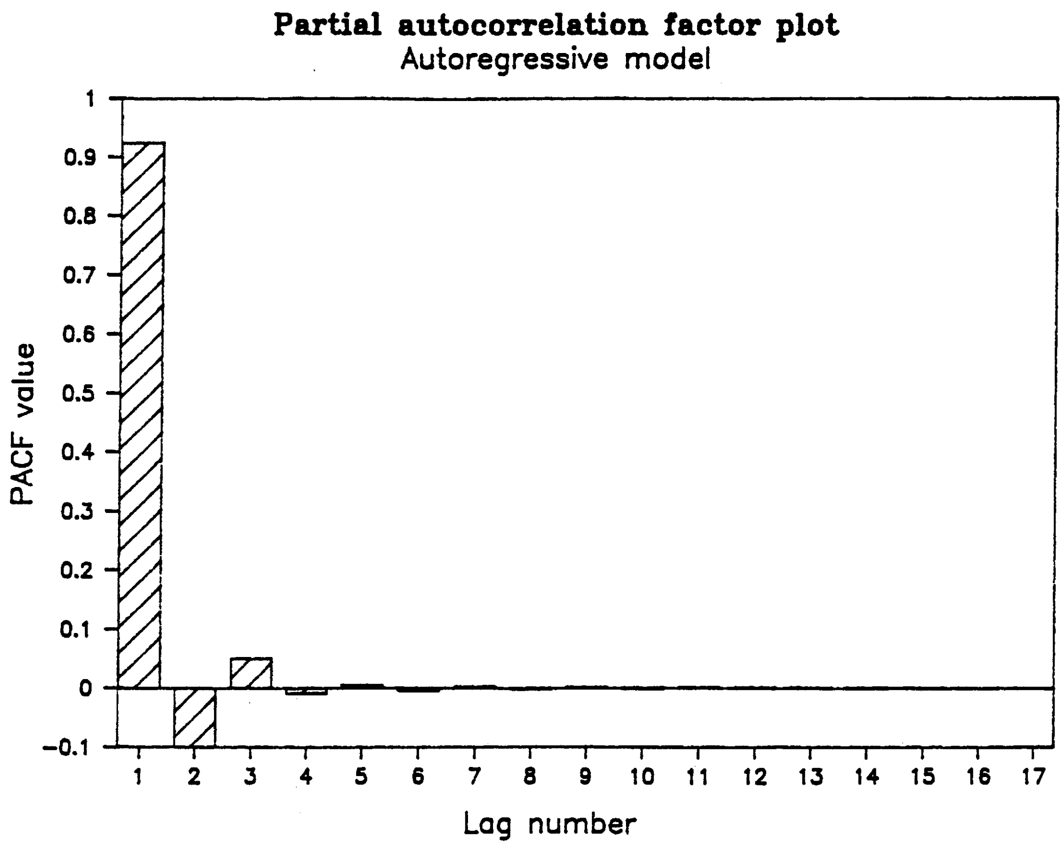

Figure 27b. Partial autocorrelation factor plot typical of autoregressive time series models.

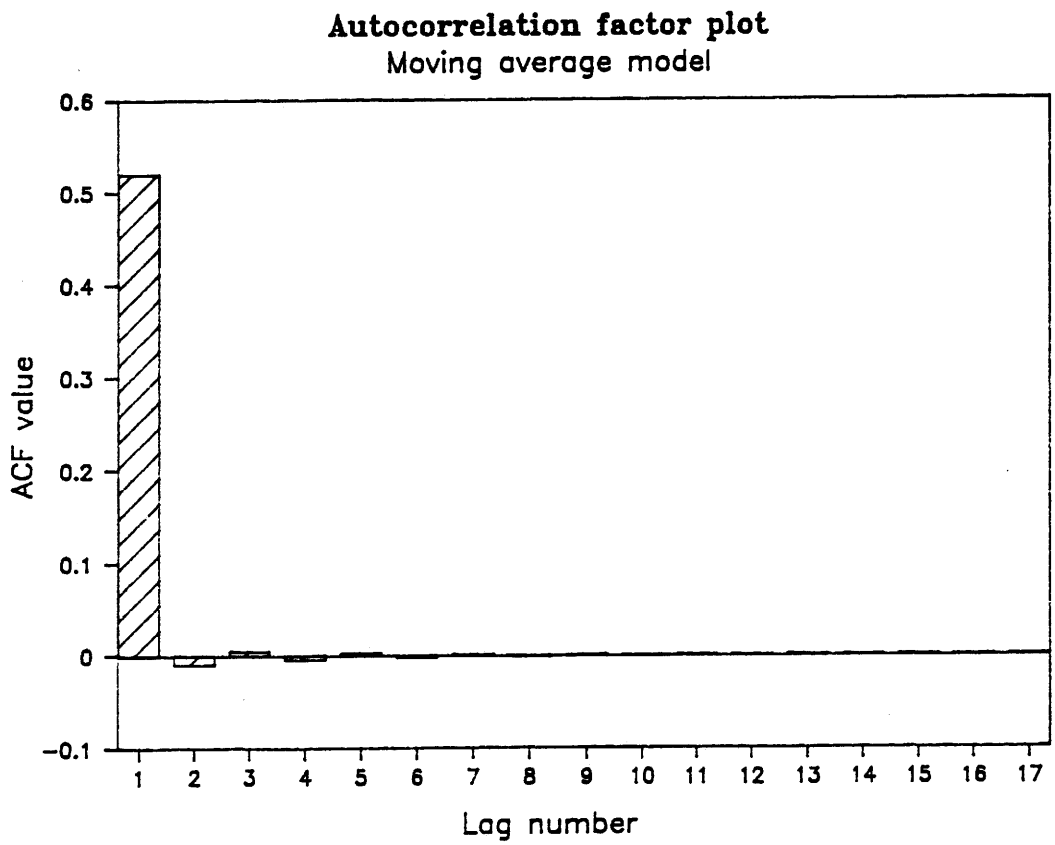

Figure 28a. Autocorrelation factor plot typical of moving average time series models.

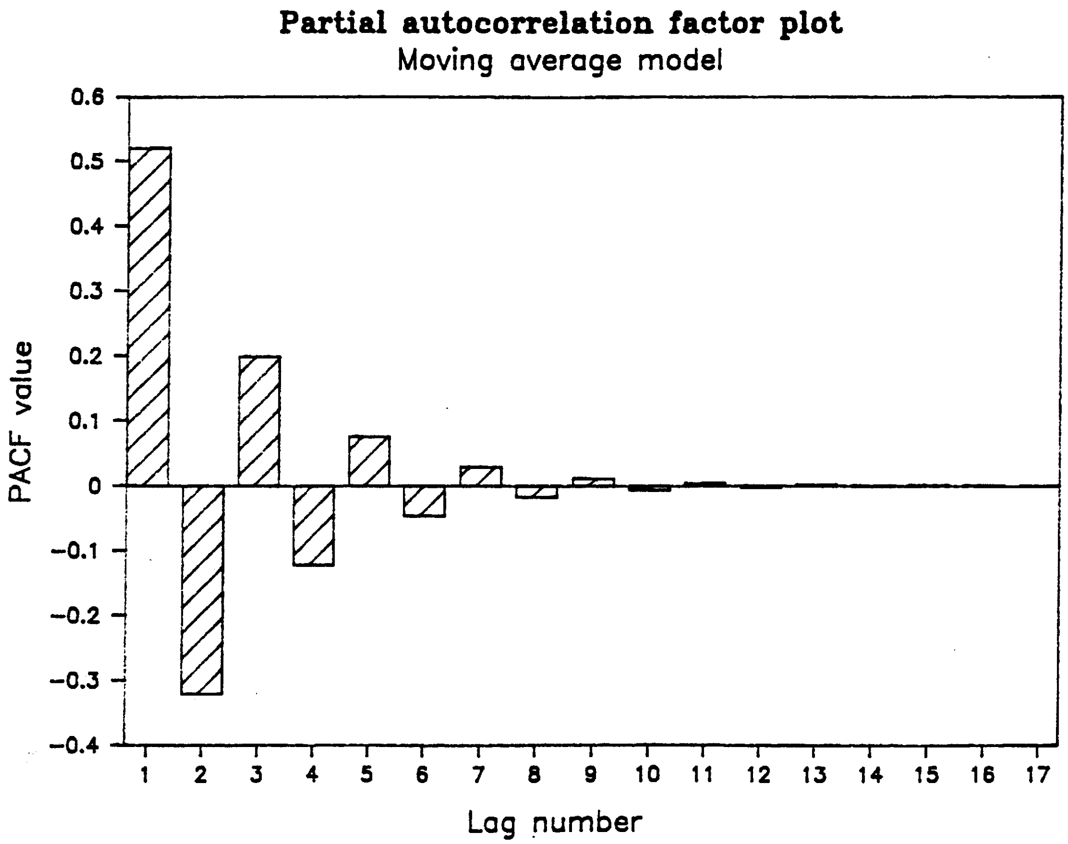

Figure 28b. Partial autocorrelation factor plot typical of moving average time series models.

```
                                        INDIVIDUAL 95 PCT CI'S FOR
 WATER      MEAN OF                         MEANS OF RESIDUALS
  YEAR     RESIDUALS    STDEV     ---------+---------+---------+-------

  1966      0.32263    1.44912          (--------*--------)
  1967      0.37303    1.30885            (-------*--------)
  1968      0.48731    2.57606              (--------*--------)
  1969      0.67908    2.44794                  (--------*-------)
  1970      0.13328    0.62967       (--------*-------)
  1971      0.19944    0.69516        (--------*--------)
  1972      0.72160    3.11637                   (-------*--------)
  1973      0.32995    1.19056           (--------*-------)
  1974      0.13945    0.24874       (--------*--------)
  1975      0.10398    0.41179      (--------*--------)
  1976      0.13516    0.40987       (--------*--------)
  1977      0.02307    0.11743     (-------*--------)
  1978      0.51930    2.77330               (-------*--------)
  1979      0.03101    0.06298     (--------*-------)

                                  ---------+---------+---------+-------
                                         0.00      0.50      1.00
```

Figure 29. Means and 95% confidence limits of the residuals between observed yearly total phosphorus loads (tons/yr) and those predicted by time series modeling. Overlapping confidence intervals indicate no significant difference (p = 0.05) between the residuals, and that the model fits the years with such overlap equally well.

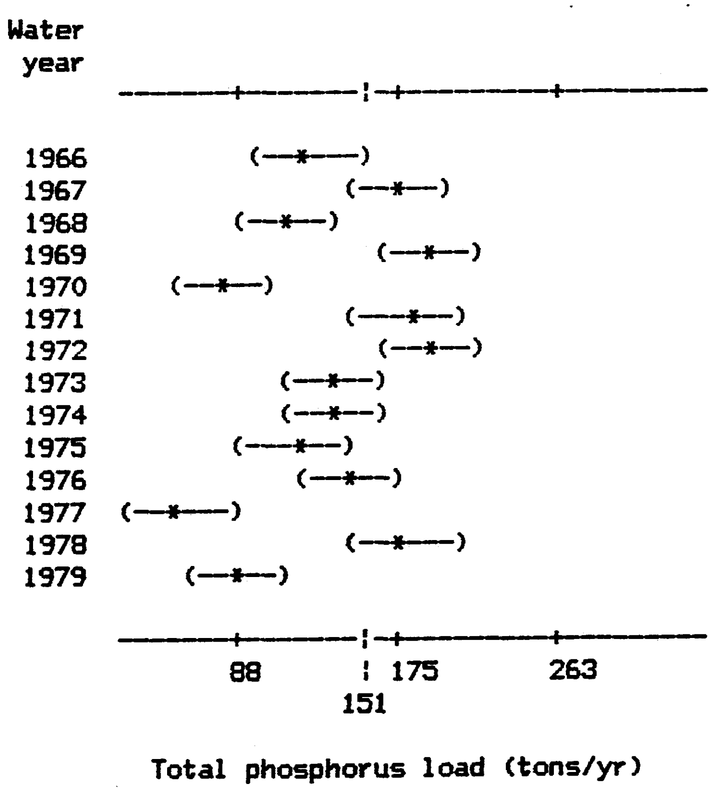

Figure 30. Means and 95% confidence limits of the annual total phosphorus load predicted by time series modeling. Overlapping confidence intervals indicate no significant difference ($p = 0.05$) between the means of years with such overlap. The mean annual TP load from 15 years of daily data is 151 tons/yr.

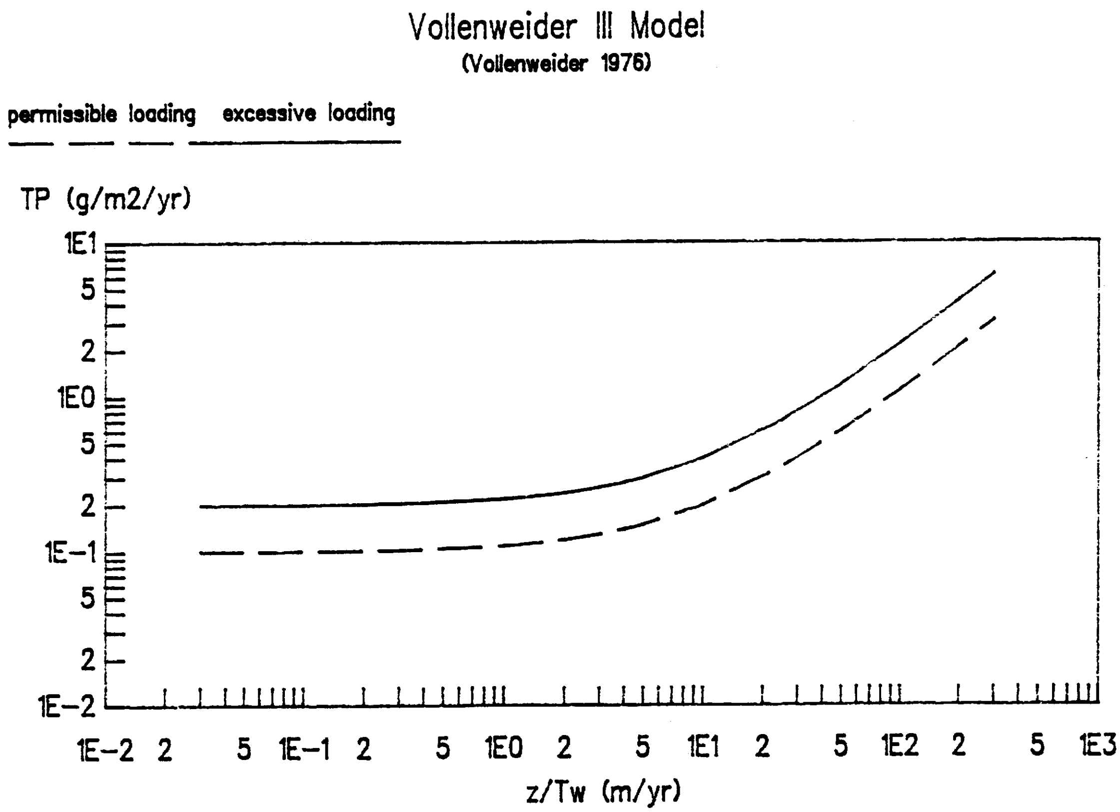

Figure 31. The Vollenweider III model of excessive and permissible phosphorus loading to a waterbody.

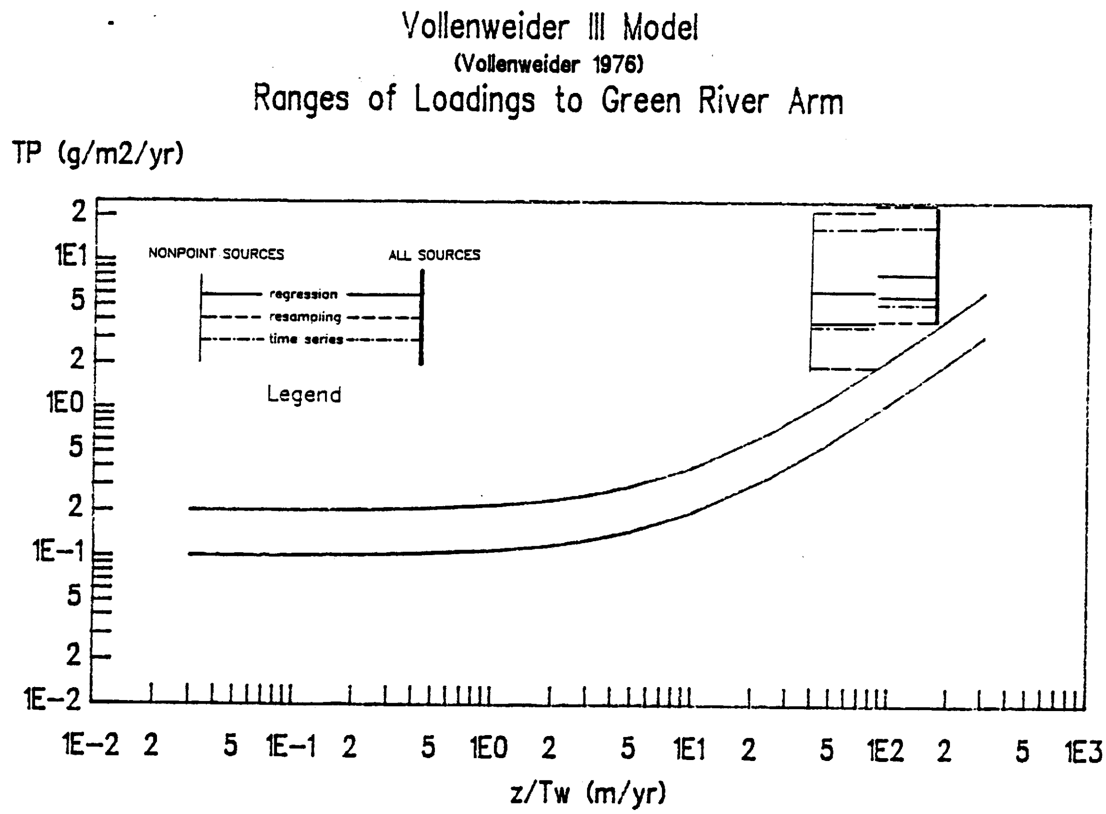

Figure 32a. Annual areal total phosphorus loads ($g/m^2/yr$) estimated by all methods in this report, compared to the excessive and permissible loads predicted for the Green River Arm of Flaming Gorge Reservoir by the Vollenweider III model.

Vollenweider III Model
(Vollenweider 1976)
Ranges of Loadings to Buckboard section

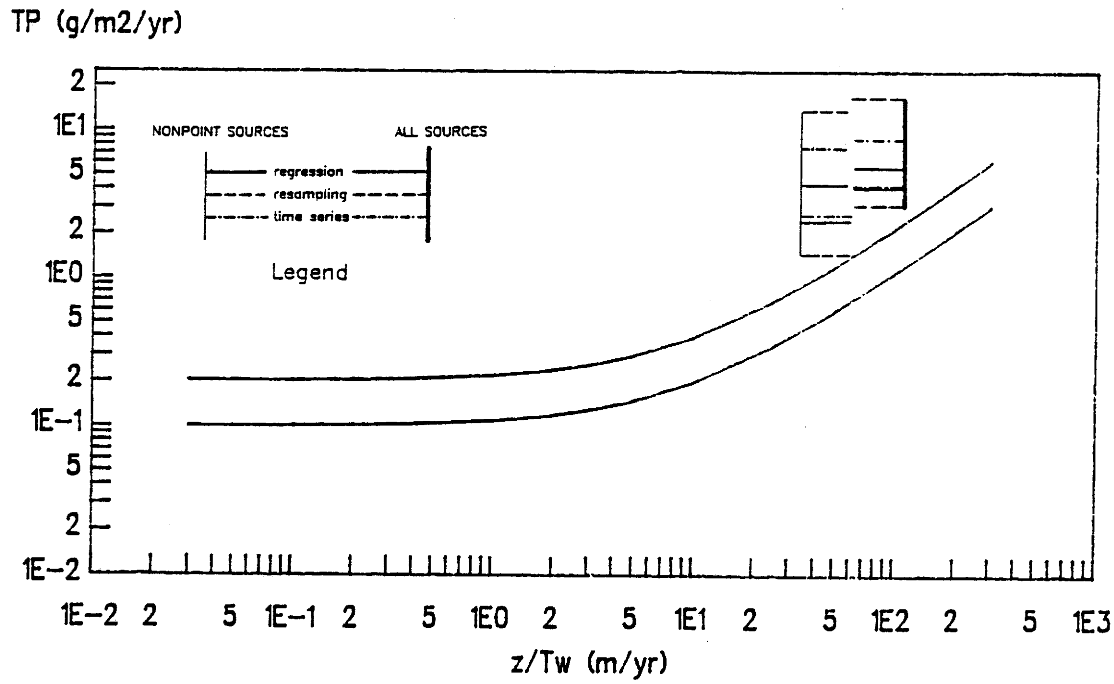

Figure 32b. Annual areal total phosphorus loads ($g/m^2/yr$) estimated by all methods in this report, compared to the excessive and permissible loads predicted for the Buckboard section of Flaming Gorge Reservoir by the Vollenweider III model.

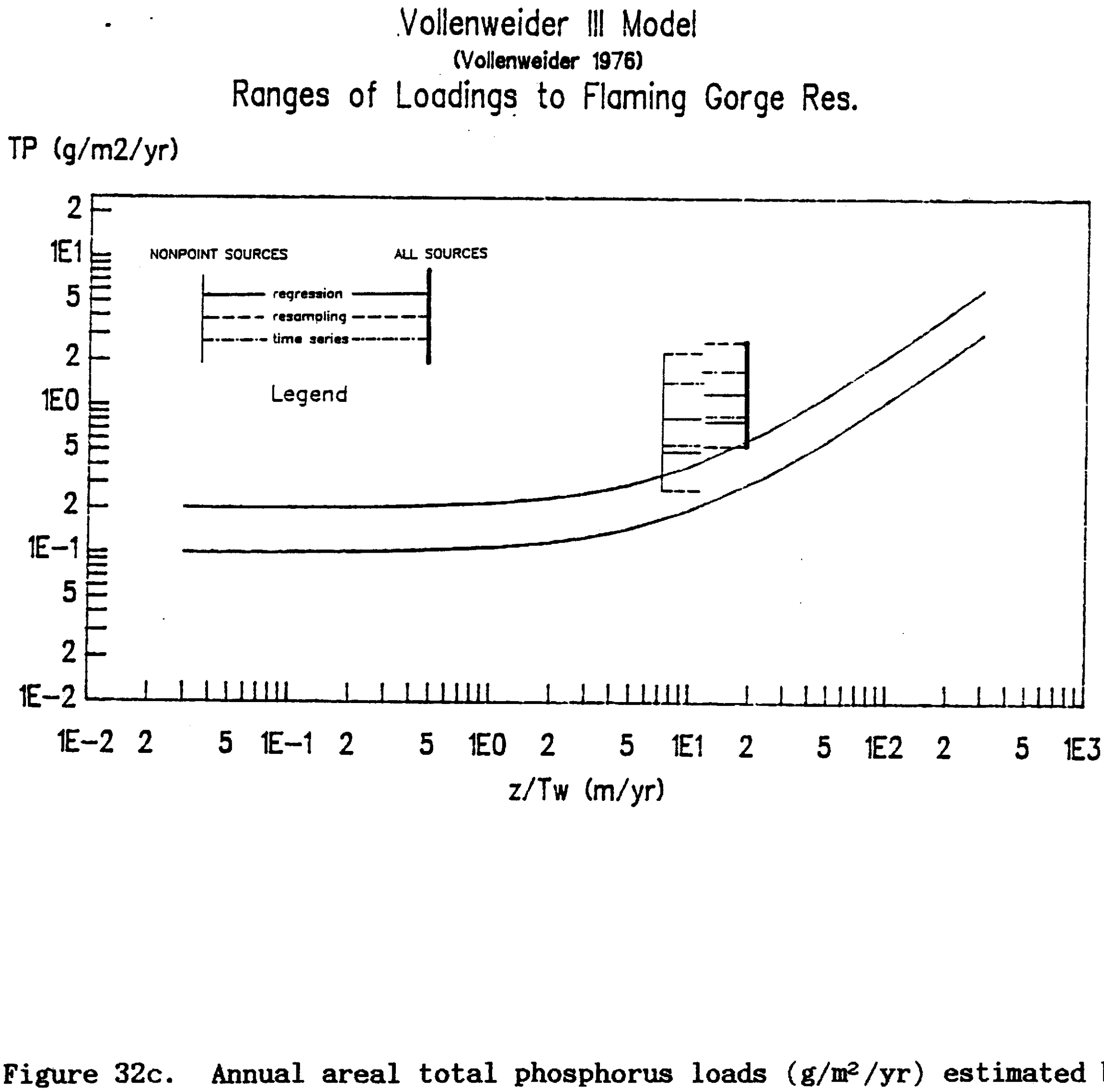

Figure 32c. Annual areal total phosphorus loads ($g/m^2/yr$) estimated by all methods in this report, compared to the excessive and permissible loads predicted for the entire Flaming Gorge Reservoir by the Vollenweider III model.

APPENDICES

Appendix A. Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	STATION#	DISCHARGE FT3/SEC DIS15	MEAN PHOS(P) MG/L PHOSC	PHOS(P) (TONS/YR) PHOSL	NITRATE(NO3) MG/L NITC
GRWB	9188500	526	0.018	9	0.151
GRBP	9192600	605	0.024	14	0.271
NFAB	9201000	441	-999.000	-999	0.229
NFBP	9205000	784	0.023	18	0.266
GRLB	9209400	1716	0.027	46	0.270
GRBF	9211200	1714	0.017	29	0.384
BSLS	9214500	22	0.097	2	-999.000
BSAF	9216000	58	0.102	6	2.303
BSBD	7135	58	-999.000	-999	-999.000
BSGB	9216050	75	0.122	9	1.941
BSAC	8011	75	-999.000	-999	-999.000
GRBI	9216300	1789	0.023	41	0.296
GRGR	9217000	1825	0.053	95	0.165
BFAL	9222000	165	-999.000	-999	0.486
HFAG	9224450	179	0.082	14	0.354
BFLA	9224700	353	-999.000	-999	0.356

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	NITRATE(NO3) T/YEAR NITL	MEAN TDS IN TPD TDSTD	MEAN TDS (TONS/YEAR) TDSTDY	MEAN TDS(SOC) MG/L TDSC
GRWB	78	224	78709	252
GRBP	162	456	175071	274
NFAB	100	115	39611	114
NFBP	206	184	63877	114
GRLB	457	905	304719	216
GRBF	649	986	360858	249
BSLS	-999	9	2965	223
BSAF	131	237	84257	1935
BSBD	-999	-999	-999	2815
BSGB	144	403	157836	2633
BSAC	-999	-999	-999	2635
GRBI	522	1376	541863	386
GRGR	297	1669	575810	398
BFAL	79	382	104325	1360
HFAG	62	130	62502	431
BFLA	124	589	191081	1096

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TDS(SOC)(T/YEAR) TDSL	MEAN TOTL ALK(MG/L CaCO3) ALKC	MEAN ALK (TONS/YR) ALKL	TURBIDITY(JTU) TURJTU
GRWB	75963	98	51010	2.26
GRBP	126364	142	84460	5.56
NFAB	34525	90	39107	-999.00
NFBP	63076	81	62848	2.71
GRLB	290023	132	222543	11.13
GRBF	364521	133	225390	2.30
BSLS	2993	75	1627	25.98
BSAF	87205	202	11459	-999.00
BSBD	-999	-999	-999	-999.00
BSGB	172595	249	18486	56.72
BSAC	-999	-999	-999	-999.00
GRBI	30160	141	248212	12.18
GRGR	103899	144	259542	18.92
BFAL	110544	190	30888	184.79
HFAG	52926	185	32591	17.97
BFLA	55403	218	75792	141.99

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	DISSOLVED Na(MG/L) SODC	SODIUM (TONS/YR) SODL	MEAN COND(UMHO/CM) COND	MEAN TOTL HARD(MG/L) HARDC
GRWB	3.2	1672	385	204
GRBP	10.0	5989	429	215
NFAB	6.5	2811	195	84
NFBP	8.8	6808	190	79
GRLB	14.8	25123	364	161
GRBF	19.5	32904	415	174
BSLS	32.9	713	362	111
BSAF	304.6	17305	2427	797
BSBD	360.1	20458	3083	-999
BSGB	446.4	33148	3303	1088
BSAC	431.6	32049	2907	-999
GRBI	46.0	81133	609	223
GRGR	52.2	93884	645	234
BFAL	201.6	32832	1808	528
HFAG	42.4	7465	690	278
BFLA	184.4	64205	1456	396

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOT HRDNESS LOAD(T/YR) HARDL	TOTAL AREA mi2 AREA1	QGL:GLACIAL QGL	QAL:ALLUVIUM QAL	QG:GRAVEL QG	QS:AEOLIANsand QS
GRWB	105906	455	131	22	0	0
GRBP	128231	1230	167	170	12	0
NFAB	36334	515	142	49	43	0
NFBP	60925	1194	216	76	140	0
GRLB	272666	3771	383	403	152	0
GRBF	293875	4144	383	412	152	0
BSLS	2401	148	6	0	0	0
BSAF	45276	1449	23	16	11	28
BSBD	-999	1449	23	16	11	28
BSGB	80802	1561	23	17	12	28
BSAC	-999	1611	23	20	24	28
GRBI	394282	6774	406	450	231	28
GRGR	420516	7243	406	460	244	28
BFAL	85964	783	86	65	81	0
HFAG	48945	605	0	69	27	0
BFLA	137863	2919	90	191	129	0

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	QAO:ALLUVIUM QAO	KCR:CAMBR TO CREAT KCR	PCR:PRECAMB PCR	LAKE AREA LAKEA	TU:UNDIVIDED TU	TW:WASATCH TW
GRWB	0	173	125	0	4	0
GRBP	0	284	125	0	152	320
NFAB	0	1	201	18	10	51
NFBP	0	2	477	18	10	255
GRLB	0	600	602	18	162	1230
GRBF	0	769	602	39	162	1255
BSLS	0	0	26	0	83	11
BSAF	0	0	114	3	200	358
BSBD	0	0	114	3	200	358
BSGB	0	0	114	3	200	358
BSAC	0	0	114	3	200	358
GRBI	0	806	716	42	362	1629
GRGR	0	806	716	42	362	1629
BFAL	4	11	86	3	0	0
HFAG	0	206	0	0	158	7
BFLA	4	430	86	3	456	90

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TGM:MID GR FMN TGM	TWN:NFKofWASATCH TWN	TGL:LANEYSHALE TGL	TGWE:MXD NFK&GRF TGWE	TGF:FONTofGRF TGF
GRWB	0	0	0	0	0
GRBP	0	0	0	0	0
NFAB	0	0	0	0	0
NFBP	0	0	0	0	0
GRLB	3	11	38	127	42
GRBF	28	16	38	206	44
BSLS	0	0	21	0	0
BSAF	0	0	477	0	0
BSBD	0	0	477	0	0
BSGB	0	0	520	0	0
BSAC	0	0	538	0	0
GRBI	46	21	633	596	48
GRGR	46	21	907	596	48
BFAL	0	0	0	32	0
HFAG	1	0	0	45	9
BFLA	31	0	0	207	29

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TB:BRIDGERfmn TB	TBP:BROWNSPKfmn TBP	TWU:UPR WASATCH TWU	TGU:UPR GRF TGU	TI:IGNEOUS plug TI
GRWB	0	0	0	0	0
GRBP	0	0	0	0	0
NFAB	0	0	0	0	0
NFBP	0	0	0	0	0
GRLB	0	0	0	0	0
GRBF	9	0	25	4	0
BSLS	1	0	0	0	0
BSAF	120	0	0	0	1
BSBD	120	0	0	0	1
BSGB	187	0	0	0	1
BSAC	204	0	0	0	1
GRBI	618	0	32	11	1
GRGR	776	0	32	11	2
BFAL	282	56	0	0	0
HFAG	81	0	1	1	0
BFLA	904	75	84	33	0

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TWC:CATHBLUFFSofWSCH TWC	TGT:TIPTONSHALEgrf TGT	TGW:WILKINSofGRF TGW	TTWA:TPtrailFMN TTWA
GRWB	0	0	0	0
GRBP	0	0	0	0
NFAB	0	0	0	0
NFBP	0	0	0	0
GRLB	0	0	0	0
GRBF	0	0	0	0
BSLS	0	0	0	0
BSAF	35	51	8	4
BSBD	35	51	8	4
BSGB	35	51	8	4
BSAC	35	51	8	4
GRBI	35	51	8	4
GRGR	35	51	21	4
BFAL	0	0	0	0
HFAG	0	0	0	0
BFLA	0	0	0	0

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TUB:UNTA&BRDGRfmn TUB	TBI:BISHOPconglom TBI	TF:FTUNIONfmn TF	KBA:BAXTERshale KBA	KLA:LANCEfmn KLA
GRWB	0	0	0	0	0
GRBP	0	0	0	0	0
NFAB	0	0	0	0	0
NFBP	0	0	0	0	0
GRLB	0	0	0	0	0
GRBF	0	0	0	0	0
BSLS	0	0	0	0	0
BSAF	0	0	0	0	0
BSBD	0	0	0	0	0
BSGB	0	0	0	0	0
BSAC	0	0	0	0	0
GRBI	0	0	0	0	0
GRGR	0	0	0	0	0
BFAL	0	77	0	0	0
HFAG	0	0	0	0	0
BFLA	0	77	0	0	0

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	KAL:ALMONDfmn KAL	KE:ERICKSNfmn KE	KR:RSPGSfmn KR	KBL:BLAIRfmn KBL	KLE:LEWISshale KLE	SUM PRECAMBRIAN PCAM
GRWB	0	0	0	0	0	125
GRBP	0	0	0	0	0	125
NFAB	0	0	0	0	0	201
NFBP	0	0	0	0	0	477
GRLB	0	0	0	0	0	602
GRBF	0	0	0	0	0	602
BSLS	0	0	0	0	0	26
BSAF	0	0	0	0	0	114
BSBD	0	0	0	0	0	114
BSGB	0	0	0	0	0	114
BSAC	0	0	0	0	0	114
GRBI	0	0	0	0	0	716
GRGR	0	0	0	0	0	716
BFAL	0	0	0	0	0	86
HFAG	0	0	0	0	0	0
BFLA	0	0	0	0	0	86

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	SUM CAMBR TO CREAT C2C	SUM CREATACEOUS CREAT	SUM TERTIARY TERT	SUM QUARTERNARY QUART	%PRECAMBRIAN/100 PPCAM
GRWB	173	0	4	153	0.27
GRBP	284	0	472	349	0.10
NFAB	1	0	61	234	0.39
NFBP	2	0	265	432	0.40
GRLB	600	0	1613	938	0.16
GRBF	769	0	1787	947	0.15
BSLS	0	0	116	6	0.18
BSAF	0	0	1254	78	0.08
BSBD	0	0	1254	78	0.08
BSGB	0	0	1364	80	0.07
BSAC	0	0	1399	95	0.07
GRBI	806	0	4095	1115	0.11
GRGR	806	0	4541	1138	0.10
BFAL	11	0	447	236	0.11
HFAG	206	0	303	96	0.00
BFLA	430	0	1986	414	0.03

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	%CAMB TO CREAT PC2C	% CREATACEOUS PCREAT	% TERTIARY PTERT	% QUARTERNARY PQUART	SUM GREEN R FMN SGRF	SUM WASATCH FMN SWAS
GRWB	0.38	0.00	0.01	0.34	0	0
GRBP	0.23	0.00	0.38	0.28	0	320
NFAB	0.00	0.00	0.12	0.45	0	51
NFBP	0.00	0.00	0.22	0.36	0	255
GRLB	0.16	0.00	0.43	0.25	210	1368
GRBF	0.19	0.00	0.43	0.23	320	1502
BSLS	0.00	0.00	0.78	0.04	21	11
BSAF	0.00	0.00	0.87	0.05	536	393
BSBD	0.00	0.00	0.87	0.05	536	393
BSGB	0.00	0.00	0.87	0.05	579	393
BSAC	0.00	0.00	0.87	0.06	597	393
GRBI	0.12	0.00	0.60	0.16	1393	2313
GRGR	0.11	0.00	0.63	0.16	1680	2313
BFAL	0.01	0.00	0.57	0.30	32	32
HFAG	0.34	0.00	0.50	0.16	56	53
BFLA	0.15	0.00	0.68	0.14	300	381

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	sum DESIGNATED shales SHALE	%GRFMN/100 PGRF	%WASATCH FMN/100 PWAS	% DESIGNATED shales PSHALE	2YR FLOOD CFS FLOD2
GRWB	0	0.00	0.00	0.00	2900
GRBP	0	0.00	0.26	0.00	3900
NFAB	0	0.00	0.10	0.00	2800
NFBP	0	0.00	0.21	0.00	5300
GRLB	38	0.06	0.36	0.01	9600
GRBF	38	0.08	0.36	0.01	7500
BSLS	21	0.14	0.07	0.14	185
BSAF	528	0.37	0.27	0.36	450
BSBD	528	0.37	0.27	0.36	450
BSGB	571	0.37	0.25	0.37	500
BSAC	589	0.37	0.24	0.37	500
GRBI	684	0.21	0.34	0.10	5400
GRGR	958	0.23	0.32	0.13	8500
BFAL	0	0.04	0.04	0.00	1700
HFAG	0	0.09	0.09	0.00	460
BFLA	0	0.10	0.13	0.00	2900

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	10YR FLOOD CFS FLOD10	25YR FLOOD CFS FLOD25	PEAK CFS P.O.R. PKPOR	PEAK CFS 1965-79 PK6579	10YR FLOOD/STUDY PK FLDRAT
GRWB	4000	4600	4840	4840	0.83
GRBP	6000	7000	-999	-999	-999
NFAB	4700	6200	12300	4420	1.06
NFBP	7700	8500	9170	9170	0.84
GRLB	15000	17500	18000	18000	0.83
GRBF	15000	18000	19400	19400	0.77
BSLS	400	700	1450	350	1.14
BSAF	1700	3000	7430	1440	1.18
BSBD	1700	3000	7430	1440	1.18
BSGB	2600	7000	7430	1130	2.30
BSAC	2600	7000	7430	1130	2.30
GRBI	15000	21400	-999	-999	-999
GRGR	15000	17000	16800	16800	0.89
BFAL	3500	4500	7960	7960	0.44
HFAG	1600	2500	-999	-999	-999
BFLA	5000	6000	9980	9980	0.50

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOT STREAMLENGTH(mi) SLENG	DRAINAGE DENSITY DDEN	STREAM ORDER @ STATN ORDR	MAIN CHANL L (mi) CHANL
GRWB	289	0.635	4	51.0
GRBP	677	0.551	5	90.7
NFAB	205	0.394	4	41.5
NFBP	513	0.424	5	59.5
GRLB	2191	0.581	6	124.3
GRBF	2444	0.590	6	140.8
BSLS	109	0.736	4	38.0
BSAF	900	0.625	5	70.7
BSBD	900	0.625	5	70.7
BSGB	958	0.617	5	80.1
BSAC	984	0.613	5	89.3
GRBI	4070	0.601	6	168.9
GRGR	4355	0.602	6	191.4
BFAL	420	0.525	4	60.1
HFAG	426	0.704	4	85.2
BFLA	1594	0.542	5	100.6

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	MAIN CHANL m (ft/mi) CHANS	Ac AC	ELONGATN RATIO ELONG	MEAN BASIN ELEV (ft) MELEV	MEAN BASIN m (ft/mi) BASINS
GRWB	10.4	24	0.471	9262	163.6
GRBP	14.7	40	0.441	8300	78.9
NFAB	25.7	26	0.627	8630	125.1
NFBP	20.6	39	0.655	8696	102.0
GRLB	12.9	69	0.555	8282	74.3
GRBF	13.2	73	0.518	7958	56.1
BSLS	86.0	14	0.368	8032	248.2
BSAF	47.2	43	0.608	7444	88.1
BSBD	47.2	43	0.608	7444	88.1
BSGB	40.8	44	0.549	7438	89.5
BSAC	32.1	45	0.504	7288	63.1
GRBI	11.4	93	0.551	7716	66.8
GRGR	11.1	96	0.502	7520	53.7
BFAL	71.0	32	0.532	9198	93.3
HFAG	18.8	28	0.329	7638	92.2
BFLA	32.5	61	0.606	8038	72.3

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	AVG BIFURCATION RATIO BIFUR	MIN SLOPE o MINS	MAX SLOPE o MAXS	MIN ELEV(ft) MINEL	MAX ELEV(ft) MAXEL	ANN PPT(") PPT1
GRWB	4.1	2	35	7067	8359	22.2
GRBP	2.8	3	29	6109	7358	17.7
NFAB	2.9	1	25	5761	6885	17.3
NFBP	3.0	1	24	5700	6812	16.3
GRLB	3.0	2	27	6005	7150	15.9
GRBF	3.0	2	29	6084	7224	16.1
BSLS	2.4	2	24	6124	7377	13.2
BSAF	3.1	3	25	6197	7183	10.2
BSBD	3.1	3	23	6197	7183	10.2
BSGB	3.1	3	25	6226	7188	10.0
BSAC	3.1	3	25	6232	7188	9.9
GRBI	3.1	3	28	6190	7226	13.7
GRGR	3.9	3	28	6201	7225	13.0
BFAL	3.0	1	26	6786	7785	13.5
HFAG	3.5	3	44	7084	8207	19.7
BFLA	3.5	3	36	6930	7856	13.9

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	MAST(oF) MAST	MIN FFD/YR MNFFD	MAX FFD/YR MXFFD	D 2 ROCK(ft) D2R	FRAC>3"(%) FRAC3	%<200 MESH M200	% CLAY PCLAY	PERM("/HR) PERM
GRWB	37.2	15	23	49	21.5	31.4	19.5	3.8
GRBP	34.1	32	47	40	16.1	38.3	19.2	2.5
NFAB	31.8	4	5	47	17.7	25.0	15.6	3.8
NFBP	32.3	12	16	44	15.8	27.5	16.2	3.4
GRLB	34.9	35	49	39	13.3	37.7	19.0	2.6
GRBF	35.5	37	51	37	13.3	38.5	19.5	2.5
BSLS	39.9	53	73	41	7.7	44.8	22.9	2.3
BSAF	41.2	72	93	35	4.1	45.7	22.0	2.2
BSBD	41.2	72	93	35	4.1	45.7	22.0	2.2
BSGB	41.4	74	94	34	3.7	46.1	22.0	2.2
BSAC	41.5	74	94	34	3.7	46.0	22.0	2.2
GRBI	38.2	54	69	35	9.7	41.8	20.4	2.4
GRGR	39.0	56	72	35	9.0	42.0	20.4	2.4
BFAL	40.3	41	49	45	11.5	37.1	19.6	3.2
HFAG	41.5	53	68	26	14.6	44.1	21.8	1.8
BFLA	42.0	60	75	33	9.0	42.8	20.9	2.4

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	H2O CAP(") WATCAP	SALINITY SAL	SHRINK-SWELL CAP SSCAP	K FACTOR KFAC	T FACTOR TFAC	WIND EROD FACTOR WIND	% ORGANIC PORG
GRWB	0.10	1.2	1.2	0.22	3	4	1.9
GRBP	0.10	1.3	1.1	0.23	3	5	1.5
NFAB	0.08	0.8	1.0	0.19	3	3	1.5
NFBP	0.09	1.0	1.1	0.20	3	3	1.4
GRLB	0.10	1.6	1.1	0.24	3	4	1.3
GRBF	0.11	1.7	1.1	0.25	3	4	1.3
BSLS	0.13	2.2	1.4	0.30	3	3	1.0
BSAF	0.13	2.8	1.3	0.31	3	3	0.6
BSBD	0.13	2.8	1.3	0.31	3	3	0.6
BSGB	0.13	2.9	1.3	0.32	3	3	0.5
BSAC	0.13	2.9	1.3	0.32	3	3	1.1
GRBI	0.12	2.1	1.2	0.28	3	4	0.9
GRGR	0.12	2.1	1.2	0.28	3	4	0.9
BFAL	0.12	1.8	1.2	0.27	4	3	1.4
HFAG	0.12	2.3	1.2	0.29	2	6	1.2
BFLA	0.13	2.2	1.2	0.30	3	4	1.0

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	SOIL pH PH	ALPINE AREA:1 ALPA	ALPINE VEG:11 ALPV	ALPINE AREA SUM SALP	CROP IRR:21 CROPI	CROP DRY:22 CROPD
GRWB	6.2	71	15	86	0	0
GRBP	6.5	81	15	96	179	0
NFAB	6.3	38	0	38	84	0
NFBP	6.4	50	0	50	158	0
GRLB	6.6	135	15	150	484	0
GRBF	6.6	135	15	150	494	0
BSLS	6.8	7	0	7	0	2
BSAF	7.0	11	0	11	52	3
BSBD	7.0	11	0	11	52	3
BSGB	7.1	11	0	11	52	3
BSAC	7.1	11	0	11	52	3
GRBI	6.7	146	15	161	551	3
GRGR	6.8	146	15	161	551	0
BFAL	6.9	0	0	0	159	1
HFAG	7.1	0	0	0	30	0
BFLA	7.2	0	0	0	194	1

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	CROPPED AREA SUM SCROP	DUNES:31 DUNE	EXPOSED:32 EXPOS	BARE OR DUNE AREA SDUNE	LACUSTRINE:42 LACUS	PALUSTRINE:43 PALUS
GRWB	0	0	0	0	2	0
GRBP	179	0	0	0	2	0
NFAB	84	0	0	0	32	0
NFBP	158	0	0	0	45	0
GRLB	484	0	0	0	49	3
GRBF	494	0	0	0	71	3
BSLS	2	0	0	0	1	0
BSAF	55	20	0	20	6	0
BSBD	55	20	0	20	6	0
BSGB	55	20	0	20	6	0
BSAC	55	20	0	20	6	0
GRBI	554	20	0	20	77	3
GRGR	551	20	0	20	79	3
BFAL	160	0	65	65	1	0
HFAG	30	0	0	0	2	5
BFLA	195	0	84	84	4	18

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	WETLAND AREA SUM SWET	URBAN:52 SURBAN	W. BASIN & FTHLS:612 BASIN	HERB RANGE SUM SHERB	SHRUB RANGE:62 SHRUBR	SAGE:621 SAGE
GRWB	2	0	0	0	0	58
GRBP	2	0	12	12	0	389
NFAB	32	1	0	0	1	78
NFBP	45	1	0	0	3	188
GRLB	52	1	13	13	17	1357
GRBF	74	1	13	13	17	1617
BSLS	1	0	0	0	0	52
BSAF	6	0	0	0	0	678
BSBD	6	0	0	0	0	678
BSGB	6	0	0	0	0	797
BSAC	6	0	0	0	0	797
GRBI	80	2	13	13	17	3264
GRGR	82	3	13	13	17	3636
BFAL	1	1	0	0	0	200
HFAG	7	1	0	0	0	383
BFLA	22	2	0	0	0	1843

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	HALOPHYT SHRUB:622 HALOS	MIXED SHRUB:624 SHRUBM	SHRUB RANGE SUM SHRUB	MIXED RANGE:63 MIXEDR	TOTAL RANGE SUM SRANGE
GRWB	0	0	58	0	58
GRBP	0	0	389	0	401
NFAB	0	0	79	73	152
NFBP	0	0	191	323	514
GRLB	0	0	1374	369	1756
GRBF	0	0	1634	369	2016
BSLS	0	0	52	99	151
BSAF	0	0	678	612	1290
BSBD	0	0	678	612	1290
BSGB	0	21	818	612	1430
BSAC	0	46	843	612	1455
GRBI	15	186	3482	981	4476
GRGR	23	252	3928	981	4922
BFAL	0	0	200	0	200
HFAG	0	0	383	7	390
BFLA	0	0	1843	119	1962

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	JUNIPER:71 JUNIP	WOODLAND SUM SWOOD	ASPEN:811 ASPEN	DECID FOR SUM SDECOD	CONIFER:82 CONIF	PINE:823 PINE	CONIF FOR SUM SCONIF
GRWB	0	0	0	0	152	86	238
GRBP	0	0	0	0	152	302	454
NFAB	0	0	0	0	217	0	217
NFBP	0	0	0	0	447	0	447
GRLB	0	0	0	0	599	588	1187
GRBF	0	0	0	0	599	675	1274
BSLS	0	0	0	0	14	0	14
BSAF	0	0	0	0	88	0	88
BSBD	0	0	0	0	88	0	88
BSGB	0	0	0	0	88	0	88
BSAC	0	0	0	0	88	0	88
GRBI	0	0	0	0	687	675	1362
GRGR	0	0	0	0	687	675	1362
BFAL	10	10	2	2	0	354	354
HFAG	0	0	0	0	0	190	190
BFLA	82	82	14	14	0	578	578

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	MIXED FOREST:83 MIXEDF	MIXED FOREST SUM SMIXF	ALL FOREST SUM SFORST	% ALPINE AREA PALPA	% ALPINE VEG PALPV
GRWB	73	73	311	0.16	0.03
GRBP	90	90	544	0.07	0.01
NFAB	0	0	217	0.07	0.00
NFBP	0	0	447	0.04	0.00
GRLB	90	90	1277	0.04	0.00
GRBF	90	90	1364	0.03	0.00
BSLS	0	0	14	0.04	0.00
BSAF	0	0	88	0.01	0.00
BSBD	0	0	88	0.01	0.00
BSGB	0	0	88	0.01	0.00
BSAC	0	0	88	0.01	0.00
GRBI	90	90	1452	0.02	0.00
GRGR	90	90	1452	0.02	0.00
BFAL	0	0	356	0.00	0.00
HFAG	0	0	190	0.00	0.00
BFLA	0	0	592	0.00	0.00

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOTAL ALPINE AREA % PALP	% CROP IRR PCI	%CROP DRY PCD	TOTAL CROPPED AREA % PCROP	% DUNES PDUNE	% EXPOSED PEXP
GRWB	0.19	0.00	0.00	0.00	0.00	0.00
GRBP	0.08	0.15	0.00	0.15	0.00	0.00
NFAB	0.07	0.16	0.00	0.16	0.00	0.00
NFBP	0.04	0.13	0.00	0.13	0.00	0.00
GRLB	0.04	0.13	0.00	0.13	0.00	0.00
GRBF	0.04	0.12	0.00	0.12	0.00	0.00
BSLS	0.04	0.00	0.01	0.01	0.00	0.00
BSAF	0.01	0.04	0.00	0.04	0.01	0.00
BSBD	0.01	0.04	0.00	0.04	0.01	0.00
BSGB	0.01	0.03	0.00	0.03	0.01	0.00
BSAC	0.01	0.03	0.00	0.03	0.01	0.00
GRBI	0.02	0.08	0.00	0.08	0.00	0.00
GRGR	0.02	0.08	0.00	0.08	0.00	0.00
BFAL	0.00	0.20	0.00	0.20	0.00	0.08
HFAG	0.00	0.05	0.00	0.05	0.00	0.00
BFLA	0.00	0.07	0.00	0.07	0.00	0.03

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	% BARE OR DUNE AREA PBARE	% LACUSTRINE PLAC	% PALUSTRINE PPAL	TOTAL WETLAND AREA % PWET	% URBAN PURBAN	% W BASN&FTHLS PBASIN
GRWB	0.00	0.00	0.00	0.00	0.00	0.00
GRBP	0.00	0.00	0.00	0.00	0.00	0.01
NFAB	0.00	0.06	0.00	0.06	0.00	0.00
NFBP	0.00	0.04	0.00	0.04	0.00	0.00
GRLB	0.00	0.01	0.00	0.01	0.00	0.00
GRBF	0.00	0.02	0.00	0.02	0.00	0.00
BSLS	0.00	0.01	0.00	0.01	0.00	0.00
BSAF	0.01	0.00	0.00	0.00	0.00	0.00
BSBD	0.01	0.00	0.00	0.00	0.00	0.00
BSGB	0.01	0.00	0.00	0.00	0.00	0.00
BSAC	0.01	0.00	0.00	0.00	0.00	0.00
GRBI	0.00	0.01	0.00	0.01	0.00	0.00
GRGR	0.00	0.01	0.00	0.01	0.00	0.00
BFAL	0.08	0.00	0.00	0.00	0.00	0.00
HFAG	0.00	0.00	0.01	0.01	0.00	0.00
BFLA	0.03	0.00	0.01	0.01	0.00	0.00

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOTAL HERB RANGE % PHERB	% SHRUB RANGE PSHRUB	% SAGE PSAGE	% HALOPHYT SHRUB PHALO	% MIXED SHRUB PSHRUBM
GRWB	0.00	0.00	0.13	0.00	0.00
GRBP	0.01	0.00	0.32	0.00	0.00
NFAB	0.00	0.00	0.15	0.00	0.00
NFBP	0.00	0.00	0.15	0.00	0.00
GRLB	0.00	0.00	0.36	0.00	0.00
GRBF	0.00	0.00	0.39	0.00	0.00
BSLS	0.00	0.00	0.29	0.00	0.00
BSAF	0.00	0.00	0.46	0.00	0.00
BSBD	0.00	0.00	0.46	0.00	0.00
BSGB	0.00	0.00	0.50	0.00	0.01
BSAC	0.00	0.00	0.49	0.00	0.03
GRBI	0.00	0.00	0.48	0.00	0.03
GRGR	0.00	0.00	0.51	0.00	0.04
BFAL	0.00	0.00	0.25	0.00	0.00
HFAG	0.00	0.00	0.62	0.00	0.00
BFLA	0.00	0.00	0.63	0.00	0.00

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOTAL SHRUB RANGE % PSHRUBR	% MIXED RANGE PMIXR	TOTAL RANGE % PRANGE	% JUNIPER PJUN	TOTAL WOODLAND % PWOOD	% ASPEN PASPN
GRWB	0.13	0.00	0.13	0.00	0.00	0.00
GRBP	0.32	0.00	0.33	0.00	0.00	0.00
NFAB	0.15	0.14	0.29	0.00	0.00	0.00
NFBP	0.16	0.27	0.42	0.00	0.00	0.00
GRLB	0.37	0.10	0.47	0.00	0.00	0.00
GRBF	0.40	0.09	0.49	0.00	0.00	0.00
BSLS	0.29	0.56	0.85	0.00	0.00	0.00
BSAF	0.46	0.42	0.88	0.00	0.00	0.00
BSBD	0.46	0.42	0.88	0.00	0.00	0.00
BSGB	0.51	0.38	0.89	0.00	0.00	0.00
BSAC	0.52	0.37	0.89	0.00	0.00	0.00
GRBI	0.52	0.15	0.66	0.00	0.00	0.00
GRGR	0.55	0.14	0.68	0.00	0.00	0.00
BFAL	0.25	0.00	0.25	0.01	0.01	0.00
HFAG	0.62	0.01	0.63	0.00	0.00	0.00
BFLA	0.63	0.04	0.67	0.03	0.03	0.00

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOTAL DECID FOR % PDECID	% CONIFER PCONIF	% PINE PPINE	TOTAL CONIF FOR % PCONF	% MIXED FOREST PMIX	TOTAL MIXED FOREST % PMXFOR
GRWB	0.00	0.33	0.19	0.52	0.16	0.16
GRBP	0.00	0.12	0.25	0.37	0.07	0.07
NFAB	0.00	0.41	0.00	0.41	0.00	0.00
NFBP	0.00	0.37	0.00	0.37	0.00	0.00
GRLB	0.00	0.16	0.16	0.32	0.02	0.02
GRBF	0.00	0.15	0.16	0.31	0.02	0.02
BSLS	0.00	0.08	0.00	0.08	0.00	0.00
BSAF	0.00	0.06	0.00	0.06	0.00	0.00
BSBD	0.00	0.06	0.00	0.06	0.00	0.00
BSGB	0.00	0.05	0.00	0.05	0.00	0.00
BSAC	0.00	0.05	0.00	0.05	0.00	0.00
GRBI	0.00	0.10	0.10	0.20	0.01	0.01
GRGR	0.00	0.10	0.09	0.19	0.01	0.01
BFAL	0.00	0.00	0.45	0.45	0.00	0.00
HFAG	0.00	0.00	0.31	0.31	0.00	0.00
BFLA	0.00	0.00	0.20	0.20	0.00	0.00

Appendix A (continued). Water quality parameters and attributes of the Green River drainage selected as candidate dependent and independent variables for regression analyses.

STATION STATN	TOTAL FOREST % PFORST	TOTAL PRECIP ("/YR) PPT2	MEAN JULY MAXT (F) MAXT	MEAN JAN MINT (F) MINT
GRWB	0.68	41	72	-5
GRBP	0.45	29	75	-6
NFAB	0.41	25	76	-4
NFBP	0.37	22	76	-5
GRLB	0.34	23	76	-6
GRBF	0.33	22	77	-6
BSLS	0.08	15	75	-3
BSAF	0.06	12	80	-4
BSBD	0.06	11	80	-4
BSGB	0.05	11	80	-4
BSAC	0.05	11	81	-4
GRBI	0.22	17	79	-5
GRGR	0.20	16	79	-4
BFAL	0.45	19	76	8
HFAG	0.31	17	82	0
BFLA	0.20	14	80	5

APPENDIX B: Point sources of total phosphorus (TP) and nitrate-nitrogen (NO_3) in the Green River drainage. All of the sources in subbasin BC (Bitter Creek), and those marked with an asterisk (*) are just downstream of the most downstream water quality station (USGS station #0917000 (GRGR)) included in the study.

TP SOURCE	SUBBASIN	DAILY FLOW (mgd)	TP CONC (mg/l)	TP load (kg/yr)	TP load (T/yr)
Volcic Trailer Pk.	BC	0.000	7.7	0	0
W-K Trailer Park	BC	0.010	7.7	106	0.11
Rock Springs #2	BC	0.200	7.7	2129	2.34
White Mtn. Plant	BC	0.000	7.7	0	0.00
Western Hills T.P.	BC	0.040	7.7	425	0.46
Husky Truck Stop	BC	0.010	7.7	106	0.11
Bridger Pwr. Plant	BC	2.700	1.5	5600	6.17
Clearview Acres	BC	0.000	7.7	0	0.00
B & R Trailer Ct.	BC	0.050	7.7	532	0.58
Quality Inn	BC	0.005	7.7	53	0.05
Mountain View	BFAL	0.100	7.7	1064	1.17
Granger	BFLA	0.000	7.7	0	0.00
UPRR-Green River*	GRGR	0.020	0.2	5	0.00
Green River City*	GRGR	2.000	7.7	21297	23.47
Labarge	GRLB	0.030	7.7	319	0.35
Marbleton	GRLB	0.050	7.7	532	0.58
Big Piney	GRLB	0.250	3.85	1331	1.46
Viva Naughton	HFAG	0.001	7.7	10	0.01
Opal Development	HFAG	0.010	7.7	106	0.11
Kemmerer	HFAG	0.600	7.7	6389	7.04
Naughton Pwr.Plant	HFAG	5.000	0.3	2074	2.28
Pinedale	NFAB	0.500	3.85	2662	2.93

APPENDIX B (continued): Point sources of the nutrients total phosphorus (TP) and nitrate-nitrogen (NO_3) in the Green River drainage study area and adjacent subbasins. All of the sources in subbasin BC (Bitter Creek), and those marked with an asterisk (*) are just downstream of the most downstream water quality station included in the Green River drainage study area. Nitrate is in units as NO3.

NO_3 SOURCE	SUBBASIN	DAILY FLOW (mgd)	NO3 CONC (mg/l)	NO3 load (kg/yr)	NO3 load (T/yr)
Volcic Trailer Pk.	BC	0.000	12.8	0	0.000
W-K Trailer Park	BC	0.010	12.8	177	0.195
Rock Springs #2	BC	0.200	12.8	3537	3.897
White Mtn. Plant	BC	0.000	12.8	0	0.000
Western Hills T.P.	BC	0.040	12.8	707	0.779
Husky Truck Stop	BC	0.010	12.8	177	0.195
Bridger Pwr. Plant	BC	2.700	0	0	0.000
Clearview Acres	BC	0.000	12.8	0	0.000
B & R Trailer Ct.	BC	0.050	12.8	884	0.974
Quality Inn	BC	0.005	12.8	88	0.097
Mountain View	BFAL	0.100	12.8	1768	1.949
Granger	BFLA	0.000	12.8	0	0.000
UPRR-Green River*	GRGR	0.020	0	0	0.000
Green River City*	GRGR	2.000	12.8	35369	38.976
Labarge	GRLB	0.030	12.8	531	0.585
Marbleton	GRLB	0.050	12.8	884	0.974
Big Piney	GRLB	0.250	6.4	2211	2.436
Viva Naughton	HFAG	0.001	12.8	18	0.018
Opal Development	HFAG	0.010	12.8	174	0.195
Kemmerer	HFAG	0.600	12.8	10611	11.691
Naughton Pwr.Plant	HFAG	5.000	0	0	0.000
Pinedale	NFAB	0.500	6.4	4420	4.871

Appendix C. Basin attributes (independent variables) common to all regression analyses. This set was further reduced to unique sets for each water quality (dependent) variable as detailed in Section 1 of this report. Explanation of the abbreviations is found in Appendix A.

Geology:	Hydrology:	Soils:	Land cover/land use:	Climate:
QGL	AREA1	MINS	ALPA	PPT2
QAL	FLOD2	MAXS	ALPV	MAXT
QG	FLOD10	MINEL	CROPI	MINT
QS	FLOD25	MAXEL	CROPD	
QAO	PKPOR	MAST	DUNE	
TU	PK6579	MINFFD	EXPOS	
TW	FLDRAT	MAXFFD	LACUS	
TGM	SLENG	D2RK	PALUS	
TWN	DDEN	FRAC3	SURBAN	
TGL	ORDER	M200	BASIN	
TGWE	CHANL	PCLAY	SHRUBR	
TGF	CHANS	PERM	SAGE	
TB	ELONG	H2OCAP	HALOS	
TBP	MELEV	SAL	SHRUBM	
TWU	BASINS	SSC	MIXEDR	
TGU	BIFUR	KFAC	JUNIP	
TI		TFAC	ASPEN	
TWC		WIND	CONIF	
TGT		PORG	PINE	
TGW		PHSOIL	MIXEDF	
TTWA				
TUB				
TBI				
TF				
KBA				
KLA				
KAL				
KE				
KR				
KBL				
KLE				

Appendix D. Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
10-01	.0274	636	.0352	2001	.0321	930	.1764	1090	.0289	2082	.0204	1058	.0196	663	.0352	1430
10-02	.0422	625	.0328	1842	.0586	938	.0945	1165	.0258	2052	.0196	1083	.0204	634	.0445	1371
10-03	.0477	631	.0313	1770	.0656	961	.1686	1176	.0250	2097	.0188	1159	.0219	634	.0516	1338
10-04	.0438	636	.0297	1736	.0570	916	.1881	1090	.0266	2067	.0196	1241	.0235	841	.0344	1331
10-05	.0453	642	.0305	1656	.0430	902	.0726	1137	.0219	2092	.0352	1234	.0258	850	.0313	1324
10-06	.0336	653	.0235	1615	.0336	878	.0679	1185	.0219	2087	.0258	1248	.0305	990	.0313	1310
10-07	.0204	653	.0235	1603	.0336	860	.0344	1213	.0235	2087	.0227	1290	.0445	1371	.0258	1324
10-08	.0196	647	.0250	1591	.0289	909	.0243	1198	.0211	2077	.0274	1338	.0539	1493	.0289	1324
10-09	.0196	647	.0243	1585	.0289	889	.0243	1185	.0219	2052	.0266	1377	.0578	1499	.0282	1324
10-10	.0211	647	.0227	1573	.0282	874	.0289	1269	.0250	2097	.0321	1404	.0477	1536	.0227	1310
10-11	.0196	642	.0227	1555	.0282	862	.0321	1331	.0211	1371	.0274	1455	.0867	1524	.0258	1310
10-12	.0196	642	.0227	1555	.0328	856	.0367	1397	.0227	1759	.0227	1487	.1732	1536	.0289	1310
10-13	.0204	636	.0227	1536	.0547	909	.0321	1442	.0258	2037	.0352	1518	.3519	1561	.0336	1317
10-14	.0196	636	.0227	1442	.0531	1036	.0289	1442	.1054	2072	.0367	1549	.1062	1499	.0289	1324
10-15	.0196	684	.0313	1391	.0305	958	.0266	1436	.1428	2087	.0321	1627	.1397	1499	.0321	1324
10-16	.0196	695	.0391	1410	.0375	901	.0266	1436	.0508	2062	.0375	1673	.2598	1499	.0321	1331
10-17	.0196	705	.0297	1391	.0282	854	.0243	1358	.0399	2062	.0289	1638	.0945	1499	.0289	1351
10-18	.0211	754	.0219	1384	.0258	830	.0211	1184	.0289	1869	.0282	1597	.1865	1499	.0383	1351
10-19	.0211	766	.0211	1377	.0328	817	.0219	1072	.0204	1573	.0243	1591	.1007	1499	.0274	1331
10-20	.0204	760	.0227	1220	.0492	833	.0204	1067	.0196	1505	.0235	1585	.1257	1442	.0250	1317
10-21	.0196	730	.0243	814	.1101	905	.0204	1069	.0211	1505	.0227	1555	.1725	1304	.0235	1317
10-22	.0196	631	.0227	706	.1647	916	.0188	1064	.0196	1455	.0219	1518	.0250	1163	.0258	1317
10-23	.0204	522	.0211	1025	.0929	755	.0211	1067	.0258	1391	.0344	1474	.0266	1027	.0235	1317
10-24	.0211	679	.0211	1198	.0492	729	.0227	1081	.0282	1404	.0243	1449	.0461	945	.0282	1317
10-25	.0219	690	.0204	1184	.0609	738	.0196	1124	.0258	1410	.0196	1404	.0344	957	.0344	1358
10-26	.0204	695	.0211	1297	.0570	733	.0196	1120	.0211	1391	.0328	1377	.0227	957	.0547	1324
10-27	.0196	690	.0235	1364	.0492	722	.0196	1122	.0196	1371	.0289	1384	.0352	945	.0321	1338
10-28	.0211	695	.0243	1499	.0289	714	.0196	1126	.0258	1364	.0321	1377	.0375	928	.0406	1304
10-29	.0235	695	.0227	1518	.0305	714	.0204	1123	.0219	1241	.0235	1344	.0305	951	.0445	1140
10-30	.0227	705	.0235	1493	.0282	707	.0188	1122	.0243	1096	.0438	1317	.0266	903	.0445	1140
10-31	.0211	710	.0227	1474	.0250	691	.0196	1121	.0250	1269	.0258	1310	.0344	903	.0328	1205
11-01	.0219	705	.0211	1449	.0360	684	.0204	1123	.0204	1331	.0204	1310	.0274	903	.0282	1269
11-02	.0219	700	.0211	1461	.0274	683	.0196	1131	.0243	1317	.0336	1304	.0227	903	.0243	1269
11-03	.0227	695	.0211	1505	.0266	678	.0196	1131	.0219	1310	.0274	1304	.0235	903	.0258	1162
11-04	.0227	700	.0204	1474	.0282	677	.0227	1124	.0211	1174	.0321	1276	.0243	908	.0282	1007
11-05	.0227	705	.0196	1518	.0328	678	.0321	1124	.0211	1164	.0258	1248	.0282	909	.0227	867
11-06	.0289	705	.0196	1555	.0336	679	.0219	1102	.0204	1198	.0258	1205	.0289	914	.0250	1124
11-07	.0375	705	.0196	1549	.0227	685	.0211	1016	.0266	1310	.0211	1149	.0289	934	.0336	1269
11-08	.0500	705	.0204	1524	.0227	706	.0211	898	.0211	1351	.0180	1109	.0383	929	.0344	1371
11-09	.0562	700	.0227	1505	.0367	702	.0219	905	.0204	1182	.0204	1096	.0367	925	.0422	1404
11-10	.0414	705	.0219	1524	.0570	634	.0219	909	.0227	1079	.0196	1083	.0360	945	.0360	1371
11-11	.0305	705	.0211	1530	.0492	689	.0258	909	.0243	1130	.0258	1065	.0321	1005	.0367	924
11-12	.0297	736	.0219	1524	.0266	711	.0235	919	.0211	1182	.0274	1046	.0321	1019	.0297	760
11-13	.0297	766	.0219	1505	.0243	679	.0274	922	.0196	1177	.0297	1033	.0367	1054	.0313	1047
11-14	.0321	770	.0211	1480	.0266	682	.0305	1133	.0188	1155	.0352	1033	.0375	1192	.0360	1297

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
11-15	.0328	690	.0219	1468	.0274	708	.0274	1324	.0211	1198	.0219	1039	.0516	1461	.0344	1283
11-16	.0344	690	.0289	1404	.0469	921	.0211	1371	.0211	1157	.0227	1039	.0594	1579	.0399	1283
11-17	.0328	690	.0484	1377	.0461	980	.0204	1371	.0243	1147	.0321	1039	.0406	1493	.0289	1276
11-18	.0282	730	.0742	1344	.0492	1004	.0196	1338	.0289	1140	.0344	988	.0313	1324	.0235	1269
11-19	.0266	730	.0913	1351	.0438	996	.0204	1276	.0258	1118	.0289	933	.0336	1086	.0289	1234
11-20	.0289	690	.0929	1338	.0383	1004	.0250	1227	.0204	1075	.0258	999	.0313	1032	.0469	1198
11-21	.0305	690	.0851	1310	.0297	979	.0258	1205	.0204	942	.0274	1028	.0289	1007	.0313	1234
11-22	.0297	710	.0773	1297	.0243	954	.0297	1169	.0196	615	.0219	983	.0297	1016	.0250	1276
11-23	.0289	690	.0718	1283	.0227	934	.0289	1162	.0188	576	.0227	969	.0297	1016	.0243	1276
11-24	.0289	669	.0711	1269	.0266	886	.0367	1162	.0180	560	.0227	963	.0305	1016	.0266	1269
11-25	.0266	690	.0726	1213	.0414	857	.0360	1094	.0204	521	.0243	975	.0399	1016	.0274	1338
11-26	.0250	710	.0734	1184	.0843	846	.0399	898	.0297	738	.0204	994	.0274	1011	.0274	1430
11-27	.0243	690	.0734	1154	.0921	808	.1179	826	.0422	1493	.0188	999	.0250	1007	.0266	1430
11-28	.0250	669	.0742	1102	.0453	789	.0609	679	.0500	1561	.1202	965	.0282	999	.0321	1423
11-29	.0250	690	.0742	1079	.0399	765	.0539	658	.0539	1404	.0383	962	.0258	1011	.0484	1417
11-30	.0243	710	.0711	1016	.0321	786	.0461	636	.0235	1047	.0305	983	.0352	1016	.0328	1404
12-01	.0274	710	.0625	966	.0399	759	.0492	591	.0235	603	.0531	1007	.0500	1032	.0258	1404
12-02	.0352	710	.0508	881	.0336	759	.0422	547	.0250	580	.2949	983	.0336	1032	.0289	1404
12-03	.0445	690	.0414	898	.0352	783	.0375	550	.0196	597	.1397	956	.0336	1016	.0258	1351
12-04	.0500	690	.0383	845	.0305	816	.0344	556	.0180	663	.1865	933	.0282	1003	.0266	1417
12-05	.0477	669	.0367	808	.0461	812	.0282	580	.0227	740	.1904	999	.0258	995	.0282	1468
12-06	.0375	647	.0352	789	.0492	784	.0375	589	.0204	740	.0321	966	.0274	987	.0235	1468
12-07	.0274	625	.0336	750	.0523	765	.0282	580	.0188	725	.0196	950	.0258	991	.0227	1499
12-08	.0243	625	.0336	740	.0718	720	.0422	580	.0188	750	.0204	966	.0219	987	.0219	1468
12-09	.0243	625	.0336	740	.0882	663	.0469	601	.0196	750	.0196	969	.0297	999	.0274	1449
12-10	.0243	647	.0344	770	.0929	636	.0352	591	.0188	765	.0211	966	.0227	999	.1085	1468
12-11	.0243	647	.0391	826	.0945	658	.0352	556	.0196	770	.0196	962	.0282	999	.1959	1468
12-12	.0243	625	.0453	789	.0812	674	.0367	544	.0196	765	.0211	1003	.0282	999	.0477	1449
12-13	.0243	625	.0523	760	.1023	684	.0399	532	.0204	755	.0196	1028	.0243	1003	.0180	1468
12-14	.0243	647	.0555	710	.0828	695	.0461	544	.0211	789	.0211	1021	.0282	1007	.0180	1499
12-15	.0243	647	.0516	690	.0726	730	.0430	538	.0180	789	.0204	1007	.0243	1016	.0188	1499
12-16	.0243	647	.0438	679	.0531	750	.0406	556	.0196	784	.0196	991	.0227	1003	.0180	1499
12-17	.0243	625	.0383	669	.0773	745	.0406	568	.0196	770	.0196	971	.0211	975	.0266	1499
12-18	.0282	625	.0367	679	.0828	740	.0360	568	.0227	745	.0211	987	.0250	971	.0196	1505
12-19	.0383	647	.0375	700	.0734	750	.0360	556	.0219	755	.0196	945	.0313	979	.0180	1512
12-20	.0477	669	.0383	730	.0789	760	.0360	550	.0219	755	.0196	979	.0352	1003	.0180	1518
12-21	.0555	690	.0399	760	.0711	750	.0328	538	.0243	740	.0196	999	.0282	987	.0180	1524
12-22	.0640	730	.0399	740	.0555	735	.0383	532	.0227	695	.0196	1016	.0344	950	.0227	1530
12-23	.0742	789	.0406	770	.0453	669	.0391	550	.0227	705	.0188	950	.0516	924	.0196	1530
12-24	.0804	836	.0406	750	.0531	642	.0297	568	.0219	779	.0188	950	.0266	907	.0219	1512
12-25	.0804	789	.0399	740	.0664	608	.0336	568	.0227	894	.0204	903	.0211	911	.0196	1524
12-26	.0757	770	.0383	750	.0672	603	.0344	556	.0227	928	.0204	894	.0211	920	.0188	1536
12-27	.0718	770	.0367	770	.0617	603	.0391	544	.0219	916	.0188	881	.0211	920	.0196	1524
12-28	.0711	770	.0375	779	.0648	603	.0305	538	.0227	950	.0196	863	.0211	916	.0188	1518
12-29	.0711	770	.0414	770	.0516	568	.0219	550	.0227	950	.0196	822	.0204	907	.0180	1499

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
12-30	.0711	770	.0469	760	.0555	544	.0282	544	.0227	933	.0219	858	.0196	894	.0180	1449
12-31	.0711	770	.0422	760	.0625	556	.0328	532	.0235	916	.0219	863	.0196	898	.0204	1404
01-01	.0687	770	.0531	750	.0406	556	.0219	550	.0219	933	.0204	885	.0204	903	.0180	1397
01-02	.0672	770	.0539	750	.0383	544	.0282	544	.0219	1000	.0211	858	.0204	907	.0180	1404
01-03	.0648	770	.0539	770	.0297	550	.0321	562	.0219	945	.0250	920	.0196	907	.0266	1404
01-04	.0633	789	.0531	789	.0375	562	.0297	556	.0235	968	.0258	916	.0204	898	.0718	1371
01-05	.0609	789	.0500	808	.0453	566	.0282	538	.0227	995	.0227	867	.0227	876	.0360	1404
01-06	.0586	789	.0453	808	.0375	580	.0297	526	.0235	1017	.0266	854	.0266	903	.0297	1404
01-07	.0570	770	.0430	863	.0375	570	.0282	526	.0250	1039	.0227	881	.0243	924	.0204	1410
01-08	.0547	770	.0438	916	.0344	559	.0328	538	.0227	1028	.0274	903	.0243	933	.0188	1436
01-09	.0531	770	.0469	898	.0313	556	.0250	550	.0211	1007	.0243	911	.0227	950	.0180	1430
01-10	.0508	770	.0500	881	.0399	561	.0266	544	.0227	1014	.0204	907	.0235	958	.0211	1404
01-11	.0484	770	.0531	898	.0399	577	.0250	532	.0235	1051	.0227	924	.0204	933	.0796	1404
01-12	.0469	789	.0555	950	.0453	582	.0235	526	.0243	1075	.0219	933	.0204	924	.0469	1404
01-13	.0461	789	.0578	950	.0555	587	.0204	513	.0227	1093	.0219	933	.0196	924	.0211	1404
01-14	.0469	789	.0570	950	.0516	591	.0204	519	.0305	1094	.0227	933	.0204	933	.0188	1404
01-15	.0461	789	.0523	983	.0383	591	.0211	526	.0243	1090	.0258	941	.0211	928	.0235	1404
01-16	.0430	789	.0453	975	.0352	586	.0243	544	.0243	1093	.0258	941	.0204	924	.0523	1410
01-17	.0391	789	.0391	966	.0422	580	.0235	556	.0250	1083	.0297	937	.0227	920	.0445	1436
01-18	.0352	789	.0344	950	.0375	580	.0266	550	.0250	1051	.0250	941	.0204	937	.0344	1442
01-19	.0328	789	.0321	933	.0383	584	.0250	568	.0243	1049	.0227	937	.0500	966	.0336	1468
01-20	.0305	789	.0321	916	.0375	591	.0250	562	.0227	1067	.0274	941	.1537	999	.0367	1480
01-21	.0305	580	.0328	881	.0227	596	.0289	556	.0219	1043	.0250	920	.1015	999	.0422	1530
01-22	.0305	580	.0367	863	.0211	603	.0297	568	.0227	1047	.0227	911	.0711	971	.0438	1530
01-23	.0336	580	.0422	845	.0328	605	.0297	586	.0219	1036	.0250	903	.0516	950	.0289	1536
01-24	.0375	580	.0477	863	.0344	605	.0313	597	.0235	998	.0211	898	.0469	945	.1233	1561
01-25	.0344	580	.0508	863	.0344	596	.0352	591	.0219	1028	.0211	887	.0438	950	.0422	1561
01-26	.0321	580	.0500	881	.0352	603	.0383	580	.0219	1079	.0250	858	.0500	999	.0430	1530
01-27	.0352	690	.0469	898	.0344	605	.0399	586	.0243	1140	.0406	854	.0679	1047	.0289	1530
01-28	.0711	789	.0445	916	.0344	612	.0438	574	.0250	1198	.0274	849	.0656	1063	.0258	1530
01-29	.1335	836	.0851	907	.0360	614	.0453	556	.0243	1262	.0243	831	.0734	1063	.0289	1499
01-30	.1803	836	.1077	916	.0344	616	.0274	562	.0243	1276	.0219	803	.0843	1079	.0367	1499
01-31	.1959	836	.1124	916	.0282	616	.0235	580	.0258	1364	.0258	779	.0820	1086	.0360	1499
02-01	.1569	863	.1007	916	.0445	614	.0243	568	.0274	1542	.0219	789	.1966	1094	.0243	1499
02-02	.1023	863	.0640	916	.0258	608	.0243	550	.0313	1487	.0227	796	.3597	1102	.0211	1468
02-03	.0843	845	.0601	916	.0360	605	.0250	568	.0367	1549	.0204	808	.2107	1094	.0344	1442
02-04	.0796	863	.0594	916	.0383	612	.0258	562	.0297	1567	.0211	831	.1093	1086	.0297	1410
02-05	.0742	863	.0609	916	.0477	603	.0282	556	.0297	1621	.0235	836	.0851	1071	.0258	1404
02-06	.0672	836	.0547	933	.0422	601	.0282	550	.0274	1656	.0219	854	.0781	1071	.1179	1410
02-07	.0601	826	.0500	933	.0399	601	.0289	544	.0258	1662	.0211	863	.0633	1071	.0430	1430
02-08	.0523	826	.0438	933	.0344	603	.0321	550	.0282	1609	.0211	872	.1030	1071	.0235	1436
02-09	.0461	826	.0445	933	.0422	608	.0328	556	.0289	1573	.0211	885	.1023	1071	.0438	1436
02-10	.0430	826	.0453	950	.0477	612	.0289	550	.0297	1585	.0211	894	.0820	1071	.0391	1442
02-11	.0414	808	.0422	966	.0422	612	.0391	562	.0321	1609	.0227	903	.0711	1109	.0235	1455
02-12	.0430	789	.0422	950	.0414	619	.0367	550	.0313	1632	.0227	916	.0711	1132	.0328	1449

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
02-13	.0500	770	.0414	966	.0328	625	.0367	550	.0289	1603	.0227	916	.0664	1140	.0258	1449
02-14	.0609	789	.0477	966	.0336	625	.0367	532	.0282	1573	.0219	911	.0640	1132	.0375	1449
02-15	.0711	808	.0531	966	.0344	620	.0336	519	.0250	1591	.0352	867	.1709	1086	.0297	1442
02-16	.0726	789	.0516	966	.0297	614	.0328	532	.0266	1603	.0289	876	.1116	1067	.0250	1436
02-17	.0640	789	.0508	950	.0375	612	.0375	538	.0266	1555	.0243	911	.0882	1063	.0336	1430
02-18	.0586	770	.0445	933	.0297	612	.0391	544	.0282	1512	.0211	898	.1179	1059	.0539	1436
02-19	.0594	789	.0508	916	.0414	614	.0812	556	.0258	1524	.0219	873	.0945	1051	.0492	1449
02-20	.0601	808	.0523	898	.0445	616	.0742	562	.0266	1561	.0211	863	.0672	1016	.0414	1468
02-21	.0601	789	.0484	881	.0367	623	.0812	562	.0297	1579	.0211	876	.0828	1032	.0367	1474
02-22	.0609	789	.0508	863	.0399	625	.0945	556	.0274	1536	.0211	881	.0812	1055	.0453	1468
02-23	.0609	826	.0500	863	.0383	632	.0633	550	.0305	1597	.0227	885	.0789	1086	.0352	1461
02-24	.0594	863	.0500	845	.0399	638	.0609	556	.0258	1656	.0250	881	.0781	1094	.0367	1455
02-25	.0570	863	.0461	826	.0352	642	.0539	568	.0250	1702	.0211	881	.0711	1094	.0617	1436
02-26	.0570	863	.0469	826	.0360	647	.0539	562	.0289	1662	.0219	881	.0391	1094	.0555	1391
02-27	.0633	916	.0508	826	.0375	642	.0438	556	.0274	1644	.0235	881	.0305	1094	.0282	1351
02-28	.0633	881	.0477	826	.0313	647	.0469	550	.0258	1591	.0250	881	.0562	1094	.0235	1324
02-29							.0477	562							.0274	1290
03-01	.0757	836	.0570	826	.0375	647	.0321	568	.0266	1615	.0219	928	.0406	1094	.0258	1283
03-02	.0734	836	.0648	826	.0562	642	.0305	562	.0305	1662	.0289	969	.0289	1094	.0235	1283
03-03	.0648	836	.0633	826	.0609	638	.0328	580	.0430	1621	.0250	950	.0344	1094	.0391	1276
03-04	.0562	836	.0594	845	.0617	638	.0274	591	.0328	1627	.0235	937	.0461	1094	.0531	1276
03-05	.0492	836	.0664	854	.0835	647	.0266	614	.0258	1597	.0274	933	.0453	1109	.0391	1283
03-06	.0453	836	.0687	863	.0913	647	.0399	603	.0282	1656	.0399	933	.0422	1086	.0406	1304
03-07	.0430	836	.0648	881	.0867	642	.0297	620	.0375	1714	.0555	939	.0539	1063	.0820	1338
03-08	.0414	836	.0601	898	.0781	638	.0258	614	.0282	1650	.0243	957	.0438	1102	.0937	1436
03-09	.0399	836	.0562	916	.0718	645	.0243	614	.0243	1567	.0235	945	.0430	1109	.1124	1530
03-10	.0399	789	.0867	966	.1335	656	.0243	608	.0243	1499	.0211	928	.0383	1109	.1436	1621
03-11	.0430	836	.1959	1047	.1569	658	.0313	603	.0211	1423	.0204	916	.0399	1109	.1475	1621
03-12	.0469	836	.2037	1198	.1803	660	.0391	608	.0250	1404	.0227	909	.0399	1109	.2746	1561
03-13	.0508	836	.2193	1338	.1881	658	.0422	604	.0219	1165	.0282	922	.0570	1109	.1381	1480
03-14	.0547	836	.2271	1468	.1959	663	.0438	605	.0180	1098	.0360	860	.2037	1109	.1249	1455
03-15	.0586	836	.2115	1591	.2271	674	.0531	636	.0266	1132	.0375	891	.1444	1109	.1670	1585
03-16	.0625	836	.1803	1708	.1803	690	.0391	647	.0968	1180	.0336	885	.1007	1117	.2099	1814
03-17	.0672	836	.1491	1885	.1491	710	.0274	629	.0726	1213	.0274	909	.0859	1117	.2871	1928
03-18	.0726	836	.1257	2347	.2037	740	.0336	625	.0648	1241	.0250	1046	.0726	1154	.1896	1912
03-19	.0765	836	.1101	2412	.2427	760	.0438	605	.0453	1220	.0383	1122	.0851	1205	.1709	1896
03-20	.0773	836	.1101	2277	.1725	770	.0469	603	.0367	1191	.0344	1205	.0695	1255	.1826	1917
03-21	.0765	881	.1179	2137	.2349	779	.0438	625	.0375	1198	.0297	1290	.0586	1269	.1428	1917
03-22	.0757	924	.1257	1990	.2583	808	.0531	647	.0211	1248	.0453	1324	.0555	1248	.1093	1906
03-23	.0734	1007	.1257	1814	.2505	798	.0695	653	.0250	1262	.0430	1324	.0874	1310	.1218	1906
03-24	.0687	966	.1179	1759	.1413	790	.1179	677	.0258	1255	.0391	1384	.3253	1719	.1662	1896
03-25	.0633	924	.1101	1597	.1491	750	.2505	732	.0508	1220	.0406	1455	.5001	1890	.1327	1885
03-26	.0796	924	.1491	1436	.1413	748	.5703	725	.0555	1227	.0406	1518	.5094	2031	.0898	1864
03-27	.1413	924	.2271	1397	.1257	725	.5235	1679	.0687	1248	.0430	1555	.3768	1864	.1007	1847
03-28	.2193	966	.2583	1417	.1257	726	.1647	1567	.1530	1283	.0352	1567	.4384	2047	.0789	1842

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
03-29	.3051	1047	.2661	1536	.2817	1182	.1179	1549	.7458	1442	.0313	1585	.5219	1985	.0484	1825
03-30	.3207	1124	.3363	1673	.4143	1719	.1101	1549	1.4595	1656	.0328	1567	.2661	1792	.0445	1809
03-31	.2973	1162	.4611	1615	.6795	2102	.0789	1561	1.0773	1776	.0243	1524	.3035	1731	.0399	1798
04-01	.2193	1248	.5703	1770	.4455	2181	.0609	1561	1.2099	1820	.0282	1512	.3425	1736	.0703	1792
04-02	.3909	1191	.5781	2047	.1725	2258	.0578	1262	.9057	1814	.0469	1567	.7887	1759	.0399	1798
04-03	1.9525	1436	.4767	2102	.1647	2200	.0516	854	.4455	1825	.0484	1603	.3300	1650	.0328	1787
04-04	1.1865	1290	.3519	2016	.1725	2142	.0812	826	.2271	1836	.0321	1615	.0859	1621	.0289	1787
04-05	1.8745	1178	.7965	2697	.1023	2092	.1101	804	.2154	1874	.0289	1615	.0851	1597	.0367	1809
04-06	.5157	1076	.5703	2964	.0757	1753	.1335	793	.2707	1938	.0438	1673	.0757	1585	.0321	1787
04-07	.3519	1025	.4221	2928	.0687	1377	.1257	758	.2629	1954	.0516	1776	.0586	1573	.0500	1792
04-08	.2817	993	.2973	2756	.0765	1455	.1023	752	.2278	1943	.0453	1776	.0586	1573	.0391	1809
04-09	.2583	993	.1569	2851	.0945	1505	.1257	732	.2302	1938	.0406	1890	.0742	1597	.0601	1831
04-10	.2349	980	.1023	2555	.0664	1474	.1179	708	.1514	1831	.0469	1864	.1249	1603	.0718	1825
04-11	.1881	960	.0804	2062	.0648	1442	.0765	704	.0898	1759	.0344	1798	.1436	1603	.0594	1809
04-12	.1569	953	.0765	2087	.0594	1417	.0594	704	.0890	1759	.0289	1719	.1436	1621	.0547	1853
04-13	.1413	946	.0703	2097	.0828	1391	.0617	759	.1335	1809	.0282	1650	.1366	1603	.0867	2047
04-14	.1101	927	.0586	2016	.0937	1512	.3753	977	.1319	1825	.0274	1536	.1233	1603	.0960	2220
04-15	.0804	927	.0492	1696	.0835	1825	.4377	907	.1467	1825	.0243	1397	.1030	1603	.0843	2258
04-16	.0648	903	.0445	1530	.1179	2229	.2661	776	.0960	1776	.0235	1290	.0804	1585	.0804	2258
04-17	.0562	896	.0414	1480	.0750	2301	.1413	752	.0882	1776	.0235	1195	.0656	1597	.0625	2258
04-18	.0539	909	.0445	1499	.0656	2296	.1413	747	.0687	1787	.0219	1109	.0679	1597	.0469	2268
04-19	.0594	915	.0484	1518	.0851	2272	.1257	748	.0812	1787	.0227	1020	.0711	1615	.0586	2282
04-20	.0648	909	.0484	1615	.0492	2258	.0945	706	.0921	1787	.0219	994	.1062	1708	.0882	2329
04-21	.0648	859	.0484	1842	.0781	2291	.0656	725	.0874	1787	.0211	981	.1865	1814	.0773	2384
04-22	.0773	872	.0477	1809	.0648	2062	.0430	700	.1420	2102	.0219	988	.2567	1864	.0757	2393
04-23	.1257	896	.0773	1673	.0742	2239	.0422	699	.3207	2403	.0227	981	.1810	1858	.0492	2393
04-24	.1803	933	.1101	1573	.0742	2253	.0617	690	.1795	2412	.0227	969	.2271	1874	.0851	2384
04-25	.1881	927	.0796	1512	.0531	2220	.0539	686	.0999	2453	.0235	957	.1428	1858	.0594	2384
04-26	.1803	946	.0477	1518	.0648	2347	.0375	695	.0890	2466	.0227	951	.0874	1858	.0422	2393
04-27	.1413	915	.0438	1524	.0562	1719	.0328	693	.1280	2484	.0243	957	.0804	1906	.0796	2403
04-28	.1023	896	.0375	1561	.0484	1262	.0258	681	.1077	2475	.0352	994	.0773	1922	.0586	2403
04-29	.0882	878	.0336	1591	.0422	1283	.0250	668	.0804	2457	.0243	1007	.0781	1906	.0445	2403
04-30	.0789	865	.0375	1585	.0484	1324	.0250	662	.0742	2453	.0204	994	.0648	1906	.0430	2403
05-01	.0687	884	.0438	1512	.0633	1391	.0266	648	.1069	2453	.0235	988	.0555	1906	.0656	2403
05-02	.0656	909	.0406	1455	.0750	1397	.0266	646	.1459	2453	.0227	981	.0601	1906	.0547	2403
05-03	.0835	939	.0328	1397	.0726	1410	.0266	645	.1007	2444	.0344	963	.0687	1906	.0430	2393
05-04	.0945	933	.0297	1364	.0633	1397	.0266	653	.0976	2444	.0414	951	.0625	1906	.0438	2393
05-05	.0734	933	.0297	1391	.0570	1269	.0375	671	.1023	2434	.0250	945	.0648	1985	.0445	2412
05-06	.0508	939	.0328	1474	.0609	1171	.0406	696	.0718	2434	.0243	928	.0960	2142	.1904	2416
05-07	.0531	933	.0399	1644	.0601	1131	.0344	764	.0765	2393	.0219	937	.1420	2291	.1069	2425
05-08	.0555	966	.0445	1679	.0516	1104	.0516	1069	.0601	2466	.0289	990	.1335	2384	.0508	2425
05-09	.0469	953	.0945	1906	.0570	1173	.0469	1077	.0640	2393	.0344	1095	.1062	2393	.0484	2425
05-10	.1023	939	.1959	2533	.0781	1410	.0469	1077	.0484	2484	.0328	1159	.0968	2412	.0664	2546
05-11	.2271	1255	.2271	3132	.0820	1487	.0414	1058	.0531	2493	.0297	1156	.1054	2524	.0804	2714
05-12	.2583	1638	.2037	3261	.0820	1753	.0328	1065	.0601	2515	.0274	1166	.2278	2676	.1264	2859

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
05-13	.2037	1668	.1959	3473	.0742	1842	.0321	1089	.0640	2537	.0235	1227	.1194	2714	.1108	2908
05-14	.4845	1748	.1569	3368	.0695	1814	.0289	1083	.0703	2572	.0243	1304	.1389	2859	.0796	2916
05-15	1.7965	1896	.0945	2984	.0609	1449	.0289	1071	.0523	2444	.0258	1358	.1709	3105	.0508	2916
05-16	.5391	1736	.0711	2555	.0461	1102	.0360	1089	.0461	2425	.0243	1377	.1803	3170	.0906	3039
05-17	.1725	1719	.0633	2210	.0453	1152	.0453	1096	.0469	2380	.0305	1377	.1366	3170	.1717	3242
05-18	.1335	1753	.0570	2097	.0547	1371	.0874	1169	.0344	2347	.0718	1371	.1233	3234	.1015	3253
05-19	.1257	1842	.0508	1912	.0492	1442	.1023	1377	.0391	2347	.0508	1461	.1444	3473	.0828	3313
05-20	.1023	1474	.0430	1719	.0375	1455	.0648	1397	.0438	2347	.0430	1650	.1654	3565	.0672	3426
05-21	.0781	1006	.0414	1770	.0399	1436	.0648	1474	.0344	2347	.0648	1685	.1046	3572	.0921	3444
05-22	.1023	986	.0414	1518	.0399	1417	.0609	1536	.0656	2789	.0406	1691	.0882	3593	.0711	3433
05-23	.1803	1324	.0383	1615	.0906	1975	.0469	1430	.0921	2888	.0375	1685	.0718	3600	.0968	3537
05-24	.1959	1980	.0406	1621	.0672	2072	.0422	1338	.0578	2888	.0477	1691	.1007	3572	.0984	3639
05-25	.1725	2011	.0523	1597	.0586	2092	.0344	1195	.0555	2888	.0430	1691	.1475	3565	.0984	3646
05-26	.1725	2087	.0601	2031	.0679	2324	.0399	1297	.0297	2879	.0453	1798	.0867	3565	.1069	3646
05-27	.1881	2117	.0578	2016	.1257	2633	.0344	1324	.0266	2277	.0851	1874	.0562	3548	.0765	3663
05-28	.1881	2196	.0555	2016	.2817	3498	.0406	1324	.0289	2062	.0913	2006	.0562	3548	.0828	3673
05-29	.1647	2181	.0664	1970	.1881	3752	.0414	1377	.0289	2072	.0687	2087	.0609	3548	.0508	3691
05-30	.0945	2152	.0867	2425	.1959	3827	.0360	1297	.0336	2493	.0672	2112	.0843	3656	.0929	3708
05-31	.1023	2127	.0913	2650	.2427	4138	.0305	1283	.0375	2611	.0594	2112	.1093	3673	.0679	3708
06-01	.0945	2107	.0851	2706	.2817	4308	.0297	1397	.0352	2642	.0414	2122	.0562	3618	.0820	3708
06-02	.1335	2186	.0874	2916	.1725	4106	.0282	1283	.0414	2659	.0718	2229	.0648	3728	.0874	3877
06-03	.2115	2366	.0898	2956	.1725	3884	.0274	1423	.0625	3151	.0945	2333	.1116	3920	.0695	4022
06-04	.2349	2629	.0773	2936	.1881	3824	.0383	1331	.0562	3287	.1069	2439	.1015	4074	.0874	4048
06-05	.1881	2620	.0601	2697	.1413	3735	.1101	1714	.0375	2964	.1218	2572	.0984	4080	.0890	4106
06-06	.1413	2559	.0523	2493	.1257	3519	.3207	1798	.0313	2731	.1436	2590	.0976	4074	.1943	4293
06-07	.1257	2506	.0477	2097	.1257	3455	.3597	2497	.0289	2453	.0562	2603	.0734	4055	.1506	4465
06-08	.1179	2607	.0430	2042	.1257	3728	.4845	3331	.8433	2731	.0726	2611	.0843	4055	.1194	4616
06-09	.2349	2689	.0399	2057	.1179	3970	.3909	3701	.7692	2506	.1015	2624	.0726	4048	.1023	4832
06-10	.4767	3361	.0367	2102	.1023	3983	.1959	3555	.3402	2706	.0851	2629	.0586	4055	.1101	5198
06-11	.5469	3078	.0375	2166	.0617	3943	.2193	3735	.7013	4255	.3129	2810	.0453	4048	.1116	5307
06-12	.5313	3170	.0399	2225	.0453	3704	.1725	3803	.1748	4861	.7068	2896	.0804	4048	.0781	5307
06-13	.6405	3143	.0430	2176	.0773	3491	.1257	3533	.2294	4947	.3597	2777	.0516	4064	.1225	5600
06-14	.5547	2908	.0445	2225	.0679	3519	.0594	3466	.1389	4684	.2099	2727	.0484	4080	.1413	5833
06-15	.2895	2839	.0430	2161	.0750	3759	.0672	2839	.1194	4574	.0937	2718	.0414	4097	.6405	6084
06-16	.2661	2984	.0352	1959	.1023	3663	.0882	2793	.1319	4633	.0562	2603	.0562	4122	.1413	6232
06-17	.4221	3920	.0297	1787	.0773	3725	.0726	2976	.0984	4106	.0477	2572	.0640	4132	.0851	6134
06-18	.4221	4607	.0282	1708	.0555	3667	.0882	3101	.1140	3455	.0562	2568	.0461	4157	.0734	6010
06-19	.3207	4975	.0258	1673	.0523	3600	.0586	3101	.0929	3051	.0516	2546	.0555	4180	.1771	5909
06-20	.2583	5115	.0274	1673	.0586	3576	.0578	3105	.0531	2798	.0555	2533	.0516	4205	.0703	5679
06-21	.2115	5087	.0289	1679	.0789	4148	.1023	3379	2.6763	2338	.0352	2537	.0570	4230	.0703	5335
06-22	.1803	4890	.0321	1731	.1023	4224	.1179	3701	.7380	1912	.0391	2533	.0484	4221	.0804	4975
06-23	.1491	4763	.0477	1928	.2115	4669	.1491	3963	.0960	1792	.0492	2528	.0477	4249	.0718	4556
06-24	.1335	4745	.0672	2225	.1959	4777	.1881	4508	.0750	1970	.0422	2466	.0617	4240	.0991	4189
06-25	.1413	4803	.0703	2659	.1725	4745	.1881	4535	.0734	2533	.0438	2389	.0500	4343	.0820	4227
06-26	.1569	5003	.0570	2659	.1569	4890	.1179	3646	.0578	2764	.0453	2324	.0547	4648	.0477	4370

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
06-27	.1803	5307	.0500	2835	.1023	4947	.0812	2585	.0492	2806	.0383	2296	.0664	4728	.0461	4586
06-28	.2193	5653	.0438	2659	.0851	4918	.0383	2062	.0687	2697	.0321	2315	.0617	4736	.0438	4736
06-29	.2193	5730	.0328	2102	.1101	4861	.0344	2127	.0516	2676	.0289	2319	.0851	4947	.0367	4678
06-30	.1803	6059	.0274	1970	.1179	4832	.0227	1627	.0539	2667	.0274	2181	.0617	5115	.0367	4352
07-01	.1335	5679	.0266	1798	.0945	4890	.0266	1597	.0531	2466	.0266	2301	.0820	5143	.0344	3914
07-02	.1101	5031	.0274	1748	.1023	5003	.0274	1579	.0414	2384	.0250	2319	.0804	4975	.0321	3763
07-03	.0913	4523	.0289	1753	.0913	4890	.0266	1524	.0305	2301	.0219	2324	.0383	4616	.0313	3708
07-04	.0804	4255	.0258	1748	.0851	4832	.0430	2186	.0227	2127	.0235	2333	.0492	4508	.0289	3509
07-05	.0750	4157	.0235	1776	.0555	4783	.0399	1603	.0313	2097	.0243	2329	.0461	4489	.0336	3491
07-06	.0765	4138	.0235	1770	.0687	4918	.0227	1512	.0336	2087	.0453	2338	.0562	4465	.0328	3480
07-07	.0773	4173	.0235	1736	.0757	4947	.0227	1505	.0289	2062	.0336	2296	.0414	4148	.0258	3268
07-08	.0726	4230	.0243	1615	.0851	4947	.0243	1505	.0274	1792	.0227	2181	.0516	3860	.0274	2944
07-09	.0679	4299	.0258	1555	.0851	5031	.0250	1505	.0297	1621	.0219	2067	.0453	3583	.0274	2916
07-10	.0718	4352	.0266	1524	.0399	4947	.0250	1518	.0305	1615	.0211	1970	.0430	3208	.0313	2916
07-11	.0757	4380	.0243	1505	.0617	4918	.0235	1487	.0297	1748	.0235	1959	.0422	2789	.0313	2928
07-12	.0648	4380	.0227	1423	.0695	4731	.0227	1499	.0297	1809	.0211	1954	.0391	2403	.0414	2806
07-13	.0586	4361	.0211	1371	.0516	4618	.0219	1518	.0258	1809	.0219	1949	.0352	1990	.0258	2773
07-14	.0640	4336	.0211	1430	.0313	4486	.0204	1410	.0321	1825	.0243	1880	.0289	1679	.0274	2756
07-15	.0672	4514	.0204	1442	.0648	3813	.0219	1397	.0406	1842	.0235	1742	.0258	1603	.0328	2756
07-16	.0586	4413	.0211	1461	.0664	3670	.0235	1397	.0617	1825	.0227	1627	.0250	1585	.0274	2739
07-17	.0523	4255	.0204	1499	.0555	3625	.0227	1417	.0360	1814	.0211	1579	.0344	1567	.0289	2722
07-18	.0586	4097	.0196	1468	.0414	3551	.0227	1480	.0422	1890	.0204	1555	.0274	1585	.0328	2706
07-19	.3129	3980	.0196	1377	.0266	3537	.0219	1377	.0547	2176	.0211	1549	.6607	1719	.0383	2680
07-20	.6093	3223	.0196	1331	.0445	3526	.0219	1474	.0562	2357	.0219	1555	.2115	1814	.0360	2594
07-21	.4221	3350	.0204	1358	.0399	3494	.0211	1461	.0586	2434	.0211	1549	.1077	2047	.0243	2416
07-22	.1491	3491	.0219	1442	.0211	3302	.0211	1480	.0578	2434	.0313	1549	.1155	2403	.0305	2361
07-23	.1101	3583	.0227	1455	.0313	3231	.0219	1468	.0695	2434	.1779	1591	.1155	2697	.0305	2380
07-24	.1023	3611	.0235	1461	.0235	3162	.0243	1297	.0461	2425	.0984	1555	.0773	2798	.0243	2380
07-25	.0945	3600	.0235	1480	.0383	3494	.0500	1324	.0266	2370	.0422	1567	.0835	3003	.0250	2380
07-26	.0859	3583	.0243	1455	.0430	3272	.0258	1317	.0383	2220	.0508	1555	.0477	3003	.0305	2319
07-27	.0789	3537	.0235	1391	.0523	2904	.0258	1455	.0367	2176	.0360	1549	.0477	2976	.0282	2291
07-28	.0656	3526	.0211	1351	.0703	2581	.0235	1449	.0289	2166	.0438	1555	.0734	2773	.0227	2220
07-29	.0531	3462	.0204	1324	.0523	2171	.0235	1436	.0250	2042	.0383	1549	.0492	2676	.0219	2176
07-30	.0500	3361	.0211	1344	.0367	1449	.0243	1436	.0274	2006	.0367	1542	.0297	2444	.0219	2161
07-31	.0508	3361	.0211	1351	.0282	1423	.0266	1417	.0266	1990	.0375	1536	.0274	2291	.0250	2161
08-01	.0445	3178	.0211	1324	.0243	1410	.0266	1449	.0274	1975	.0360	1530	.0258	2249	.0274	2137
08-02	.0383	3086	.0219	1310	.0266	1255	.0266	1442	.0430	1975	.0375	1518	.0266	2258	.0352	2031
08-03	.0399	3003	.0586	1384	.0243	1474	.0227	1436	.0375	1985	.0383	1505	.0391	2258	.0422	1970
08-04	.0383	2936	.1257	1404	.0235	1512	.0243	1442	.0297	1985	.0453	1505	.0414	2196	.0235	1864
08-05	.0367	2814	.1335	1297	.0204	1518	.0250	1397	.0289	1928	.0765	1518	.0469	2112	.0235	1874
08-06	.0328	2676	.0828	1262	.0250	1530	.0235	1449	.0266	1753	.0601	1518	.0414	2047	.0258	1906
08-07	.0305	2550	.0570	1241	.0305	1542	.0211	1449	.0391	1585	.0422	1512	.0344	1975	.0235	1912
08-08	.0289	2416	.0617	1283	.0266	1542	.0235	1442	.0297	1555	.0282	1499	.0305	1985	.0266	1906
08-09	.0297	2315	.0617	1351	.0258	1542	.1257	1423	.0243	1549	.0305	1493	.0508	2016	.0274	1885
08-10	.0305	2234	.0492	1377	.0258	1549	.0804	1536	.0243	1555	.0438	1505	.0664	2047	.0711	1776

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
08-11	.0289	2171	.0391	1344	.0258	1555	.2349	1549	.0375	1536	.0297	1505	.0313	2196	.0461	1809
08-12	.0282	2117	.0336	1255	.0274	1555	.2193	1906	.0328	1530	.0250	1505	.0258	1906	.0282	1814
08-13	.0711	2077	.0289	1169	.0235	1555	.0929	2062	.0266	1530	.0266	1499	.0305	1759	.0367	1809
08-14	.1101	2047	.0266	1119	.0266	1561	.0492	1609	.0243	1530	.0243	1505	.0274	1814	.0422	1809
08-15	.0711	2026	.0250	1096	.0227	1561	.1179	1990	.0227	1530	.0227	1499	.0282	1825	.0282	1776
08-16	.0282	2062	.0243	1079	.0219	1561	.0742	2107	.0227	1549	.0227	1512	.0258	1814	.0344	1776
08-17	.0258	2011	.0243	1041	.0289	1561	.0430	1644	.0227	1555	.0235	1505	.0243	1787	.0243	1792
08-18	.0266	2006	.0243	1011	.0250	1549	.0399	1719	.0414	1561	.0211	1499	.0219	1759	.0243	1792
08-19	.0328	2037	.0258	1025	.0227	1468	.0523	1954	.0391	1549	.0204	1404	.0211	1736	.0243	1798
08-20	.0406	2102	.0274	1016	.0243	1555	.0414	1781	.0297	1530	.0211	1213	.0211	1714	.0196	1814
08-21	.0391	2215	.0274	994	.0258	1549	.0344	1621	.0250	1493	.0204	1062	.0204	1696	.0258	1814
08-22	.0375	2277	.0243	981	.0250	1542	.0711	1990	.0266	1449	.0196	1151	.0204	1696	.0235	1798
08-23	.0399	2286	.0235	993	.0274	1542	.1491	2137	.0219	1423	.0211	1317	.0243	1696	.0258	1792
08-24	.0375	2277	.0243	1012	.0250	1536	.1335	2310	.0227	1417	.0204	1310	.0243	1691	.0258	1776
08-25	.0321	2249	.0243	1005	.0243	1536	.1413	2718	.0235	1404	.0258	1417	.0204	1679	.0211	1753
08-26	.0274	2205	.0227	1002	.0243	1248	.2115	3116	.0235	1391	.0250	1536	.0188	1549	.0211	1731
08-27	.0243	2137	.0219	961	.0250	893	.1335	2633	.0227	1364	.0258	1530	.0204	1461	.0204	1696
08-28	.0227	2067	.0227	924	.0243	939	.0921	2594	.0204	1324	.0258	1549	.0250	1480	.0250	1673
08-29	.0227	2011	.0305	912	.0305	1512	.0703	2594	.0211	1324	.0399	1549	.0625	1493	.0219	1656
08-30	.0227	1949	.0399	918	.0305	1518	.0469	1696	.0243	1310	.0321	1549	.0531	1493	.0235	1638
08-31	.0235	1864	.0352	942	.0586	1567	.0648	2444	.0227	1310	.0227	1542	.0235	1487	.0266	1627
09-01	.0243	1809	.0523	973	.0531	1518	.0820	2564	.0211	1317	.0250	1536	.0321	1480	.0289	1638
09-02	.0243	1770	.0804	949	.0383	1397	.0874	2581	.0250	1317	.0562	1536	.0243	1430	.0219	1638
09-03	.0250	1736	.0633	934	.0305	1499	.0539	2577	.0266	1317	.0375	1536	.0266	1397	.0188	1638
09-04	.0266	1708	.0406	922	.0289	1493	.0399	2225	.0266	1317	.0250	1530	.0211	1404	.0188	1627
09-05	.1491	4296	.0531	943	.0313	1480	.0383	2210	.0344	1304	.0375	1549	.0188	1404	.0508	1650
09-06	.3628	6084	.0726	994	.0313	1474	.0367	1975	.0243	1304	.1249	1603	.0196	1417	.0945	1668
09-07	.2193	6544	.0633	1050	.0305	1468	.0321	1798	.0235	1310	.0984	1579	.0344	1449	.0313	1650
09-08	.1725	6473	.0438	1036	.0258	1344	.0258	1836	.0250	1317	.0360	1555	.0664	1430	.0321	1627
09-09	.1491	6377	.0367	1021	.0313	1461	.0313	1885	.0227	1317	.0328	1536	.0258	1417	.0250	1621
09-10	.1335	6280	.0321	1036	.0250	1455	.0492	1896	.0258	1331	.0282	1536	.0227	1404	.0219	1615
09-11	.1101	6280	.0297	1017	.0289	1449	.0344	1702	.0313	1423	.0274	1536	.0321	1397	.0219	1615
09-12	.0945	6059	.0297	990	.0258	1234	.0274	1781	.0266	1391	.0321	1524	.0243	1384	.0258	1621
09-13	.0929	5833	.0282	980	.0219	1109	.0297	1573	.0391	1344	.0336	1542	.0211	1377	.0313	1384
09-14	.1023	5627	.0328	976	.0219	1142	.0211	1708	.0523	1331	.0305	1555	.0274	1371	.0219	1351
09-15	.1023	4061	.0617	994	.0227	1104	.0211	1685	.0321	1317	.0243	1555	.0235	1371	.0188	1255
09-16	.0874	3234	.0835	989	.0243	1102	.0211	1685	.0282	1324	.0227	1555	.0227	1377	.0196	1097
09-17	.0757	3600	.0633	1066	.0219	1109	.0219	1662	.0289	1331	.0438	1542	.0235	1391	.0188	1087
09-18	.0625	3444	.0383	1076	.0235	1133	.0196	1561	.0289	1324	.0297	1549	.0227	1397	.0188	1089
09-19	.0531	3331	.0321	1047	.0375	1177	.0204	1591	.0375	1317	.0258	1536	.0258	1397	.0196	1102
09-20	.0531	3261	.0321	1059	.0211	1136	.0250	1597	.0258	1317	.0789	1524	.0258	1397	.0204	1097
09-21	.0555	3223	.0313	1098	.0305	1184	.0235	1621	.0243	1338	.0399	1530	.0235	1391	.0219	1091
09-22	.0531	3162	.0274	1087	.0313	1241	.0196	1708	.0289	1351	.0211	1384	.0227	1391	.0196	1110
09-23	.0445	3078	.0250	1055	.0211	1241	.0235	1708	.0344	1331	.0219	1114	.0430	1377	.0180	1213
09-24	.0414	3031	.0266	1028	.0204	1241	.0243	1685	.0422	1269	.0243	830	.0336	1371	.0196	1248

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1964-65		1965-66		1966-67		1967-78		1968-69		1969-70		1970-71		1971-72	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
09-25	.0438	2976	.0289	1028	.0227	1234	.0204	1685	.0289	1227	.0204	665	.0781	1371	.0227	1255
09-26	.0422	2896	.0375	1055	.0196	1166	.0204	1685	.0297	1193	.0188	658	.0867	1377	.0235	1255
09-27	.0383	2851	.0477	1024	.0227	1072	.0211	1765	.0227	1160	.0204	844	.0375	1391	.0235	1138
09-28	.0375	2785	.0422	989	.0196	1054	.0227	2011	.0227	1132	.0227	851	.0243	1391	.0235	1137
09-29	.0375	2748	.0305	953	.0235	1051	.0274	2087	.0227	1128	.0211	852	.0243	1371	.0219	1234
09-30	.0367	2697	.0282	936	.0211	1057	.0289	2092	.0211	1096	.0196	838	.0305	1364	.0211	1234

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
10-01	.0219	1234	.0414	716	.0445	973	.0196	1030	.0227	1147	.0609	754	.0266	736
10-02	.0211	1283	.0976	1060	.0305	979	.0227	1030	.0227	1154	.0555	760	.0204	1008
10-03	.0211	1310	.0555	1317	.0243	985	.0188	1023	.0282	1162	.0539	760	.0188	1014
10-04	.0227	1310	.0570	1536	.0250	1072	.0188	1016	.0266	1162	.0547	754	.0204	1014
10-05	.0243	1331	.0360	1638	.0227	1190	.0211	1016	.0243	1170	.0578	766	.0188	1014
10-06	.0523	1331	.0289	1644	.0188	1183	.0188	1016	.0258	1162	.0640	806	.0180	1014
10-07	.0258	1269	.0601	1603	.0180	1190	.0219	1016	.0274	1162	.2247	907	.0188	1020
10-08	.0180	1324	.0321	1377	.0180	1196	.0219	1065	.0274	1162	.3168	812	.0219	1025
10-09	.0188	1324	.0227	1227	.0180	1183	.0258	1154	.0243	1162	.1335	795	.0321	1025
10-10	.0367	1344	.0204	1234	.0180	1170	.0188	1162	.0250	1154	.1132	789	.0204	1025
10-11	.0672	1331	.0204	1220	.0188	1170	.0180	1154	.0282	1154	.0414	800	.0188	1020
10-12	.0227	1324	.0243	1205	.0188	1157	.0180	1162	.0289	1154	.0492	823	.0188	1014
10-13	.0211	1331	.0243	1205	.0180	1170	.0196	1198	.0289	1154	.0516	806	.0188	1014
10-14	.0227	1317	.0250	1198	.0172	1163	.0243	1186	.0274	1147	.0531	789	.0180	1014
10-15	.0196	1338	.0266	1196	.0243	1163	.0211	1178	.0258	1140	.0539	795	.0188	1014
10-16	.0344	1338	.0258	1197	.0196	1157	.0219	1178	.0266	1140	.0516	795	.0180	1014
10-17	.0352	1436	.0266	1190	.0180	1157	.0204	1186	.0391	1140	.0453	783	.0188	1020
10-18	.0227	1297	.0274	1187	.0188	1150	.0196	1186	.0289	1140	.0430	783	.0204	1036
10-19	.0196	1118	.0289	1184	.0188	1150	.0219	1186	.0250	1147	.0422	789	.0235	1020
10-20	.0196	1124	.0336	1183	.0188	1157	.0211	1186	.0243	1147	.0445	800	.0250	1020
10-21	.0211	1234	.0313	1183	.0196	1157	.0211	1186	.0274	1147	.0508	829	.0204	1020
10-22	.0258	1536	.0313	1191	.0180	1163	.0172	1186	.0289	1147	.0477	817	.0196	1020
10-23	.0227	1555	.0360	1189	.0180	1170	.0188	1194	.0266	1147	.0484	806	.0188	1020
10-24	.0383	1585	.0367	1185	.0188	1163	.0196	1220	.0243	1147	.0461	800	.0235	1014
10-25	.0258	1579	.0297	1187	.0188	1157	.0180	1213	.0250	1154	.0461	800	.0204	1025
10-26	.0227	1579	.0289	1227	.0188	1157	.0219	1213	.0235	1162	.0453	800	.0219	1025
10-27	.0235	1567	.0352	1283	.0196	1150	.0235	1234	.0360	1162	.0477	800	.0196	1020
10-28	.0211	1561	.0640	1276	.0204	1150	.0211	1220	.0243	1162	.0399	800	.0211	1014
10-29	.0211	1579	.0445	1283	.0188	1157	.0227	1220	.0204	1170	.0477	806	.0196	1014
10-30	.0196	1567	.0367	1283	.0867	1196	.0188	1213	.0250	1170	.0469	812	.0204	1014
10-31	.0204	1555	.0282	1276	.1085	1170	.0321	1213	.0274	1170	.0360	812	.0204	1020
11-01	.0250	1549	.0289	1290	.0344	1131	.0477	1213	.0336	1162	.0297	812	.0250	1020
11-02	.0219	1542	.0258	1283	.0243	1092	.0336	1194	.0313	1178	.0469	795	.0235	1025

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
11-03	.0188	1561	.0289	1290	.0305	1085	.0289	1194	.0250	1194	.0297	789	.0204	1031
11-04	.0196	1567	.0266	1283	.0227	1085	.0243	1194	.0219	1194	.0336	800	.0219	1014
11-05	.0258	1567	.0243	1276	.0274	1085	.0243	1194	.0266	1186	.0399	817	.0219	1008
11-06	.0282	1579	.0227	1255	.0196	1085	.0250	1198	.0196	1186	.0422	829	.0188	1008
11-07	.0219	1512	.0274	1290	.0180	1085	.0282	1198	.0188	1186	.0430	836	.1608	1003
11-08	.0344	1213	.0305	1310	.0188	1085	.0235	1198	.0204	1186	.0375	829	.0211	1003
11-09	.0235	1035	.0492	1297	.0188	1085	.0227	1198	.0204	1186	.0406	823	.0235	1003
11-10	.0204	1028	.0321	1290	.0196	1085	.0266	1198	.0219	1186	.0321	806	.0492	1014
11-11	.0196	1072	.0243	1290	.0196	1079	.0243	1176	.0211	1186	.0687	812	.0687	863
11-12	.0204	1317	.0258	1283	.0188	1085	.0282	1184	.0227	1186	.0313	800	.0422	941
11-13	.0196	1317	.0321	1283	.0180	1079	.0321	1184	.0196	1186	.0328	800	.0508	1032
11-14	.0243	1410	.0243	1283	.0180	1079	.0227	1178	.0211	1186	.0360	806	.0289	1016
11-15	.0227	1480	.0211	1276	.0180	1092	.0219	1178	.0188	1170	.0328	800	.0235	999
11-16	.0211	1480	.0211	1276	.0196	1092	.0196	1194	.0266	1154	.0344	806	.0211	983
11-17	.0196	1480	.0227	1276	.0180	1099	.0258	1194	.0204	1170	.0305	800	.0243	999
11-18	.0204	1480	.0235	1283	.0188	1105	.0219	1198	.0274	1162	.0250	800	.0219	1047
11-19	.0227	1487	.0250	1283	.0180	1124	.0235	1198	.0258	1162	.0204	765	.0219	1162
11-20	.0219	1487	.0258	1213	.0180	1176	.0492	1184	.0243	1154	.0601	740	.0235	1234
11-21	.0196	1493	.0243	1046	.0188	1183	.0274	1176	.0243	1162	.0711	710	.0274	1269
11-22	.0235	1512	.0243	1063	.0211	1190	.0204	1162	.0321	1162	.0352	750	.0235	1248
11-23	.0313	1591	.0227	1086	.0188	1196	.0196	1176	.0227	1154	.0352	876	.0219	1262
11-24	.0336	1650	.0235	1094	.0204	1190	.0188	1198	.0180	1154	.0453	922	.0313	1198
11-25	.0297	1650	.0250	1102	.0204	1190	.0235	1198	.0196	1147	.0461	985	.0227	1102
11-26	.0367	1638	.0414	1109	.0196	1190	.0250	1198	.0570	1140	.0344	939	.0219	1198
11-27	.0274	1650	.0258	1102	.0211	1191	.0282	1269	.0945	1094	.0438	922	.0227	1198
11-28	.0648	1650	.0445	1124	.0243	1191	.0445	1304	.0289	1032	.0352	865	.0211	1147
11-29	.0352	1650	.0609	1102	.0219	1187	.0375	1324	.0274	1032	.0414	888	.0219	1124
11-30	.0289	1579	.0375	1094	.0250	1184	.0219	1371	.0235	1071	.0360	817	.0258	1269
12-01	.0243	1499	.0664	999	.0211	1187	.0243	1404	.0258	1124	.0305	750	.0219	1269
12-02	.0219	1377	.0555	1016	.0243	1187	.0360	1468	.0352	1162	.0383	745	.0235	1147
12-03	.0219	1234	.0414	1063	.0266	1191	.0211	1468	.0672	1198	.0344	854	.0204	1047
12-04	.0555	1047	.0492	1102	.0204	1191	.1319	1449	.0391	1169	.0414	817	.0211	1032
12-05	.0867	916	.0445	1102	.0211	1190	.1038	1404	.0235	1109	.0516	745	.0297	1124
12-06	.0321	881	.0539	1109	.0211	1176	.0578	1455	.0336	1147	.0578	695	.0235	1032
12-07	.1959	889	.0508	1113	.0227	1162	.1124	1430	.0734	1198	.0570	779	.0243	898
12-08	.2154	898	.0375	1117	.0235	1099	.0960	1358	.0484	1184	.0640	636	.0258	1016
12-09	.3285	907	.0360	1102	.0601	924	.0321	1310	.0383	1154	.0360	720	.0360	933
12-10	.2286	958	.0274	1071	.1077	1007	.0250	1338	.0679	1109	.0274	889	.0219	991
12-11	.1101	1007	.0282	1063	.0344	1162	.0235	1310	.0383	1102	.0336	983	.0219	1147
12-12	.0336	1086	.0258	1102	.0297	1169	.0235	1297	.0297	1094	.0328	1063	.1647	1198
12-13	.0227	1169	.0243	1094	.0352	1169	.0235	1297	.0328	1106	.0313	1047	.0227	1269
12-14	.0235	1176	.0282	1071	.1920	1169	.0258	1297	.0243	1147	.0235	1109	.0219	1234
12-15	.0235	1184	.0297	1071	.0882	1169	.0258	1269	.0235	1176	.0258	1124	.0219	1269
12-16	.0196	1176	.0360	1055	.1218	1176	.0258	1234	.0219	1198	.0274	983	.0211	1304
12-17	.0188	1154	.0367	1086	.0508	1176	.0196	1198	.0235	1241	.0258	889	.0227	1304

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
12-18	.0211	1117	.0305	1102	.0235	1184	.0375	1198	.0219	1234	.0243	999	.0227	1304
12-19	.0204	1039	.0274	1109	.0250	1184	.0539	1234	.0243	1220	.0227	907	.0211	1269
12-20	.0204	1016	.0305	1117	.0258	1184	.0890	1304	.0250	1198	.0211	889	.0211	1269
12-21	.0180	1007	.0367	1109	.0266	1198	.0890	1338	.0250	1191	.0243	1007	.0211	1198
12-22	.0188	999	.0274	1086	.0235	1198	.1475	1338	.0243	1191	.0250	1079	.0204	1169
12-23	.0196	1032	.0313	1117	.0219	1198	.1413	1338	.0289	1198	.0360	1109	.0211	1184
12-24	.0211	1063	.0243	1102	.0219	1198	.0352	1331	.0266	1205	.0438	1162	.0204	1234
12-25	.0211	1063	.0367	1086	.0391	1191	.1140	1338	.0250	1234	.0297	1162	.0211	1269
12-26	.0258	1063	.0328	1079	.0547	1191	.1155	1344	.0258	1248	.0305	1140	.0227	1269
12-27	.0227	1063	.0235	1055	.0266	1191	.0625	1338	.0328	1255	.0274	1094	.0219	1255
12-28	.0211	1063	.0204	1086	.0211	1191	.0687	1331	.0250	1248	.0313	1047	.0243	1234
12-29	.0250	1047	.0422	1117	.0227	1184	.0336	1331	.0235	1220	.0266	1086	.0289	1124
12-30	.0258	966	.0305	1102	.0508	1184	.0219	1338	.0289	1205	.0266	1176	.0243	1047
12-31	.0243	1047	.0227	1132	.0625	1184	.0219	1331	.0289	1184	.0367	1147	.0250	966
01-01	.0196	1094	.0211	1162	.0375	1191	.0196	1317	.0250	1176	.0367	1055	.0243	907
01-02	.0211	1079	.0274	1176	.0258	1198	.0250	1297	.0289	1198	.0243	966	.0227	924
01-03	.0508	1055	.0227	1184	.0204	1198	.0227	1304	.0282	1205	.0266	898	.0235	991
01-04	.0321	1124	.0219	1184	.0266	1198	.0204	1324	.0282	1184	.0258	1024	.0227	1102
01-05	.0539	1147	.0227	1169	.0828	1191	.0196	1338	.0227	1162	.0289	1132	.0219	1269
01-06	.0898	1154	.0227	1162	.0243	1191	.0258	1324	.0243	1140	.0282	1191	.0250	1338
01-07	.0360	1154	.0235	1140	.0196	1191	.0360	1310	.0289	1117	.0274	1269	.0258	1338
01-08	.0726	1154	.0243	1147	.0180	1184	.0235	1304	.0250	1094	.0352	1304	.0266	1269
01-09	.0336	1154	.0235	1154	.0180	1162	.0188	1297	.0266	1109	.0391	1304	.0227	1184
01-10	.0211	1154	.0211	1140	.0188	1147	.0227	1283	.0243	1124	.0282	1304	.0235	1162
01-11	.0227	1024	.0227	1109	.0180	1162	.0211	1283	.0250	1140	.0305	1310	.0266	1184
01-12	.0219	1176	.0196	1071	.0196	1184	.0211	1283	.0258	1154	.0297	1297	.0227	1234
01-13	.0219	1176	.0196	1071	.0211	1198	.0219	1283	.0258	1162	.0274	1297	.0211	1269
01-14	.0204	1241	.0196	1094	.0204	1205	.0227	1283	.0250	1198	.0297	1304	.0211	1269
01-15	.0204	1331	.0211	1055	.0211	1213	.0344	1283	.0243	1255	.0321	1310	.0227	1269
01-16	.0243	1417	.0211	1039	.0196	1213	.0305	1297	.0250	1269	.0313	1297	.0235	1241
01-17	.0266	1487	.0219	1032	.0219	1234	.0258	1324	.0243	1304	.0282	1290	.0227	1198
01-18	.0250	1499	.0211	1024	.0227	1234	.0250	1338	.0235	1304	.0282	1290	.0243	1184
01-19	.0258	1542	.0243	1169	.0188	1227	.0282	1371	.0243	1269	.0289	1304	.0313	1191
01-20	.0250	1585	.0289	1397	.0219	1227	.0219	1371	.0235	1220	.0289	1310	.0227	1198
01-21	.0243	1561	.0274	1518	.0305	1220	.0211	1364	.0219	1198	.0297	1310	.0211	1191
01-22	.0227	1505	.0258	1679	.0188	1213	.0211	1338	.0274	1176	.0274	1290	.0219	1198
01-23	.0227	1493	.0258	1765	.0282	1213	.0188	1297	.0438	1184	.0391	1290	.0204	1198
01-24	.0211	1480	.0258	1820	.0336	1213	.0180	1269	.0289	1198	.0406	1269	.0204	1234
01-25	.0211	1468	.0274	1825	.0196	1213	.0219	1255	.0282	1205	.0250	1213	.0211	1269
01-26	.0219	1474	.0274	1820	.0211	1213	.0188	1255	.0211	1205	.0250	1283	.0211	1269
01-27	.0211	1468	.0243	1814	.0180	1220	.0188	1269	.0204	1198	.0297	1262	.0211	1269
01-28	.0227	1461	.0235	1809	.0188	1220	.0235	1276	.0211	1198	.0383	1198	.0219	1269
01-29	.0282	1461	.0282	1809	.0204	1213	.0266	1283	.0352	1227	.0289	1079	.0219	1269
01-30	.0243	1468	.0313	1820	.0305	1191	.0235	1324	.0336	1255	.0321	1071	.0211	1269
01-31	.0243	1461	.0219	1825	.0219	1191	.0297	1338	.0282	1262	.0258	1071	.0219	1269

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
02-01	.0274	1338	.0204	1820	.0321	1198	.0204	1324	.0305	1262	.0258	1071	.0227	1269
02-02	.0289	1442	.0243	1825	.0250	1213	.0196	1338	.0289	1262	.0243	1071	.0235	1269
02-03	.0243	1455	.0227	1820	.0406	1213	.0227	1310	.0243	1262	.0258	1071	.0266	1262
02-04	.0227	1449	.0211	1814	.0508	1220	.0204	1269	.0282	1262	.0313	1079	.0250	1255
02-05	.0211	1461	.0211	1820	.0430	1220	.0196	1241	.0289	1262	.0336	1071	.0243	1269
02-06	.0211	1468	.0211	1809	.0258	1227	.0196	1241	.0453	1262	.0313	1079	.0235	1269
02-07	.0211	1530	.0211	1792	.0399	1227	.0235	1227	.0305	1262	.0305	1079	.0243	1269
02-08	.0227	1603	.0204	1776	.0539	1227	.0282	1241	.0313	1269	.0352	1071	.0352	1262
02-09	.0250	1656	.0196	1792	.0500	1220	.0243	1269	.0321	1276	.0297	1079	.0430	1262
02-10	.0250	1708	.0274	1814	.0399	1220	.0243	1283	.0336	1283	.0289	1071	.0258	1255
02-11	.0250	1736	.0274	1820	.0352	1220	.0235	1269	.0328	1255	.0305	1079	.0235	1255
02-12	.0258	1736	.0211	1820	.0633	1220	.0227	1269	.0344	1213	.0313	1063	.0219	1262
02-13	.0250	1736	.0227	1820	.0812	1227	.0219	1269	.0367	1213	.0282	1039	.0235	1262
02-14	.0289	1736	.0235	1820	.0321	1220	.0204	1269	.0422	1184	.0289	1024	.0258	1269
02-15	.0258	1736	.0243	1820	.0438	1220	.0211	1269	.0360	1198	.0360	1248	.0321	1269
02-16	.0305	1736	.0258	1814	.0360	1220	.0243	1269	.0344	1184	.0352	1404	.0266	1283
02-17	.0289	1731	.0250	1809	.0227	1220	.0258	1262	.0328	1176	.0352	1449	.0406	1304
02-18	.0274	1731	.0391	1809	.0258	1220	.0313	1262	.0305	1162	.0399	1404	.0289	1304
02-19	.0250	1731	.0305	1809	.0227	1220	.0266	1269	.0344	1147	.0406	1371	.0430	1262
02-20	.0243	1731	.0305	1809	.0243	1220	.0211	1269	.0313	1132	.0445	1404	.0282	1234
02-21	.0235	1725	.0360	1809	.0219	1220	.0188	1255	.0313	1124	.0430	1404	.0250	1241
02-22	.0297	1719	.0289	1809	.0227	1227	.0180	1269	.0321	1140	.0469	1404	.0235	1255
02-23	.0274	1725	.0336	1809	.0250	1213	.0204	1283	.0328	1154	.0453	1404	.0243	1255
02-24	.0243	1725	.0258	1792	.0219	1198	.0180	1304	.0360	1124	.0469	1430	.0235	1262
02-25	.0258	1719	.0196	1765	.0227	1213	.0180	1304	.0266	1086	.0531	1461	.0243	1255
02-26	.0258	1719	.0227	1803	.0227	1220	.0227	1338	.0282	1109	.0547	1461	.0250	1255
02-27	.0250	1714	.0445	1809	.0219	1213	.0227	1371	.0250	1094	.1116	1449	.0235	1269
02-28	.0266	1650	.0399	1814	.0235	1213	.3472	1436	.0258	1086	.0890	1430	.0235	1269
02-29							.2934	1505						
03-01	.0321	1468	.0430	1820	.0547	1205	.4494	1530	.0274	1094	.0711	1404	.0250	1297
03-02	.0336	1269	.0461	1765	.0360	1205	.2154	1468	.0211	1109	.0562	1391	.0243	1269
03-03	.0274	1162	.0445	1714	.0313	1205	.0828	1404	.0321	1109	.0531	1391	.0243	1248
03-04	.0227	1143	.0430	1696	.0266	1213	.0555	1338	.0328	1132	.0711	1455	.0243	1255
03-05	.0219	1147	.0336	1662	.0227	1205	.0851	1338	.0266	1140	.0851	1530	.0250	1269
03-06	.0243	1149	.0336	1685	.0243	1205	.0812	1371	.0305	1124	.1288	1591	.0243	1283
03-07	.0235	1147	.1101	1708	.0235	1198	.0812	1371	.0313	1109	.3565	1650	.0835	1290
03-08	.0250	1162	.1725	1736	.0211	1205	.0695	1404	.0352	1102	.3425	1708	.0890	1290
03-09	.0266	1198	.1725	1803	.0266	1213	.0906	1417	.0461	1094	.2700	1638	.0453	1269
03-10	.0445	1304	.2466	1864	.0289	1205	.1350	1455	.0383	1079	.2115	1536	.0414	1248
03-11	.0321	1410	.2481	1906	.0282	1205	.2029	1468	.0375	975	.1335	1524	.0328	1255
03-12	.0367	1474	.1951	1928	.0282	1213	.1327	1555	.0968	950	.1803	1549	.0399	1290
03-13	.0367	1597	.0750	1742	.0313	1213	.0867	1650	.0492	941	.2466	1505	.0344	1269
03-14	.0367	1662	.0484	1621	.0469	1213	.0906	1708	.0313	928	.1615	1442	.0360	1269
03-15	.0313	1708	.0555	1638	.0274	1205	.1132	1820	.0375	916	.0445	1397	.0375	1269
03-16	.0391	1765	.0984	1714	.0211	1198	.1686	1765	.0422	899	.0484	1391	.0399	1241

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
03-17	.0313	1770	.2294	1719	.0266	1198	.0757	1673	.0352	829	.0453	1310	.0445	1255
03-18	.0313	1776	.3300	1842	.0219	1198	.0835	1742	.0336	812	.0695	1227	.0469	1304
03-19	.0414	1765	.5593	1847	.0274	1198	.4065	1954	.0321	800	.1608	1338	.0516	1391
03-20	.0679	1759	.4977	1853	.0297	1205	.4104	1809	.0430	800	.5430	1391	.0531	1468
03-21	.0336	1719	.1030	1725	.0289	1205	.2598	1673	.0274	789	.3675	1276	.0500	1499
03-22	.0383	1736	.0898	1685	.0289	1198	.0773	1650	.0328	823	.3129	1213	.0453	1530
03-23	.0258	1668	.0765	1650	.0297	1205	.0898	1696	.0258	829	.2271	1234	.0422	1591
03-24	.0219	1650	.0633	1638	.0258	1213	.1194	1742	.0297	836	.2271	1163	.0406	1650
03-25	.0243	1638	.0399	1621	.0196	1213	.1748	1725	.0305	841	.1647	1130	.0414	1765
03-26	.0243	1632	.0430	1621	.0211	1220	.2364	1662	.0422	836	.1452	1103	.4923	1708
03-27	.0250	1632	.0445	1632	.0204	1220	.1077	1615	.0399	817	.1179	1103	.1647	1493
03-28	.0367	1632	.0594	1638	.0211	1220	.0835	1603	.0289	817	.1350	1109	.1257	1338
03-29	.0305	1627	.2419	1753	.0383	1213	.0633	1603	.0235	772	.2068	1198	.1491	1358
03-30	.0344	1621	.4735	1869	.0726	1213	.0539	1621	.0313	847	.3285	1455	.1569	1351
03-31	.0469	1621	.2115	1719	.0352	1213	.0477	1591	.0633	1017	.2567	1573	.1491	1351
04-01	.0469	1627	.1413	1708	.0289	1213	.0500	1555	.0516	836	.2583	1573	.0789	1310
04-02	.0508	1621	.1615	1736	.0227	1190	.0523	1518	.0297	836	.2661	1573	.0711	1276
04-03	1.0414	1615	.1491	1696	.0227	1196	.0336	1468	.0211	836	.2232	1573	.0399	1276
04-04	1.0945	1621	.0781	1691	.0305	1205	.0375	1417	.0305	836	.2310	1573	.0274	1269
04-05	1.1569	1615	.0562	1691	.0243	1205	.0492	1384	.0321	865	.1491	1632	.0297	1269
04-06	.3753	1585	.0461	1673	.0219	1205	.0633	1338	.0422	962	.1062	1662	.1023	1304
04-07	.6951	1627	.0438	1668	.0321	1213	.0789	1324	.0289	847	.0960	1708	.1257	1317
04-08	.2037	1461	.0367	1673	.0219	1205	.0929	1304	.0258	853	.0843	1708	.1491	1351
04-09	.1007	1410	.0796	1673	.0243	1196	.1069	1310	.0289	859	.0843	1696	.1491	1351
04-10	.2817	1474	.0906	1615	.0219	1196	.1210	1317	.0258	881	.0718	1691	.1296	1468
04-11	.4923	1615	.0991	1621	.0243	1196	.1335	1324	.0399	898	.0640	1691	.1296	1603
04-12	.6077	1792	.1413	1621	.0227	1196	.1647	1338	.0375	907	.0484	1696	.1319	1615
04-13	.7419	1831	.1030	1549	.0274	1190	.2427	1404	.0586	870	.0469	1696	.1272	1603
04-14	.6873	1809	.0633	1505	.0289	1190	.3589	1518	.0570	847	.0500	1696	.1272	1579
04-15	.3909	1673	.0695	1493	.0321	1205	.3121	1708	.0367	841	.0461	1696	.0906	1567
04-16	.2489	1591	.0414	1468	.0328	1227	.1740	1853	.0406	847	.0391	1696	.1218	1573
04-17	.2388	1549	.0360	1461	.0430	1255	.1179	1885	.0328	849	.0414	1696	.1335	1627
04-18	.1701	1725	.0406	1442	.0484	1234	.1030	1885	.0344	854	.0321	1696	.2349	1736
04-19	.1608	1842	.0438	1561	.0375	1220	.0851	1885	.0282	845	.0453	1696	.3051	1770
04-20	.1584	1847	.3511	1787	.0289	1213	.0726	1885	.0274	836	.0367	1696	.3363	1869
04-21	.1030	1803	.4065	1825	.0367	1220	.0718	1885	.0250	817	.0321	1696	.2060	1820
04-22	.1093	1765	.1147	1770	.0367	1276	.0734	1885	.0282	808	.0375	1679	.1280	1742
04-23	.1444	1748	.0851	1748	.0469	1371	.0672	1874	.0305	806	.0336	1679	.0906	1696
04-24	.0851	1753	.0750	1742	.0640	1512	.0617	1885	.0282	795	.0477	1696	.0828	1679
04-25	.1085	1809	.0562	1753	.0991	1627	.0547	1917	.0274	789	.0453	1696	.0594	1662
04-26	.1904	1890	.0516	1792	.0882	1650	.0531	1922	.0297	777	.0500	1696	.0547	1650
04-27	.2793	2011	.0586	1776	.1007	1650	.0586	1990	.0250	766	.0578	1696	.0492	1644
04-28	.1803	2062	.0414	1765	.1350	1662	.0796	2092	.0344	772	.0695	1673	.0461	1644
04-29	.1218	2072	.0360	1770	.1023	1603	.0648	2171	.0360	789	.0625	1662	.0399	1638
04-30	.2083	2122	.0633	1938	.0672	1561	.0796	2181	.0282	772	.3636	1742	.0399	1638

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
05-01	.2294	2132	.0757	2021	.0461	1555	.0438	2171	.0274	766	.2154	1696	.0375	1644
05-02	.1257	2092	.0945	2031	.0313	1518	.0477	2171	.0227	777	.0726	1691	.0422	1644
05-03	.2739	2181	.2044	2200	.0360	1518	.0360	2171	.0274	777	.0523	1691	.0367	1650
05-04	.1413	2181	.1413	2291	.0367	1499	.0555	2171	.0219	783	.0508	1679	.0383	1638
05-05	.0750	2215	.1023	2305	.0383	1542	.0640	2161	.0227	777	.0984	1943	.0500	1627
05-06	.0703	2258	.1163	2305	.0781	1561	.0726	2286	.0258	789	.0937	2092	.0391	1638
05-07	.0851	2244	.1381	2370	.0742	1555	.1038	2430	.0282	777	.0695	2092	.0336	1644
05-08	.1124	2277	.1116	2343	.0648	1668	.0867	2448	.0282	760	.1335	2102	.0375	1638
05-09	.1678	2352	.2271	2620	.0555	1765	.0906	2457	.0321	760	.4689	2112	.0352	1627
05-10	.0945	2229	.1912	2672	.0328	1742	.0913	2457	.0328	760	.3441	2092	.0375	1638
05-11	.0648	2026	.1101	2680	.0321	1696	.0991	2515	.0274	806	.1413	2092	.0282	1638
05-12	.0453	1938	.1787	2689	.0336	1714	.1147	2577	.0219	806	.0945	2082	.0274	1627
05-13	.0367	1938	.1264	2680	.0718	1714	.1335	2731	.0266	754	.1101	2092	.0297	1615
05-14	.0399	1922	.0976	2879	.0555	1714	.1475	2863	.0289	754	.1218	2082	.0375	1615
05-15	1.0430	2057	.0757	2928	.0625	1668	.1218	2908	.0274	766	.1023	2082	.0406	1627
05-16	.0461	2102	.1210	2928	.0391	1656	.1210	2908	.0266	749	.1023	2087	.0321	1627
05-17	.0422	2107	.0711	2936	.0492	1668	.1124	2928	.0243	749	.0750	2087	.0375	1638
05-18	.0344	2092	.0555	2936	.0445	1656	.1249	3027	.0258	783	.4182	2087	.0999	1627
05-19	.0367	2102	.1943	2932	.0321	1656	.1335	3249	.0211	795	.3324	2082	.0391	1638
05-20	.0430	2176	.0687	2932	.0414	1814	.1319	3287	.0227	772	.0984	2082	.0406	1644
05-21	.1202	2258	.0570	2760	.0383	1814	.0921	3287	.0243	783	.1023	2082	.0406	1644
05-22	.0672	2333	.0555	2706	.1116	1803	.1077	3473	.0344	888	.1335	2082	.0344	1644
05-23	.1054	2389	.0453	2537	.2434	2215	.1296	3628	.0297	882	.1335	2132	.0321	1644
05-24	.0835	2403	.0477	2457	.2138	2357	.1108	3803	.0305	859	.0945	2229	.0399	1644
05-25	.0664	2412	.0282	2112	.1709	2296	.1132	3914	.0321	795	.1023	2277	.0360	1662
05-26	.0531	2393	.0250	1765	.1124	2268	.1257	4064	.0282	812	.1647	2439	.0461	1792
05-27	.0601	2389	.0336	1753	.0648	2239	.1069	4071	.0258	777	.1709	2689	.0851	2215
05-28	.0586	2380	.0633	1753	.0492	2215	.0952	4055	.0250	777	.1413	2843	.0586	2633
05-29	.0570	2370	.0594	1985	.0578	2215	.0804	4045	.0250	760	.1194	2843	.0991	2718
05-30	.0523	2370	.0516	2357	.0414	2181	.0664	4038	.0219	760	.1023	2855	.1358	2710
05-31	.0640	2366	.0781	2748	.0664	2166	.0734	4019	.0243	754	.1686	2936	.1225	2731
06-01	.0601	2370	.0976	3082	.0586	2161	.0648	4019	.0438	744	.1771	3178	.1015	2956
06-02	.0555	2352	.0679	3170	.0516	2200	.0617	4009	.0274	732	.1491	3261	.0874	3074
06-03	.0586	2343	.0960	3189	.0531	2181	.0609	4009	.0274	738	.1381	3287	.1023	3062
06-04	.0555	2343	.1101	3298	.0375	2142	.0609	3877	.0250	727	.2083	3375	.1093	3062
06-05	.0453	2357	.0945	3480	.0367	2137	.0516	3850	.0258	738	1.5453	3498	.0991	3074
06-06	.0406	2366	.1023	3491	.0422	2122	.0492	3860	.0274	722	.2895	3313	.0991	3062
06-07	.0383	2366	.1569	3576	.1069	2555	.0516	3850	.0250	700	.1101	3249	.0843	3054
06-08	.0477	2370	.1257	3625	.1108	2672	.0578	3725	.0274	695	.0929	3223	.0531	3062
06-09	.0609	2389	.0789	3618	.0890	2667	.0539	3579	.0289	727	.0804	3375	.0414	3062
06-10	.0625	2412	.0773	3600	.1779	3082	.0430	3551	.0477	766	.1062	3544	.0601	3062
06-11	.0422	2434	.0523	3253	.1857	3498	.0539	3579	.0461	783	.1132	3593	.0531	3074
06-12	.0375	2457	.0789	2908	.1982	3516	.0531	3579	.0609	772	.1062	3614	.0445	3082
06-13	.0352	2448	.1225	2533	.1530	3480	.0711	3621	.0406	772	.1225	3752	.0422	3062
06-14	.0360	2479	.0672	2416	.1584	3437	.1264	3628	.0492	766	.1615	3957	.0360	3047

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
06-15	.0328	2444	.0399	2412	.1335	3430	.0453	3462	.0414	754	.1491	4132	.0375	3054
06-16	.0367	2244	.0492	2425	.0859	3430	.0375	3279	.0445	749	.1210	4151	.0399	2936
06-17	.0336	2166	.0531	2466	.0523	3437	.0375	3109	.0289	727	.1218	4268	.0289	2689
06-18	.0282	2161	.0656	2798	.2512	3509	.1615	3007	.0274	727	.1147	4346	.0399	2680
06-19	.0258	2026	.0750	3170	.1491	3480	.0672	2764	.0336	754	.0960	4346	.0297	2701
06-20	.0274	1954	.0757	3551	.1600	3509	.0430	2594	.0235	722	.0906	4361	.0297	2528
06-21	.0445	1949	.0555	3583	.1888	3523	.0352	2594	.0250	732	.0906	4361	.0250	2329
06-22	.0313	1938	.0617	3660	.1405	3516	.0406	2506	.0227	749	.0648	4252	.0243	2062
06-23	.0243	1906	.0952	3996	.1085	3491	.0321	2370	.0196	690	.0578	4019	.0235	1798
06-24	.0235	1901	.0913	4343	.1124	3491	.0321	2132	.0235	607	.0531	3752	.0227	1719
06-25	.0243	1901	.0874	4514	.1069	3480	.0344	1964	.0250	587	.0547	3437	.0227	1708
06-26	.0235	1890	.0906	4508	.0929	3480	.0352	1943	.0258	593	.0391	3155	.0227	1691
06-27	.0227	1885	.0960	4404	.0664	3473	.0321	1943	.0250	587	.0399	3109	.0227	1691
06-28	.0235	1880	.0594	4116	.0828	3491	.0250	1922	.0266	561	.0375	3082	.0204	1696
06-29	.0243	1880	.0570	3877	.0703	3509	.0211	1753	.0742	561	.0352	3027	.0219	1579
06-30	.0250	1869	.0477	3790	.0718	3541	.0204	1679	.0617	550	.0313	3082	.0204	1455
07-01	.0235	1842	.0984	3701	.0742	3551	.0204	1691	.0430	556	.0328	3074	.0211	1455
07-02	.0227	1814	.0757	3491	.0726	3565	.0204	1719	.0344	566	.0328	3074	.0196	1455
07-03	.0227	1809	.0375	3253	.0679	3576	.0219	1719	.0461	582	.0305	3074	.0196	1455
07-04	.0227	1803	.0367	3261	.0804	3607	.0211	1708	.0516	593	.0321	3074	.0204	1410
07-05	.0235	1787	.0336	3305	.0898	3642	.0211	1696	.0360	607	.0258	3101	.0211	1331
07-06	.0227	1753	.0274	3109	.0843	3677	.0211	1679	.0360	593	.0282	3101	.0204	1324
07-07	.0235	1748	.0305	2996	.0773	3684	.0219	1662	.0375	582	.0336	3204	.0188	1297
07-08	.0250	1742	.0305	2892	.0874	3783	.0235	1644	.0367	582	.0305	3261	.0196	1191
07-09	.0243	1742	.0305	2603	.0492	3766	.0211	1725	.0399	577	.0297	3216	.0188	1184
07-10	.0227	1736	.0250	2282	.0399	3593	.0289	2052	.0406	572	.0266	3143	.0188	1170
07-11	.0274	1719	.0227	2132	.0492	3246	.0321	2338	.0625	561	.0282	3216	.0219	1157
07-12	.0586	1725	.0180	2171	.0695	3082	.0243	2528	.0414	572	.0282	3279	.0211	1150
07-13	.0500	1748	.0196	2191	.0555	3039	.0227	2642	.0344	572	.0313	3313	.0204	1150
07-14	.1374	1842	.0243	2186	.0547	3047	.0274	2731	.0282	566	.0406	3305	.0211	1143
07-15	.0453	1825	.0250	2176	.0531	3162	.0274	2777	.0282	556	.0289	3313	.0227	1130
07-16	.0313	1742	.0399	2181	.0453	2855	.0235	2777	.0328	566	.0305	3313	.0219	1116
07-17	.0250	1702	.0274	2191	.0321	2475	.0274	2739	.0344	561	.0297	3305	.0235	1103
07-18	.0274	1702	.0321	2210	.0305	2524	.0243	2680	.0336	561	.0305	3313	.0227	1103
07-19	.6132	1742	.3331	2234	.0445	2843	.0219	2594	.0258	561	.0360	3305	.0250	1227
07-20	.4806	1970	.1397	2253	.0773	3253	.0211	2564	.0289	582	.0297	3313	.0297	1317
07-21	.8277	2181	.0601	2301	.0601	3558	.0196	2537	.0313	582	.0289	3294	.0508	1331
07-22	.6093	2031	.0461	2282	.0609	3642	.0282	2537	.0336	582	.0321	3242	.0383	1351
07-23	.6483	1842	.0336	2277	.0539	3625	.0336	2506	.0414	598	.0305	3189	.0266	1358
07-24	.1686	1906	.0297	2277	.0523	3558	.0484	2457	.7949	690	.0328	3155	.0547	1338
07-25	.1023	2031	.0578	2249	.0516	3448	.0445	2407	.7660	922	.0321	3074	.0430	1324
07-26	.1647	2087	.0360	2215	.0399	3298	.0383	2357	1.5687	1304	.0305	2964	.0367	1317
07-27	.1257	2057	.0282	2176	.0422	3143	.0367	2315	1.2411	968	.0282	2843	.0297	1324
07-28	.1257	2026	.0274	2127	.0406	2996	.0297	2277	1.0383	882	.0391	2748	.0305	1276
07-29	.0609	1985	.0274	2082	.0321	2863	.0352	2215	.3285	705	.0321	2680	.0305	1170

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
07-30	.0523	1938	.0289	2031	.0297	2798	.0344	2161	.2817	643	.0274	2633	.0375	1157
07-31	.0913	1890	.0250	2181	.0266	2722	.0687	2191	.1452	614	.0313	2672	.0391	1157
08-01	.0867	1853	.0258	2176	.0235	2697	.5820	2697	.1428	591	.0289	2701	.0297	1157
08-02	.0750	1825	.0305	1975	.0235	2650	.4548	2515	.1140	580	.0336	2680	.0321	1170
08-03	.0734	1792	.0289	1781	.0297	2620	.1569	2479	.1069	568	.0258	2611	.0313	1163
08-04	.0711	1770	.0227	1765	.0258	2550	.1647	2672	.0898	556	.0266	2546	.0266	1157
08-05	.0492	1753	.0211	1781	.0258	2466	.1803	2594	.0789	568	.0297	2466	.0305	1163
08-06	.0469	1725	.0258	1792	.0282	2380	.1257	2506	.2193	636	.0258	2380	.0274	1157
08-07	.0609	1719	.0243	1787	.0274	2282	.0742	2416	.2692	730	.0274	2296	.0282	1163
08-08	.0453	1702	.0235	1770	.0250	2181	.0687	2315	.2029	679	.0289	2215	.0289	1176
08-09	.0399	1691	.0250	1736	.0250	2092	.0570	2205	.1452	638	.0305	2102	.1116	1198
08-10	.0360	1673	.0211	1714	.0227	2001	.0477	2092	.1062	607	.0274	2031	.0422	1241
08-11	.0243	1662	.0211	1691	.0227	1928	.0516	2021	.1007	613	.0258	1985	.0336	1351
08-12	.0219	1656	.0219	1668	.0243	1880	.0352	1943	.0874	603	.0266	1922	.0297	1220
08-13	.0305	1656	.0227	1650	.0211	1825	.0375	1874	.0906	582	.3675	1906	.1023	1255
08-14	.0258	1567	.0227	1638	.0243	1792	.0367	1820	.0898	577	.0648	1917	.1896	1304
08-15	.0219	1461	.0211	1638	.0243	1765	.0360	1765	.0890	582	.1335	1906	.8277	1461
08-16	.0250	1461	.0219	1536	.0204	1742	.0367	1736	.0835	572	.0406	1906	.2661	1269
08-17	.0274	1474	.0219	1638	.0227	1714	.0360	1691	.0984	593	.0352	1906	.1179	1241
08-18	.0196	1567	.0227	1656	.0328	1702	.0328	1650	.0835	623	.0313	1874	.0711	1220
08-19	.0266	1662	.0196	1656	.0243	1673	.0328	1644	.0991	700	.0258	1836	.0633	1227
08-20	.0250	1662	.0211	1542	.0219	1668	.0328	1615	.1225	722	.0266	1792	.1101	1262
08-21	.0266	1673	.0227	1455	.0219	1656	.0367	1615	.1974	658	.0289	1742	.3675	1317
08-22	.0235	1685	.0211	1468	.0227	1627	.0453	1627	.1233	633	.0282	1708	.1413	1317
08-23	.0274	1702	.0204	1461	.0227	1621	.0406	1644	.1194	627	.0266	1650	.1101	1262
08-24	.0243	1696	.0274	1449	.0243	1603	.0399	1627	.0945	619	.0235	1603	.0555	1176
08-25	.0211	1696	.0243	1442	.0235	1603	.0344	1644	.0960	679	.0235	1609	.0867	1176
08-26	.0211	1691	.0204	1430	.0227	1512	.0352	1650	.0913	695	.0219	1603	.0617	1176
08-27	.0243	1696	.0211	1417	.0266	1391	.0367	1650	.1210	800	.0250	1603	.0555	1170
08-28	.0352	1714	.0211	1417	.0297	1364	.0375	1662	.1194	991	.0188	1603	.0477	1176
08-29	.0289	1691	.0211	1410	.0227	1371	.0344	1673	.1124	789	.0204	1591	.0555	1157
08-30	.0243	1685	.0367	1397	.0211	1377	.0313	1673	.1381	795	.0219	1603	.1335	1150
08-31	.0289	1685	.0289	1397	.0204	1377	.0313	1673	.1015	727	.0204	1591	.0945	1157
09-01	.0313	1725	.0235	1397	.0204	1371	.0336	1673	.0789	705	.0227	1579	.0438	1176
09-02	.1865	1847	.0227	1397	.0211	1377	.0367	1662	.0804	679	.0204	1579	.0406	1191
09-03	.0375	1770	.0204	1417	.0219	1397	.0297	1650	.0765	679	.0211	1573	.0399	1191
09-04	.0305	1685	.0196	1364	.0227	1397	.0297	1662	.0750	679	.0211	1573	.0375	1191
09-05	.0274	1662	.0196	1184	.0250	1391	.0321	1650	.0867	679	.0243	1555	.0383	1191
09-06	.0297	1673	.0204	1099	.0266	1371	.0336	1673	.0773	674	.0250	1555	.0360	1191
09-07	.0477	1719	.0367	1092	.0250	1371	.1413	1696	.0913	658	.0188	1555	.0313	1176
09-08	.0414	1725	.0313	1099	.0250	1371	.0274	1417	.1023	647	.0219	1549	.0313	1184
09-09	.0399	1736	.0211	1099	.0243	1358	.0196	1058	.0789	643	.0196	1536	.0360	1170
09-10	.0336	1725	.0180	1085	.0196	1283	.0196	1051	.0711	663	.0219	1536	.0422	1170
09-11	.7216	2057	.0266	1066	.0211	1290	.0211	1051	.0726	674	.0227	1549	.0336	1170
09-12	.9837	2191	.0219	1079	.0235	1310	.0243	1044	.0711	679	.0188	1549	.0297	1170

Appendix D (continued). Augmented data on concentration of total phosphorus (TP, mg/liter) and load of total dissolved solids (TDS, units of tons/day) created as described in Section 3A. Daily data are presented by month and day (Mo-Day) for the time period indicated at the top of each pair of columns.

	1972-73		1973-74		1974-75		1975-76		1976-77		1977-78		1978-79	
Mo-Day	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS	TP	TDS
09-13	.2481	1787	.0227	1092	.0204	1310	.0196	1044	.0726	700	.0196	1555	.0282	1176
09-14	.1085	1338	.0196	1118	.0235	1297	.0196	1044	.0804	663	.0243	1549	.0313	1198
09-15	.0656	1248	.0196	1118	.0235	1297	.0243	1044	.0906	679	.0266	1567	.0321	1213
09-16	.0383	1196	.0180	1105	.0211	1213	.0196	1030	.0945	663	.0196	1579	.0289	1205
09-17	.0282	1163	.0172	1092	.0188	1099	.0211	1086	.0960	638	.0219	1603	.0313	1198
09-18	.0274	1150	.0196	1079	.0188	985	.0289	1178	.0711	643	.4462	1831	.0321	1191
09-19	.0266	1131	.0188	1047	.0188	991	.0227	1162	.0586	638	.1920	1736	.0321	1191
09-20	.0266	1112	.0180	1105	.0196	1041	.0196	1170	.2154	989	.0687	1644	.0297	1191
09-21	.0570	1072	.0196	1092	.0188	1041	.0188	1162	.2973	1493	.0391	1627	.0352	1176
09-22	.0453	875	.0344	1092	.0180	1035	.0180	1170	.1974	1536	.0321	1609	.0453	1176
09-23	.0352	844	.0250	1105	.0180	1028	.0219	1162	.1584	1579	.0258	1603	.0367	1170
09-24	.0305	831	.0180	1105	.0180	1009	.0219	1162	.1046	1262	.0243	1536	.0313	1072
09-25	.0227	837	.0180	1066	.0188	1009	.0227	1147	.0664	817	.0219	1220	.0235	800
09-26	.0211	844	.0180	1009	.0188	998	.0235	1162	.0453	789	.0188	722	.0204	695
09-27	.0219	782	.0180	960	.0211	1085	.0211	1154	.0375	754	.0211	669	.0219	684
09-28	.0204	728	.0180	960	.0204	1079	.0219	1154	.0305	749	.0196	653	.0235	679
09-29	.0196	728	.0180	966	.0196	1060	.0188	1147	.0367	749	.0219	638	.0243	674
09-30	.0235	722	.0227	966	.0211	1054	.0211	1140	.0648	760	.0336	638	.0282	783